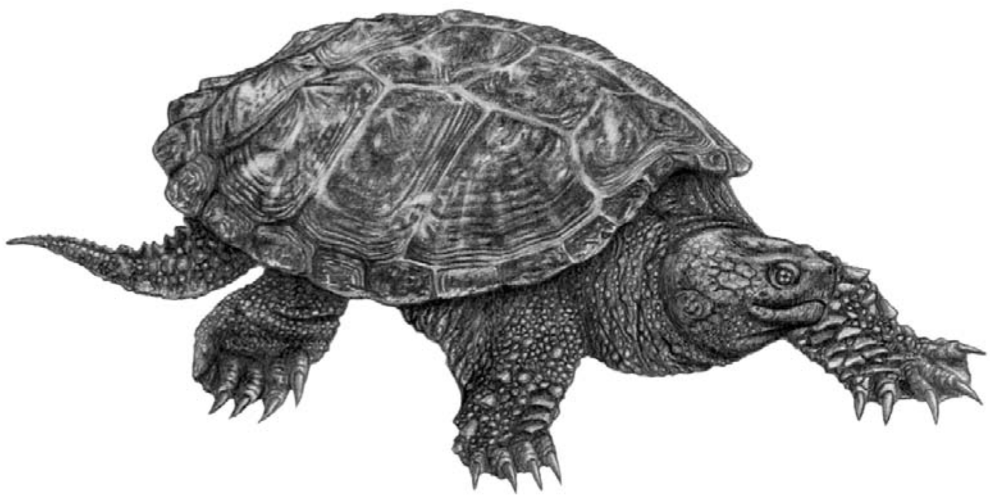
COSEWIC
Assessment and Status Report

on the

Snapping Turtle
Chelydra serpentina

in Canada



SPECIAL CONCERN
2008

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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COSEWIC
Assessment Summary

Assessment Summary – November 2008

Common name
Snapping Turtle

Scientific name
Chelydra serpentina

Status
Special Concern

Reason for designation
Although this species is widespread and still somewhat abundant, its life history (late maturity, great longevity, low recruitment, lack of density-dependent responses) and its dependence on long warm summers to complete incubation successfully make it unusually susceptible to anthropogenic threats. When these threats cause even apparently minor increases in mortality of adults, populations are likely to decline as long as these mortality increases persist. There are several such threats and their impacts are additive. Aboriginal Traditional Knowledge generally supports the declining trend and population figures in the COSEWIC report.

Occurrence
Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia

Status history
Designated Special Concern in November 2008. Assessment based on a new status report.

COSEWIC
Executive Summary

Snapping Turtle
Chelydra serpentina

Species information

Canada's largest freshwater turtle, the Snapping Turtle, *Chelydra serpentina* (Linnaeus 1758), is monotypic for North America and globally is one of three species within the genus *Chelydra* and is one of four species within the family Chelydridae. The keeled carapace is brown, black or olive, and the cross-shaped plastron is much reduced compared with other turtles, leaving the limbs and sides of the body exposed. The Snapping Turtle's head is large with a hooked upper jaw, the neck is relatively long, and the tail is approximately as long as the carapace. In a central Ontario population, adult males have an average carapace length of 32.3 cm and an average mass of 9.3 kg, whereas adult females average 28.5 cm carapace length with an average mass of 5.3 kg.

Distribution

The Snapping Turtle has the greatest latitudinal distribution of any turtle in North America, ranging from southern Manitoba south to Texas, In Canada, the species is present in mainland Nova Scotia, southern New Brunswick, southern and central Quebec, southern and central Ontario, southern Manitoba and southeastern Saskatchewan. Within the Canadian range of the species, a range disjunction occurs in northwestern Ontario, north of Lake Superior. where summers are likely too cool for Snapping Turtle embryos to complete development successfully.

Habitat

The preferred habitat for the Snapping Turtle is characterized by slow-moving water with a soft mud bottom and dense aquatic vegetation. Established populations are most often located in ponds, sloughs, shallow bays or river edges and slow streams, or areas combining several of these wetland habitats. Although individual turtles will persist in developed areas (e.g. golf course ponds, irrigation canals), it is unlikely that populations persist in such habitats. Snapping Turtles can occur in highly polluted waterways, but environmental contamination is known to limit reproductive success. Snapping Turtle habitat is diminishing in both quantity and quality in Canada with losses primarily due to conversion of wetlands to agriculture and urban development.

Biology

Snapping Turtles have a life-history strategy characterized by high and variable mortality of embryos and hatchlings, delayed sexual maturity, extended adult longevity, and iteroparity (repeated reproductive events) with low reproductive success per reproductive event. Females, and presumably also males, in more northern populations mature later (at 15-20 years) and at a larger size than in more southern populations (~12 years). Lifespan in the wild is poorly known, but long-term mark-recapture data from Algonquin Park suggest a maximum age of over 100 years. Nesting takes place in late May and June, with females laying approximately 40 eggs in a flask-shaped nest. In Algonquin Park, the probability of a Snapping Turtle embryo surviving to sexual maturity is less than 0.1%. Active adult Snapping Turtles have few predators other than humans, but in some localized cases, mammalian predators have developed techniques for preying upon hibernating adults.

Population sizes and trends

Although the Snapping Turtle is one of Canada's more widespread turtle species, long-term studies of two populations in Ontario have demonstrated that even large and apparently secure populations are vulnerable to increases in adult mortality and do not recover quickly from declines. Life-history models indicate that only slight increases (0.1) in annual adult mortality rate (such as from road mortality or harvesting) will cause a population to be halved in under 20 years. The Snapping Turtle remains relatively abundant in eastern Canada, but is less often encountered in Saskatchewan and Manitoba.

Limiting factors and threats

Snapping Turtle populations in Canada are limited primarily by their life-history strategy (slow recruitment, late maturity, long lifespan, high adult survival) and by short, cool summers which reduce hatching success. Population persistence is critically dependent on high adult survivorship; thus, most of the serious threats to Snapping Turtles in Canada are events that increase adult mortality. Legal and illegal harvesting of adults, persecution and road mortality (particularly of females traveling to nest sites) are the most prominent causes of premature death in adult Snapping Turtles. Other long-term threats to the persistence of the Snapping Turtle in Canada include on going loss of habitat, decreased reproductive success due to environmental contamination, unnaturally high rates of nest predation by large populations of raccoons (*Procyon lotor*) and other mammals, boat propeller strikes, "bycatch" from both sport and commercial fishing, dredging, road grading, water drawdowns and other practices.

Special significance of the species

The Snapping Turtle is Canada's largest terrestrial or freshwater reptile with a lifespan similar to or greater than humans and has scientific, ecological and cultural significance. Its prehistoric appearance is familiar to Canadians, many of whom have personal stories (often exaggerated) about the enormous size, jaw strength or ferocity of the species.

Existing protection or other status designations

There is no existing legal protection for the species in Canada. The Snapping Turtle is ranked S5 (demonstrably widespread, abundant, and secure) in Nova Scotia, while in Ontario, New Brunswick and Quebec, the species is ranked S4, apparently secure. In both Manitoba and Saskatchewan the Snapping Turtle is ranked S3, due to its restricted range and relatively few populations. The Snapping Turtle is protected from hunting in Manitoba and Quebec, but may be hunted with a licence in Ontario, and Nova Scotia, and without a licence in Saskatchewan. In Ontario, under the *Fish and Wildlife Conservation Act*, Section 31 (1) a and b, If a person believes on reasonable grounds that wildlife (e.g., Snapping Turtle) is damaging or is about to damage the person's property (e.g., ear waterfowl), the person may, on the person's land capture or kill the turtle.

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
(2008)

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 Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

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

COSEWIC Status Report

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Chelydra serpentina

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2008

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SPECIES INFORMATION

Name and classification

The Snapping Turtle, *Chelydra serpentina* (Linn. 1758), is one of only three species within the genus *Chelydra* and is one of just four species within the family Chelydridae. There have been two recognized subspecies of *C. serpentina*, but only *C. s. serpentina* resides in Canada. The other subspecies, *C. s. osceola* is restricted to peninsular Florida. In a recent phylogenetic study, very little molecular differentiation was found between *C. s. serpentina* and *C. s. osceola* (Phillips *et al.* 1996), and this lack was supported recently by mtDNA and allozyme data (Shaffer *et al.* 2008). Two other subspecies, *C. s. rossignonii* and *C. s. acutirostris* are found in Central and South America. However, the greater divergence measured between the North and Central American subspecies, as well as between the two Central American subspecies, prompted Phillips *et al.* (1996) and Shaffer *et al.* (2008) to recommend that both subspecies be elevated to separate species, *C. acutirostris* and *C. rossignonii*. Gaffney (1984) has hypothesized that Chelydridae is the basal clade among cryptodires (80% of extant turtle species).

Morphological description

The Snapping Turtle is Canada's largest freshwater turtle (Figure 1). The carapace is brown, black or olive with three keels running lengthwise. Posterior marginal scutes are noticeably serrated. As with many turtles, the scutes of young Snapping Turtles have concentric growth lines corresponding approximately to each year of growth which can be used to roughly estimate age in an individual until maturity (Galbraith and Brooks 1987b; Brooks *et al.* 1997). The cross-shaped yellow, gray or tan plastron is not hinged and is much reduced compared with other turtles, leaving the limbs and sides of the body exposed (Harding 1997; Ernst *et al.* 1994; Ernst 2008). The Snapping Turtle's head is large, with a hooked upper jaw which is yellow to cream in colour and patterned with dark vertical streaks. The neck is relatively long with blunt tubercles along the dorsal surface and two barbels under the chin. Skin colour is typically tan, but can vary from cream to grey to black to yellow and even reddish-brown in iron-rich environments. The tail is almost as long as the carapace and bears three longitudinal rows of triangular tubercles. The long tail is unique among North American turtles.

Adult male Snapping Turtles are larger than females and male pre-cloacal tail length (i.e. the linear distance from the cloaca to the posterior tip of the plastron) is generally greater than the length of the posterior lobe of the plastron, whereas female posterior pre-cloacal length is generally less than the length of the posterior lobe (Mosimann and Bider 1960). In a central Ontario population, adult males have an average carapace length of 32.3 cm (range 25-40 cm) and an average mass of 9.3 kg (range 5-18 kg), whereas adult females average 28.5 cm carapace length (range 23-36 cm) with an average mass of 5.3 kg (range 3-9 kg; R. Brooks unpublished data). Both sexes of adult Snapping Turtles in Grafton Lake, Nova Scotia, are similar in size and mass to those in central Ontario (Gilhen 1984, Hurlburt *et al.* 1997, Whynot 1996). Hatchling Snapping Turtles are much smaller and darker replicas of adults, with a carapace length of about 2.7 cm upon emergence (R. Brooks unpublished data).

Adult Snapping Turtles are unlikely to be confused with any other freshwater turtle in Canada due to their large size and long tail. Hatchlings and juveniles can be distinguished from other species by their combination of carapacial ridges, serrated posterior marginal scutes, reduced unhinged plastron and long tail with its rows of tubercles.

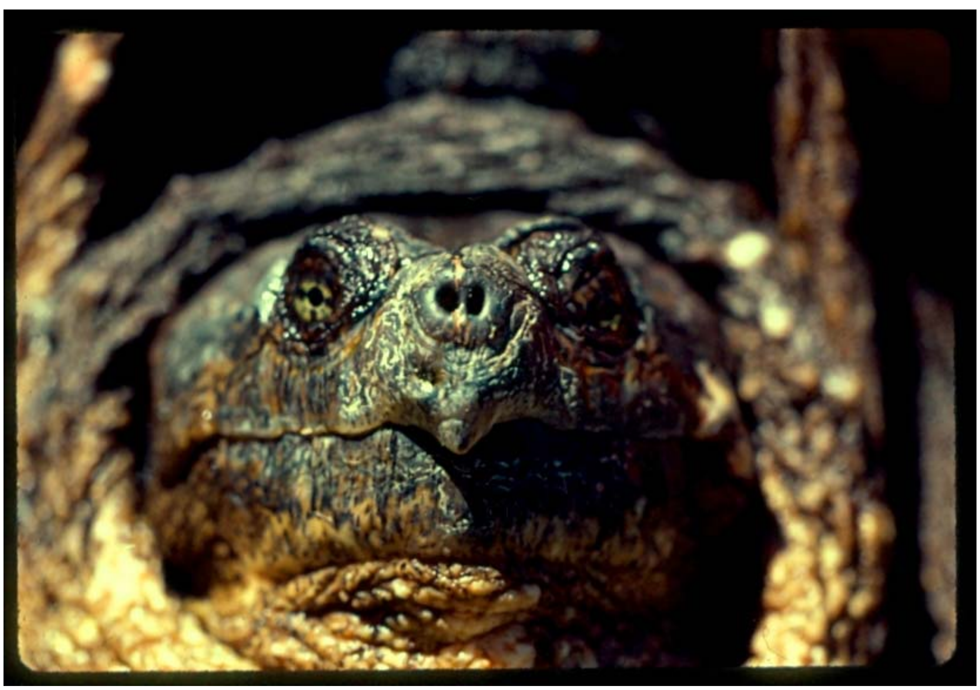

Figure 1. Adult Male Snapping Turtle.

Genetic description

To the present, no studies have examined population genetics of the Snapping Turtle in Canada. However, while examining parentage of hatchling Snapping Turtles in Algonquin Park, Ontario, Galbraith (1991) found evidence that this population may be relatively inbred. Due to the highly stochastic survival patterns in turtle clutches, where entire cohorts may come from only one or a few successful nests, it is possible that most populations of Snapping Turtles and other freshwater turtle species have relatively low genetic variation. This pattern of inbreeding in Snapping Turtles could also be explained by a high variance in male reproductive success (Galbraith 1991).

Judging by the distribution of the Snapping Turtle (Figure 2), a major barrier to gene flow in Canada occurs in northern Ontario where summer temperatures are too low for embryos to complete development successfully (see Reproduction). Snapping Turtle populations from northwestern Ontario, Manitoba and Saskatchewan are likely more closely related to Snapping Turtles from North Dakota and Minnesota than to populations in southern Ontario. However, Shaffer *et al.* (2008) point out that there is limited differentiation in U.S. *Chelydra*, so it is possible there is a similar lack of mtDNA and allozyme variation in Canadian populations.

Designatable units

No genetic or morphological distinctions among populations of Snapping Turtles in Canada have been identified. Snapping Turtles in the Western Boreal faunal province as well as those in the northwestern portion of the Canadian Shield faunal province (Green 2003) are geographically isolated from the remaining Snapping Turtle populations in Ontario and eastward. However, these western populations likely interact with turtles in the neighbouring states (Montana, Minnesota and North Dakota) and thus may not significantly differentiated from Snapping Turtles in the rest of Canada. Regardless, there is no evidence of any genetic or morphological differences to suggest these western populations qualify as separate DUs. Similarly, no data exist to suggest distinct DUs elsewhere in the species' Canadian range or even North American range (Shaffer *et al.* 2008).

DISTRIBUTION

Global range

The global range of *Chelydra serpentina* can be divided into a northern and southern portion, with a substantial disjunction between the two. *Chelydra serpentina* is distributed throughout the United States and Canada east of the Rocky Mountains, with approximately 10% of its range contained within Canada (Figure 2). In the southern portion of the species' range, there is a gap with no Snapping Turtles from southern Texas to southeast Mexico, then two other species appear. *Chelydra rossignonii* (Mexican Snapping Turtle) is distributed from southeastern Mexico to Honduras, while *C. acutirostris* (South American Snapping Turtle) is found from the Honduras-Nicaragua border region south to Ecuador (Iverson 1992, Ernst 2008). These were previously called subspecies of *C. serpentina*, but Philips *et al.* (1996) using mtDNA suggested that these two southern subspecies are separate species from *C. serpentina* and this seems to be the current view (Ernst, 2008, Shaffer *et al.* 2008). Still, *Chelydra serpentina* has the greatest latitudinal range of any freshwater turtle species in the Americas (Ernst *et al.* 1994), and perhaps the world.

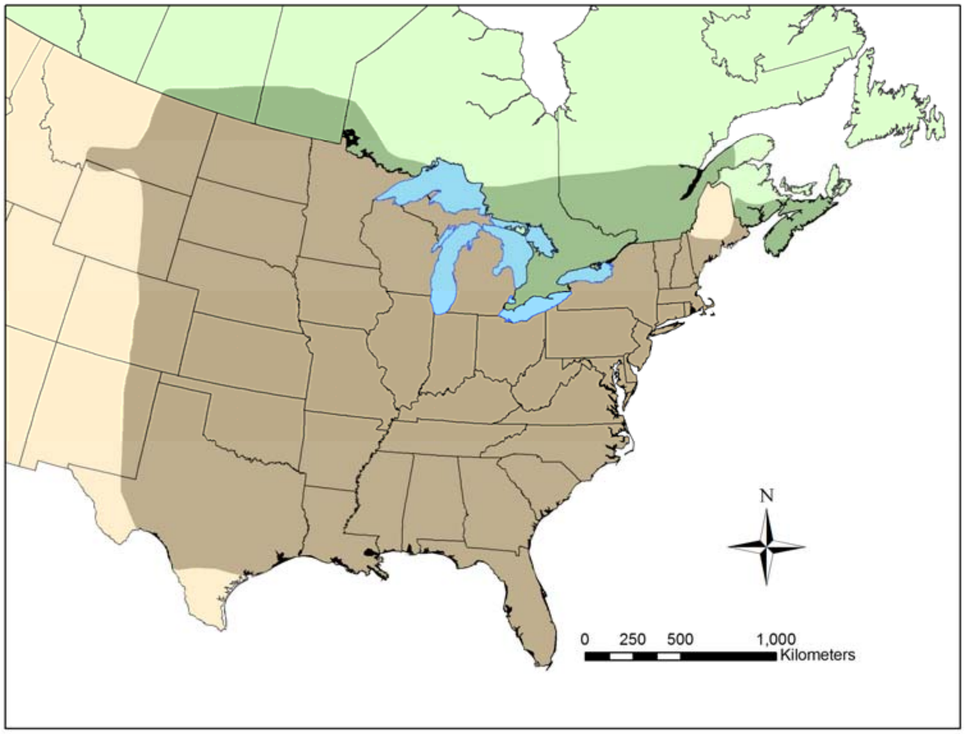

Figure 2. Distribution of the Snapping Turtle *Chelydra serpentina* in the United States and Canada. The species' range is shown in shaded area. U.S. distribution after Ernst *et al.* 1994, and Ernst 2008).

Canadian range

In Canada, the Snapping Turtle is widespread from Nova Scotia to southeastern Saskatchewan with one major gap in northcentral Ontario (Figure 2). Herpetofaunal atlas records are available from Nova Scotia, Quebec and Ontario; distribution information from the remaining provinces is derived from a combination of park, museum and government records, personal observations, and field guide descriptions. There has been no systematic attempt to map the species' distribution across Canada.

The Snapping Turtle is found throughout mainland Nova Scotia (Scott 2002; Figure 3), particularly in the watersheds of the upper Tusket River, Mersey River, Medway River, Annapolis River, Musquodoboit River and St. Mary's River (Gilhen 1984, J. Gilhen pers. comm. 2006). Snapping Turtles have been reported from various localities on Cape Breton Island; however, all records place individuals out of context of the species' natural habitat (e.g. roadside ditches) suggesting specimens are likely released captives (J. Gilhen, pers. comm. 2006). Summers may be too short and cool in Cape Breton to allow embryos to successfully complete development, thus preventing populations from becoming established on the island (M. Elderkin pers. comm. 2006).

Records of the Snapping Turtle in New Brunswick show the species distributed predominantly in the southern half of the province (Bleakney 1958, Cook 1984, McAlpine and Godin 1986). Although originally thought to be restricted to the Grand Lake-Saint John River area (York, Sunbury, Queens, Kings and St. John Counties; Bleakney 1958), Snapping Turtles have since been recorded from all New Brunswick counties except Restigouche in the north and Kent in the east (McAlpine and Godin 1986). It is unclear if records from the northern half of New Brunswick represent breeding populations, migrants from other parts of the species' range, or released captives (McAlpine and Godin 1986).

In Quebec (Figure 4), the Snapping Turtle is present in many watersheds including the Ottawa River, St. Maurice River, Saguenay River, Rouge River, Richelieu River and Saint-François River as well as along the St. Lawrence River (J. Jutras pers. comm. 2006). Snapping Turtles have been captured in the Lake St. Francis National Wildlife Area (NWA) and on the Akwesasne First Nation Reserve, and are highly suspected to occur in the Iles-de-la-Paix NWA (S. Giguère pers. comm. 2005).

The Snapping Turtle is distributed throughout Ontario south of a line from approximately Wawa to Kirkland Lake (Figure 4), and has been reported sporadically in northwestern Ontario along the Ontario-Minnesota border (Figure 5). The Ontario Ministry of Natural Resources Natural Heritage Information Centre database contains observations from every Ontario district with the exception of Cochrane in northeastern Ontario (Weller and Oldham 1988). An individual recorded from Pukaskwa National Park was likely transplanted from elsewhere in Ontario as the northern and eastern shores of Lake Superior are outside the species' known range. Similarly, an adult captured in downtown Wawa was believed to have been a released or escaped captive and was subsequently released on the north shore of Lake Huron (N. Dawson, pers. comm. to M. Oldham, 2007).

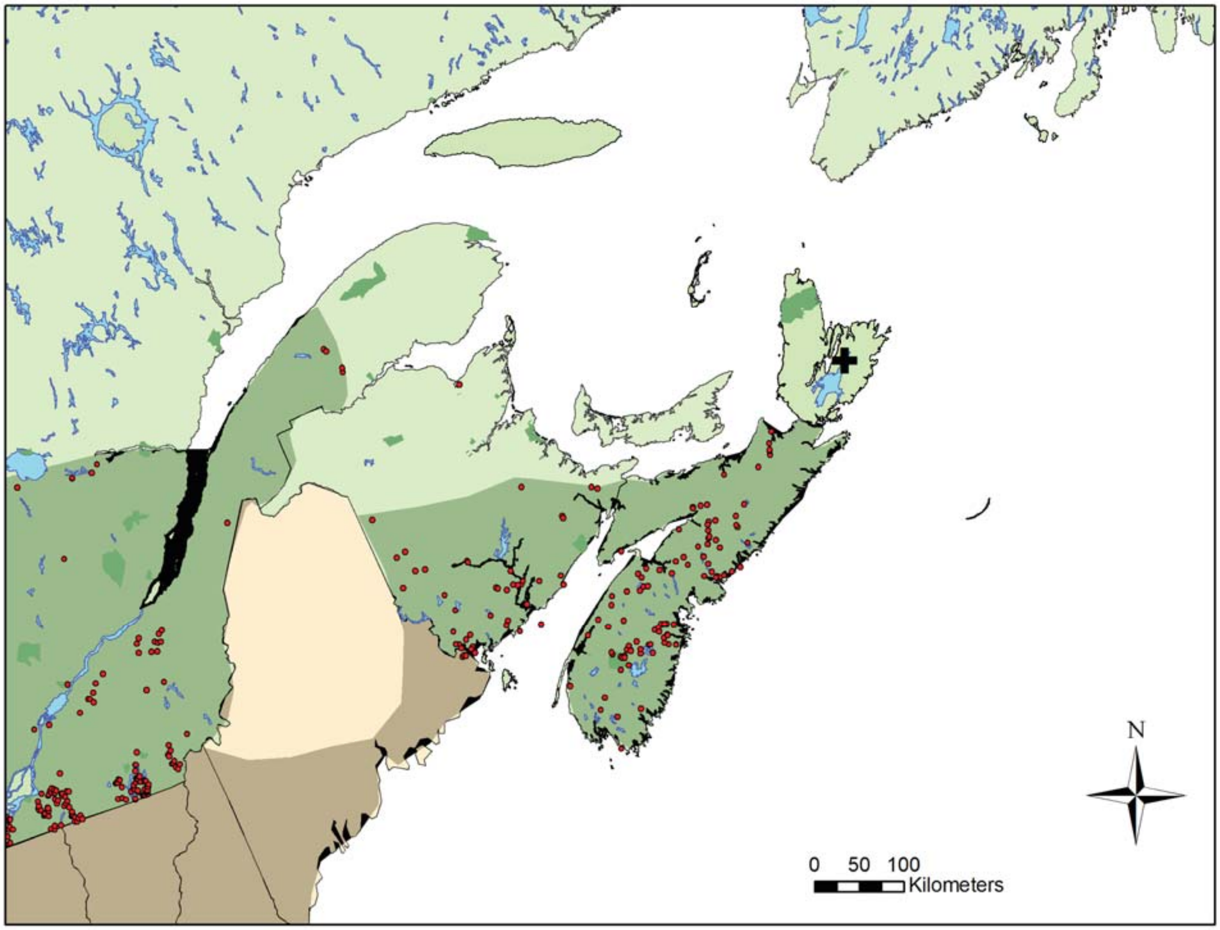

Figure 3. Distribution of the Snapping Turtle in New Brunswick and Nova Scotia. Point locations were obtained from the Atlantic Conservation Data Centre (Tims and Craig 1995; Scott 2002). • denotes confirmed record within the species' range, **+** denotes known or probable introduction outside of species' natural range. Extent of Occurrence shown in shaded regions (adapted from Ernst *et al.* 1994). National and Provincial Parks are shown in darkest green.

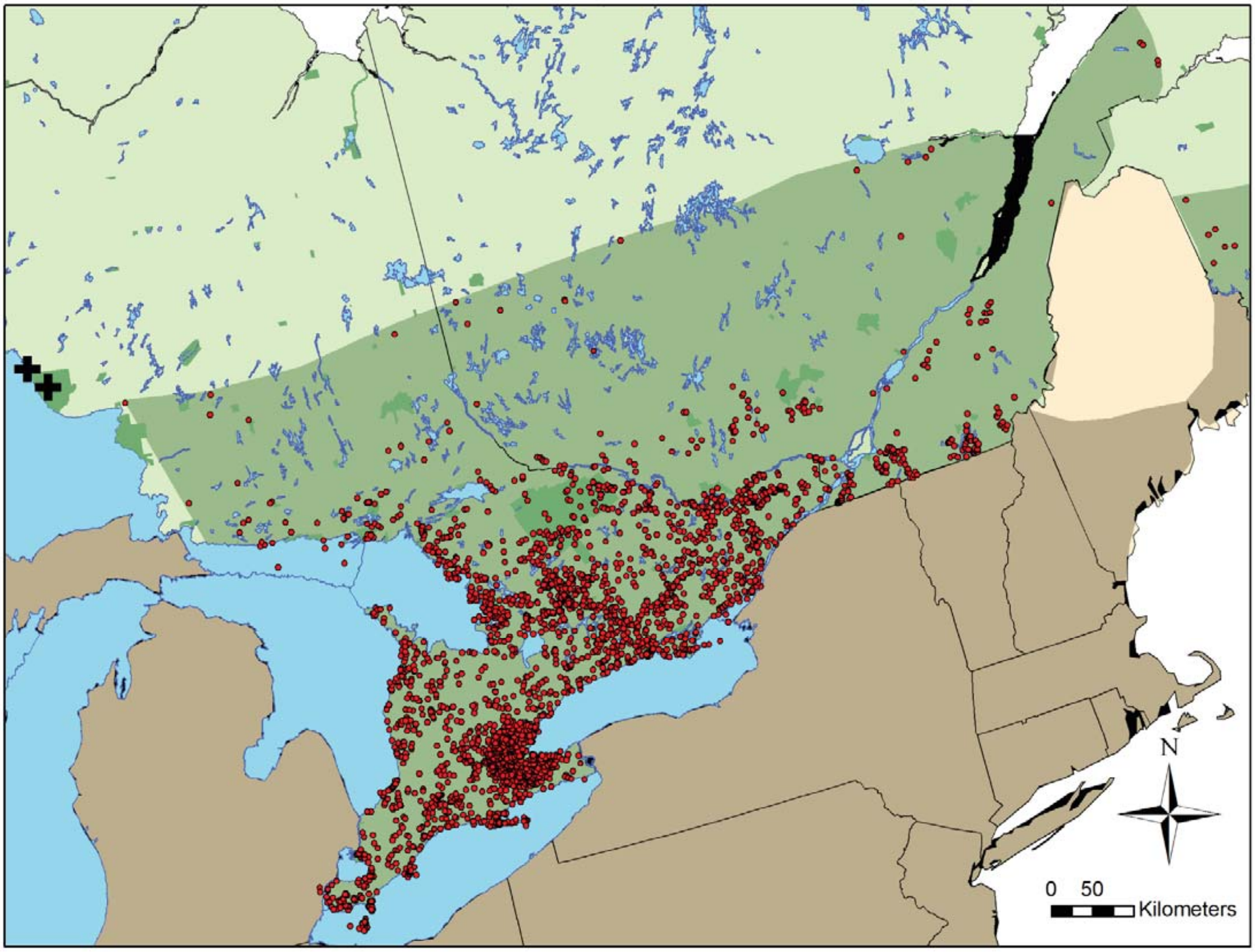

Figure 4. Distribution of the Snapping Turtle in southcentral Ontario and southeastern Quebec. Point locations were obtained from the Ontario Herpetofaunal Summary Database, Ontario Ministry of Natural Resources Natural Heritage Information Centre (2005), and the Quebec Atlas of Reptiles and Amphibians (2006). • denotes record within the species' range; **+** denotes known or probable introduction outside of species' natural range. Extent of Occurrence shown in shaded regions (adapted from Ernst *et al.* 1994). National and Provincial Parks are shown in darkest green.

In Manitoba, the Snapping Turtle is known from the southern quarter of the province, as far north as the Berens River on the east side of Lake Winnipeg and Clear (Wasamin) Creek on the west (Preston 1982). Reputable sources claim that the species' range may extend as far north as The Pas on the western side of Lake Winnipeg (R. Mooi pers. comm. 2005); however, no records were available to the author to support this claim. Numerous specimens have been observed in Whiteshell Provincial Park in southeastern Manitoba (Norris-Elye 1949, Preston 1982, R. Wilson pers. comm. 2006, R. Mooi pers. comm. 2005). In contrast, Snapping Turtles are relatively rare in the Little Saskatchewan River system in Riding Mountain National Park in southwestern Manitoba. Individual records in Figure 5 are taken from Preston (1982). Historically, these turtles were abundant in both the Assiniboine and Red Rivers in the city of Winnipeg (Norris-Elye 1949).

The western range limit of the Snapping Turtle in Canada occurs in southeastern Sskatchewan (Figure 5), in the Qu'Appelle watershed (D. Secoy pers. comm. 2006), although unconfirmed reports suggest that the species may also be present in the Frenchman and Missouri drainages in southwestern Saskatchewan (J. Keith pers. comm. 2006; L. Powell pers. comm. 2006). Only one record of a Snapping Turtle is listed in the Saskatchewan Herpetology Atlas, from Roche Percee near the Souris River (A. Didiuk pers. comm. 2006), although other records exist (F Cook pers. comm. 2008).

Records of the Snapping Turtle in Alberta and British Columbia (Figure 6) are all likely to be of released captives (Russell and Bauer 2000; D. Fraser pers. comm. 2006; W. Roberts pers. comm. 2006). A single specimen has been recorded from Dillberry Lake in Dillberry Provincial Park in east central Alberta (W. Nordstrom pers. comm. 2006). Individuals were also released into the Battle River area (Russell and Bauer 2000), but the introduction was apparently unsuccessful (W. Nordstrom pers. comm. 2006). The British Columbia Conservation Data Centre has a single report of a Snapping Turtle from Cowichan Bay, Vancouver Island (L. Ramsey pers. comm. 2006). Two other records of Snapping Turtles released in British Columbia are from Memorial South Park in Vancouver and Liard Hot Springs near the northern BC border (D. Fraser pers. comm. 2006).

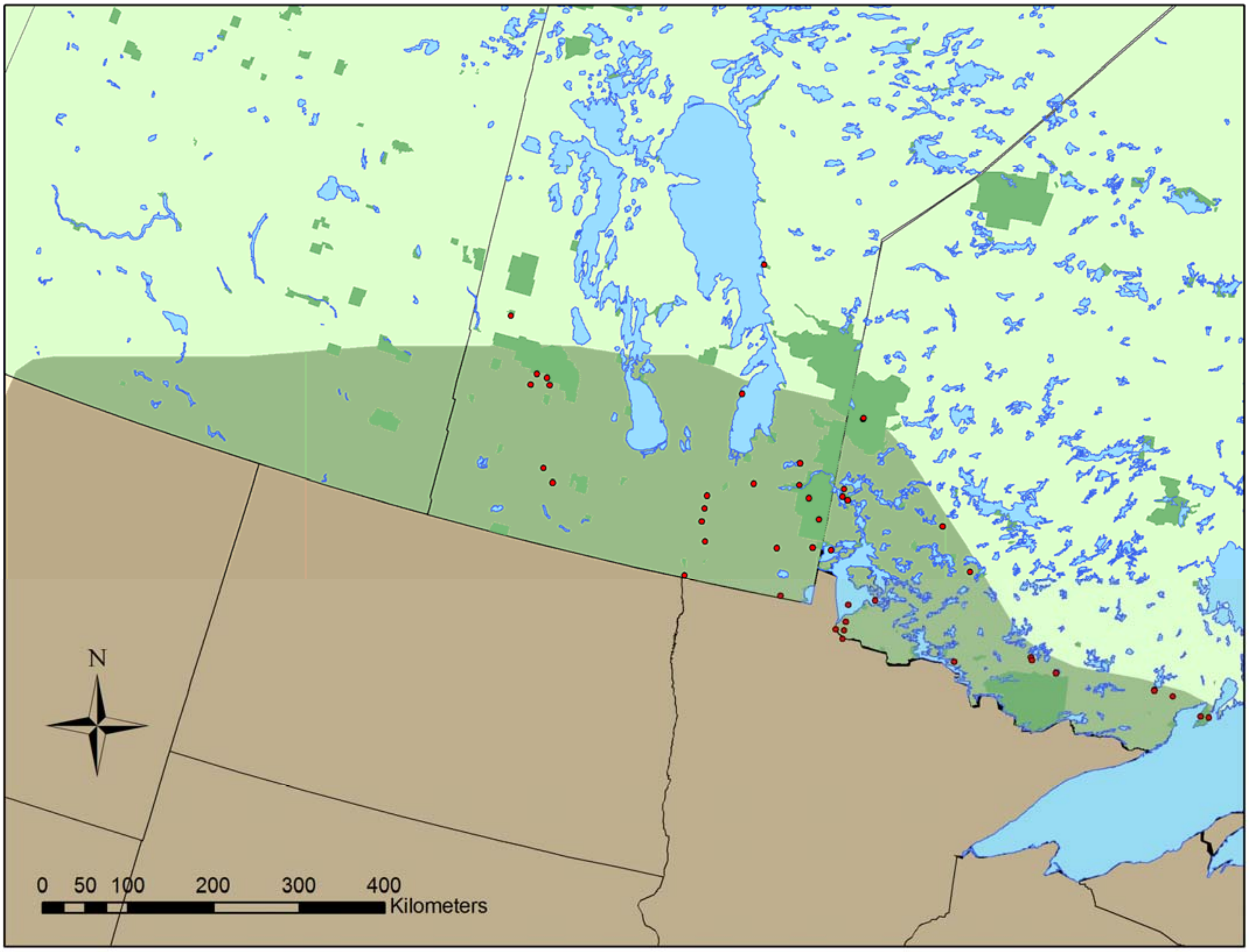

Figure 5. Distribution of the Snapping Turtle in northwestern Ontario, Manitoba and Saskatchewan. Point locations were obtained from the Ontario Herpetofaunal Summary Database, Ontario Ministry of Natural Resources Natural Heritage Information Centre (2005), and Preston (1982). • denotes confirmed record within the species' range; Extent of Occurrence shown in shaded regions (Ernst *et al.* 1994). National and Provincial Parks are shown in darkest green.

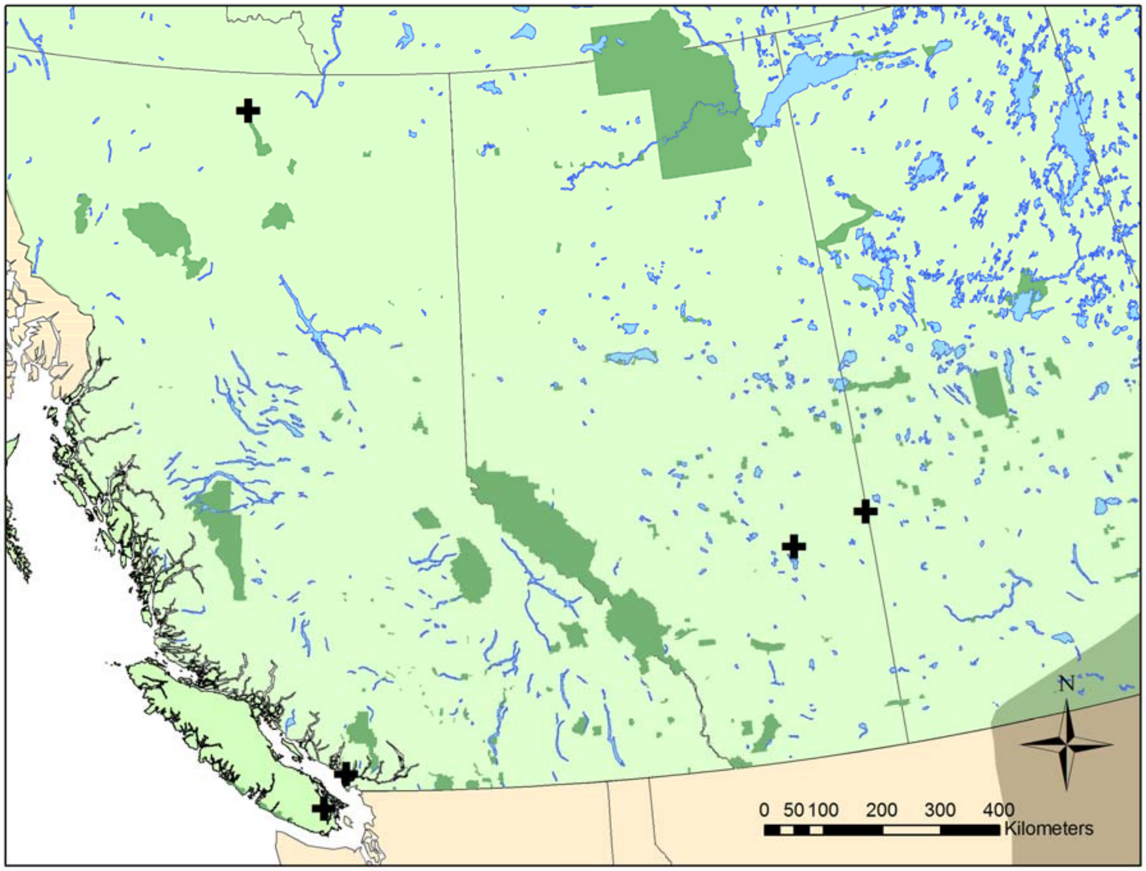

Figure 6. Distribution of the Snapping Turtle in Alberta and British Columbia. + denotes known or probable introduction outside of species' natural range. National and Provincial Parks are shown in darkest green.

HABITAT

Habitat requirements

Although Snapping Turtles have been found in almost every kind of freshwater habitat (Ernst *et al.* 1994), and occasionally enter brackish coastal waters (Kiviat 1980), the preferred habitat for the species is characterized by slow-moving water with a soft mud bottom and dense aquatic vegetation (Ernst *et al.* 1994; Harding 1997). Established populations are most often located in ponds, sloughs, shallow bays or river edges and slow streams, or areas combining several types of wetland habitat (Harding 1997). Although individual turtles will persist in heavily urbanized water bodies (e.g. golf course ponds, irrigation canals), it is unlikely that populations could become established in such habitats. Snapping Turtles are also tolerant of highly polluted waterways (e.g. Hamilton Harbour, Ontario), but environmental contamination has been shown to feminize male turtles (de Solla *et al.* 1998) and increase embryonic deformities (Bishop *et al.* 1998), and may have long-term population consequences (Rowe 2008).

Although capable of swimming through deep water, Snapping Turtles rarely cross a lake basin, preferring instead to utilize the lake periphery (within 5 m of shore and 2 m depth; Brown 1992). In Algonquin Park, adult turtles were most often found on the lake bottom, partially covered by sediment, vegetation or logs (Brown *et al.* 1990). Basking on offshore logs and rocks can be common in Snapping Turtles depending on environmental temperature (Obbard and Brooks 1979; Brown *et al.* 1990). Previous claims that Snapping Turtles rarely leave the water to bask are contradicted by behavioural observations in Algonquin Park (Brown *et al.* 1990) and elsewhere (J. Litzgus, pers. comm. 2007, P. Gregory pers. comm 2008).

In early spring, both male and female Snapping Turtles have been observed using rocky streams (atypical habitat) to move between water bodies. Mating may occur in these streams as individuals of both sexes have been observed in close proximity (Brown and Brooks 1993). Females generally nest on sand and gravel banks along waterways, including artificial dam and railway embankments, but muskrat houses, abandoned beaver lodges, road shoulders, fissures in rocky shorelines, sawdust heaps, freshly dug soil, gardens, lawns and forest clearings have all been selected as nest sites with unknown success (Obbard and Brooks 1980; Ernst *et al.* 1994; Congdon *et al.* 2008). Upon emergence from the nest in early fall, hatchling Snapping Turtles usually move to water, after which they bury themselves under leaf litter or debris (Ernst *et al.* 1994). Little else is known of the habitat preferences of newly hatched or juvenile Snapping Turtles. Three types of hibernacula used by adult Snapping Turtles in Algonquin Park have been identified by Brown and Brooks (1994): Stream sites-turtles are buried beneath logs, sticks, or overhanging banks in small streams that flow continuously throughout the winter; Lakeshore sites-turtles are wedged beneath or beside submerged logs and stumps, sometimes covered in silt, within 5 m of the shoreline; and Muddy sites-turtles are buried in deep anoxic mud in marshy areas or beneath floating mats of vegetation.

Habitat trends

In general, Snapping Turtle habitat is diminishing in both quantity and quality in Canada. Agriculture has claimed 71% of southern Ontario wetlands and 70% of wetlands in the prairie provinces (Natural Resources Canada 2004). Although Snapping Turtle populations appear capable of persisting in highly disturbed and contaminated habitat, the toxicity in these sites is known to reduce the already low reproductive output of this species (Bishop *et al.* 1998, de Solla *et al.* 1998). Road construction along wetland edges can create nesting habitat for female turtles, but the increased adult mortality from vehicular traffic would offset any reproductive gains if indeed there were any. Dredging of ponds to reduce sediment build-up likely diminishes the quality of summer habitat for Snapping Turtles, and may kill turtles that are in or on the substrate (S. Gillingwater, pers. comm. 2008). Artificially lowering water levels in lakes and impoundments (a common practice) may limit the availability of hibernacula to turtles and may strand turtles in freezing temperatures depending on when such operations take place.

Habitat protection/ownership

The Snapping Turtle occurs in many national parks and wildlife areas, provincial parks, and crown lands from Saskatchewan through to Nova Scotia (Figures 3-6). However, because of the species' perceived status as common, very few sightings are recorded by park authorities (S. Frey pers. comm. 2005). At present, no data are available to determine whether or not the existing protection, or lack of it, afforded the species within Canada is sufficient for the species to persist. Within the protected Wildlife Research Area of Algonquin Provincial Park, Ontario, where a study of Snapping Turtles has been ongoing since 1972, the adult population size appears to have been declining since the late 1980s (R. Brooks pers. comm. 2005). A large part of this decline was caused by predation by otters (*Lontra canadensis*), but an undetermined portion was derived from mortality from vehicles and perhaps from poaching, particularly of females attempting to nest along roads.

BIOLOGY

Much of the biology of the Snapping Turtle is known from long-term studies on the E.S. George Reserve (ESGR; 42°28'N, 84°00'W) in southeast Michigan, USA, the Wildlife Research Area (45°35'N, 78°30'W) of the Ontario Ministry of Natural Resources in Algonquin Provincial Park, Ontario, and Cootes' Paradise (43°17'N, 79°53'W) in Hamilton, Ontario. More recently, toxicological studies have been conducted on populations of Snapping Turtles in the southern Great Lakes watershed.

Life history

Snapping Turtles, like many other freshwater turtles, have a life-history strategy characterized by high and stochastic embryo and hatchling mortality, delayed sexual maturity, extended adult longevity, and iteroparity with low reproductive success per reproductive event (Galbraith and Brooks 1987a; Congdon *et al.* 1994). Survivorship measured from egg-laying to hatchling emergence in a Michigan population was 0.23, and survival from hatchling emergence to the following summer was 0.09 (Congdon *et al.* 1994). In Algonquin Park, the probability of surviving from egg to sexual maturity was estimated to be only 0.000692 (Brooks *et al.* 1991a). Mean annual female survivorship of Algonquin Park turtles was calculated from mark-recapture data as 0.93 (95% CI: 0.90-0.97; Galbraith and Brooks 1987a) and measured at 0.88 in Michigan (Congdon *et al.* 1994). True female survivorship in Algonquin Park is likely higher, as emigrants cannot be accounted for (Galbraith and Brooks 1987a). Snapping Turtles do not appear capable of compensating for large increases in mortality. Following a 20-fold increase in adult mortality from 1987-1989 in Algonquin Park (see below), there was no evidence of density dependent response to the decline as measured by subsequent changes in clutch size, numbers of hatchlings and juveniles, growth rates or adult recruitment (Brooks *et al.* 1991a; R. Brooks unpublished data, 1987-2008).

Age can be estimated in juvenile Snapping Turtles by counting growth lines on the vertebral scutes of the carapace, but once turtles reach sexual maturity the pattern of growth line deposition varies considerably between individuals and lines can only be used to produce a minimum age estimate at best (Galbraith and Brooks 1987b; Brooks *et al.* 1997). Nevertheless, a small number of known-age individuals, age estimates interpolated from measurements of growth and evidence of reproductive maturity (e.g. nesting), have helped determine age of maturity in Snapping Turtles in Algonquin Park. Juvenile Snapping Turtles grow at a rate of 15 to 20 mm carapace length (CL) per year until 11 to 13 years, when growth rate drops by 40%. A second rapid decrease in growth rate occurs between 17 and 19 years. These two reductions in growth rates of females were interpreted as representing age of first follicular enlargement and age of first oviposition (Galbraith *et al.* 1989). On average, it is estimated that females nest for the first time between 17 and 19 years of age at a CL between 24.9 and 25.8 cm (Galbraith *et al.* 1989). Three known-age females laid their first clutches at 16 or 17 years (R. Brooks unpublished data). It is estimated that males reach sexual maturity between 15 and 20 years of age (R. Brooks unpublished data). Obtaining an accurate estimate of sexual maturity in males is considerably more difficult as there is no distinct and easily observed reproductive event with which to clearly define maturity (such as oviposition in females).

Female Snapping Turtles in Algonquin Park mature later and at a larger size than those in more southern populations. Whereas the smallest female observed nesting in Algonquin Park had a CL of 23.6 cm and was estimated to be 19.2 ± 3.9 years of age (Galbraith *et al.* 1989), in Michigan the smallest nesting female had a CL of 20.6cm and was known to be 12 years of age (Congdon *et al.* 1987). In Cootes' Paradise, the smallest nesting female had a CL of 22.2 cm (Bishop *et al.* 1994). Brown *et al.* (1994a) found that the growth rate of adults in Algonquin Park was almost four times less than adults in Cootes' Paradise. A similar difference in growth rate was also noted between hatchlings from Algonquin Park and Cootes' Paradise when reared in identical laboratory conditions. Although Algonquin Park hatchlings were significantly larger at hatching than Cootes' Paradise hatchlings, growth rate up to 22 months post-hatching was significantly lower for Algonquin Park hatchlings (Bobyn and Brooks 1994).

Absolute longevity of Snapping Turtles in the wild remains undetermined, but long-term data collection (35+ years) in Algonquin Park continues to increase the accuracy of estimates. After sexual maturity, growth slows considerably, and in some older turtles no measurable growth may be detected. Approximately half of adult females captured between 1976 and 1985 had stopped growing (Galbraith and Brooks 1987b). A female first captured nesting in 1972 at a CL of 30.0 cm was recaptured during nesting in 27 subsequent years and was last measured at 30.8 cm CL in 2004-a growth rate of ~0.03 mm/yr. Assuming age of maturity is somewhere between 15 and 20 years, and that she was first caught at age 15, this female was at least 48 to 53 years of age in 2004. However, given that 30.0 cm CL is 4-5 cm larger than estimated CL at sexual maturity (see above), and that mean growth rate in the population is 0.095 cm/year, then it would have taken a minimum of 42 years and a maximum of 53 years from sexual maturity to reach 30.0 cm. Therefore, in 2004, this female was a minimum of 90 and a maximum of

106 years old (R. Brooks unpublished data). Anecdotal reports of ancient snappers lend additional support to the suggestion that Snapping Turtles can regularly reach ages greater than 50 years. In 2005, a male was captured in Nova Scotia with what appears to be the year 1942 carved into its carapace, placing the turtle at a minimum of 79-84 years (M. Elderkin pers. comm. 2006). Apparently carving dates into Snapping Turtles has been a practice for over 100 years, as a “monster” turtle captured in a garden pond near Bolton, Ontario, in 1875 had the year 1839 carved into its carapace placing it at a minimum of 52-57 years old (Bull 1938). Generation time is estimated as GT=Age at Maturity+1/annual mortality rate =17+1/0.07= 17 + 14 = 31 years (Galbraith and Brooks 1987a; Galbraith *et al.* 1989).

Reproduction

Follicular development in female Snapping Turtles begins in July and August of the year prior to nesting, with follicles reaching a pre-ovulatory diameter of 20-24 mm in late fall. Follicular maturation, ovulation, fertilization and shelling of the eggs occur in early spring just prior to nesting (White and Murphy 1973, Congdon *et al.* 2008, Mahmood and Alkindi 2008). The spermatogenic cycle in male Snapping Turtles begins in late June and peaks in mid-September, at which point sperm are transferred from the testes to the epidymides for storage over winter (White and Murphy 1973). Mating takes place in early spring (May in Algonquin Park) when males appear to forcibly inseminate females (Obbard 1983). Galbraith (1991) found evidence that sperm from multiple males can be used to fertilize a single clutch of eggs and females may be capable of retaining viable sperm for several years (Ernst *et al.* 1994).

The earliest nesting season recorded in Algonquin Park between 1972 and 2005 started on May 26 and the latest start was June 18, with an average duration of 19 days (range 12-34). Nesting in Quebec also takes place from late May to late June (Desroches and Rodrigue 1994). The onset of nesting can be predicted by calculating accumulated Turtle Heat Units (mean daily water temperature above 5^{o}C see Holt 2000) from early spring onward. Using 344 Turtle Heat Units as the minimum required for females to begin nesting, Obbard and Brooks (1987) were able to predict within one day when the first nesting attempts would take place. Females show strong nest site fidelity, moving up to 0.5 km overland and 8.0 km downstream in multiple years to a chosen nest site (Obbard and Brooks 1980). In Michigan, 80% of nesting occurs before 1100h and between 2000-2300h (Congdon *et al.* 1987). In Algonquin Park, 61% of clutches are laid in the evening after 1800h, and most of the remainder are laid between 0400-0900h. On warm rainy days, nesting may occur all through the day and night (R. Brooks unpublished data). Females dig a flask-shaped nest with a depth up to 18 cm using their hind feet (Ernst *et al.* 1994). A single clutch is laid each year, varying in size from 12 to 69 eggs in Algonquin Park (average 36 eggs; R. Brooks unpublished data), with clutches approximately 30% larger at Cootes’ Paradise (Brown *et al.* 1994a). The largest clutch size observed at Rondeau Provincial Park was 68 eggs (S. Gillingwater, pers. comm. 2007), and a clutch of 73 eggs was found at Tiny Marsh near Elmvale Ontario in 2002 (S. deSolla, pers. comm. 2008). In Michigan, clutch size averages 27.9 eggs (range 12-41; Congdon *et al.* 1987), whereas in Manitoba clutches of 77 and 80 eggs have been recorded (Norris-Elye 1949). Clutch size and clutch mass are significantly positively correlated with maternal body size (CL) and body mass (Obbard 1983, Congdon *et al.* 2008), indicating that larger (older?) females have a reproductive advantage over smaller (younger?) females (see also Congdon *et al.* 2002). Approximately 85% of females reproduce annually in Michigan and Ontario (Congdon *et al.* 1994, 2008).

Sex determination in Snapping Turtles is temperature-dependent (Yntema 1976, Ewert 2008), although adult sex ratios do not tend to deviate from 1:1 (Obbard 1983). At constant temperatures, males develop between approximately 23-28˚C, and females develop at temperatures above or below these values (Yntema 1976). Under fluctuating temperatures, however, the relationship between sex and incubation temperature is less clear. Generally, eggs developing at relatively constant moderate temperatures become male, whereas eggs incubating in more highly fluctuating temperatures become female (Wilhoft et al. 1983). Incubation length is strongly negatively correlated with ambient temperature (Holt 2000, Ewert 2008). On average in Algonquin Park, incubation takes 101 days with hatchlings emerging in mid-to late September (S. Holt unpublished data), but in cool summers few or no clutches successfully develop and emerge. In Algonquin Park, hatchlings emerge from nests in only ~50% of years because of this temperature constraint (R. Brooks, pers. comm. 2006). In contrast, incubation can take as little as 60 days in sandy sites at Rondeau Provincial Park and 70 days at Long Point NWA (S. Gillingwater, pers. comm.).

At incubation temperatures below 22^{o}C, embryonic development is severely impaired and even successful hatchlings have significantly lower post-hatching growth and survival rates compared to hatchlings incubated at higher temperatures (Brooks *et al.* 1991b, Bobyn and Brooks 1994). Overwintering in the nest is not a viable option for hatchling Snapping Turtles in Algonquin Park, as only 1 in 129 clutches remaining in the ground over winter had live hatchlings the following spring (Obbard and Brooks 1981b), although these hatchlings did not survive long (R. Brooks pers. comm. 2006). Hatchling Snapping Turtles reared in the laboratory had an initial mass of 8.24 g ± 1.32 for eggs collected from Algonquin Park and 7.40g ± 1.32 for eggs from Cootes' Paradise (Bobyn and Brooks 1994).

Thermoregulation

Snapping Turtles first become active in spring when water temperatures reach 7.5^{o}C (Obbard and Brooks 1981a). Although the mean selected temperature (MST) for captive adults in a temperature gradient was 28^{o}C (Schuett and Gatten 1980) and MST of hatchlings was 29.8^{o}C ± 0.4; (Knight *et al.* 1990), the mean body temperature of adults radio-tracked in Algonquin between July 1 and August 14 was 22.7 ^{o}C (± 2.8; Brown *et al.* 1990). The average environmental temperature (a combination of air temperature and solar radiation) corresponding to the body temperatures recorded in the radio-tracking experiment was 24.9 ^{o}C (± 6.2), demonstrating that Snapping Turtles in their natural habitat are not always exploiting opportunities to increase their body temperatures to the MST from laboratory experiments (Brown *et al.* 1990). Adult turtles in Cootes' Paradise and Lynde Creek Marsh, Ontario (43°17'N, 79°53'W), spend a great deal of time in the coolest available microclimates, buried in mud in shallow water or under banks and vegetation (Brown *et al.* 1994a). Nevertheless, Snapping Turtles have been known to bask to raise their body temperature. The mean cloacal temperature of 12 basking turtles was 27.6°C (± 4.65) which was significantly higher than mean ambient air temperature (24.3°C ± 4.12; Obbard and Brooks 1979).

Despite predictions to the contrary, Snapping Turtles do not exhibit a thermophilic response to feeding. Satiated hatchling turtles tend to be more sedentary than unfed turtles, and will remain in the cold end of a laboratory temperature gradient if they are initially fed there (Knight *et al.* 1990). Fed turtles that were initially located among floating aquatic vegetation in Algonquin Park consistently retreated to shallow (<0.25m) water and buried themselves in the bottom substrate, but there was no difference in MST between fed and unfed turtles (Brown and Brooks 1991). Although nesting often takes place during the cool morning and evening hours, in Michigan female body temperature during nesting is highly variable, ranging from 20.4 to 28°C (Congdon *et al.* 1987), and in Algonquin Park body temperatures at nesting ranged from 12 to 34°C (R. Brooks unpublished data).

Nutrition

Snapping Turtles are primarily omnivorous, although they will also scavenge recently dead animals (Ernst *et al.* 1994; Harding 1997). Plant matter is generally more abundant than animal matter in the stomachs of adults. Lagler (1940) found vegetation comprising over 90% of stomach matter from 278 individuals. Adult turtles in Algonquin Park are frequently observed eating water shield (*Brasenia schreberi*), which may be their main food source in late summer and early fall (Obbard and Brooks 1981a, Ernst *et al.* 1994). Other plant genera consumed include filamentous algae (*Spirogyra*), duckweed (*Lemna*), pondweed (*Potamogeton, Elodea*), cattail (*Typha*), sedge (*Carex*) and water lily (*Nymphaea*; Pell 1941; Ernst *et al.* 1994). Animal food items, eaten both live and as carrion, include molluscs, crustaceans, insects, small fish, frogs, juvenile turtles, and birds (Pell 1941). Young Snapping Turtles actively forage for food, whereas older individuals generally lie in ambush (Ernst et al. 1994).

Annual and daily activity patterns

In addition to nest-site fidelity (see Reproduction), many Snapping Turtles return annually to a summer home range and/or a hibernaculum. Males remain in one general area of a lake each summer (Galbraith *et al.* 1987), and many adults migrate annually up to 3.9 km (mean 1.0 km ± 0.75) to return within as little as 1 m of their previous years' hibernation site (Brown and Brooks 1994). The turtles may hibernate individually, or in groups. In Cootes' Paradise, females generally had larger home ranges than males and nesting migrations tended to be shorter than in Algonquin Park (Pettit *et al.* 1995). Males are significantly more active and move significantly longer distances than females in May after emergence from hibernation. Whereas females tended to remain buried in substrate for up to 10 days, 81% of male-male combative and male-female copulatory behaviour took place in May (Brown and Brooks 1993). Females were more active than males in Algonquin Park in July. No differences in rate or distance of movement between the sexes were observed in June and August (Brown and Brooks 1993).

Snapping Turtles are primarily diurnal, although activity is occasionally observed on bright moonlit nights. For most of the day, these turtles are inactive, with activity peaks in early morning and late afternoon (Obbard and Brooks 1981a). Basking is generally observed between 1000 h and 1400 h. After 1800 h, 83% of records from a radiotelemetry study showed turtles to be inactive (Obbard and Brooks 1981a). When inactive, at any time of day, Snapping Turtles move to shallower water (mean depth 0.42 m ± 0.14; Obbard and Brooks 1981a).

Behaviour

As their name implies, Snapping Turtles have a reputation for ornery behaviour. When confronted on land, adults normally turn to face a potential enemy and strike quickly with their long neck extended. However, when disturbed underwater these turtles generally flee and conceal themselves in sediment. Hatchlings and small juveniles, for which striking is a less effective defence, secrete a foul-smelling amber-coloured liquid from the bridge region of the plastron which may deter predators (Harding 1997).

Male Snapping Turtles have been observed in combat with other males, particularly in May when testosterone levels are high (Brown and Brooks 1993). When a clear victor has been identified in combat, the successful male is usually the larger of the two. The smaller male is displaced (Obbard 1983) and injured or occasionally killed (R. Brooks pers. comm. 2006). It is unclear whether males are defending territories, access to females, or fighting for another reason (Obbard 1983; Galbraith *et al.* 1987). Combative behaviour between males and courtship behaviour between the sexes can result in wounds to the head, neck and legs. Females frequently display scarring on top of their heads in spring and early summer (S. Gillingwater, pers. comm.), although this has not been observed in the Algonquin Park population (R. Brooks pers. comm. 2008).

Predation

Active adult Snapping Turtles have few known predators other than humans. Small adults are occasionally killed and their internal organs eaten by Mink (*Mustela vison*) at Big Creek National Wildlife Area (S. Gillingwater, pers. comm.). Adults in hibernation are vulnerable to predation by the Northern River Otter (*Lontra canadensis*). Over two winters, otters in Algonquin Park located several group hibernacula and consumed the internal organs of at least 31 adults (Brooks *et al.* 1991). Prior to 1986 and after 1989 such predation was not observed, suggesting that otters do not regularly view hibernating turtles as prey but rather take advantage of the easy resource when "discovered". Although most adults are infested with *Placobdella spp.* leeches (Brooks *et al.* 1990), these parasites do not appear to reduce reproductive success in female Snapping Turtles (Brown *et al.* 1994b).

Snapping Turtles are most vulnerable to predation in the egg and hatchling stages. Nest predation in Michigan varied between 100% and 30% of unprotected nests, with 70% of nests destroyed between 1976 and 1983 (Congdon *et al.* 1987). At Grafton Lake, Nova Scotia, 23%-47% of Snapping Turtle nests were depredated even in years of low Raccoon abundance (Oickle 1997; Shallow 1998). At Point Pelee National Park, the proportion of nests preyed upon ranged from 63% to 100% in 2001-2002 (Browne and Hecnar 2007). In 2000 and 2001, 100% of Snapping Turtle nests (N=697 and 784 respectively) were depredated, primarily within the first few days of nesting at Rondeau Provincial Park (S. Gillingwater, pers. comm.).

The most common nest predators are Raccoons (*Procyon lotor*) and Red Foxes (*Vulpes fulva*); however, Coyotes (*Canis latrans*), Striped Skunks (*Mephitis mephitis*) and Virginia Opossums (*Didelphis virginiana*) have also been observed preying on Snapping Turtle eggs (Ernst *et al.* 1994, S. Gillingwater, pers.comm. at Rondeau PP). At Point Pelee National Park, the Raccoon population density is four times the average for rural Ontario (Phillips and Murray 2005). Sarcophagid fly larvae are common nest parasites along the Thames River, consuming both rotted eggs and developing embryos (S. Gillingwater, pers. comm. 2006). An experimental study using decoy nests to study mammalian predation of Snapping Turtle nests in New York demonstrated that nest predators do not require visual or recent scent cues to find nests and that predation is as likely to occur within the normal nesting period as without (Wilhoft *et al.* 1979). Intense predation (up to 100%) can take place within one day of "nesting". The only reliable cue that predators detect may be the soil disturbance left after the female has completed her nest (Wilhoft *et al.* 1979).

POPULATION SIZES AND TRENDS

Search effort

In the majority of the Snapping Turtle's range, observations are incidental and estimates of abundance are anecdotal. Two notable exceptions are long-term mark-recapture studies in Algonquin Park, Ontario, and Hamilton, Ontario, both of which are conducted by researchers from the University of Guelph and their affiliates. At the Wildlife Research Area in Algonquin Park, Snapping Turtles inhabiting local lakes and streams have been marked and recaptured annually since 1972 (R. Brooks, pers. communication 2006). During the nesting season, known nest sites are routinely patrolled for nesting females. All observed females are captured after nesting, measured and identified, or affixed with a new ID tag if they are previously unrecorded. Throughout the summer, males, females, and juveniles are also captured using baited hoop traps (Brooks *et al.* 1991a). At the Royal Botanical Gardens in Hamilton, Ontario, Snapping Turtles were first captured and marked in 1984, and since that time the population has been surveyed most intensively in 1984-1985, 1990-1991, and 1994-1995. However, the population estimates have large confidence intervals (Galbraith *et al.* 1988; S. de Solla, unpublished data). Recapture success also varies considerably throughout the active season, producing bias in estimates of population sex ratio and population size (S. de Solla, pers. comm. 2007, T. Theysmeyer, pers. Comm. 2007).

Ontario has the largest number of recorded Snapping Turtle sightings of any province, with 4466 observations in the Ontario Ministry of Natural Resources Natural Heritage Information Centre database from 1800 to 2002 (Ontario Herpetofaunal Survey 2005). Quebec's Atlas of Amphibians and Reptiles contains 799 records from 1833 to 2005 (Atlas of Amphibians and Reptiles of Quebec). Atlantic Canada has 112 observations of the Snapping Turtle recorded between 1890 and 2002, with data maintained by the Atlantic Canada Conservation Data Centre (Scott 2002, Tims and Craig 1995) and the New Brunswick Museum. At the moment, Manitoba does not have a herpetofaunal atlas program or a herpetofaunal database (J. Duncan, pers. comm.).

Abundance and trends

Reliable population size estimates of Snapping Turtles are extremely difficult to obtain, even with 30+ years of census data. The primary assumption of population closure in many population estimation models is often violated by a change in the annual search area or search effort, or by migrants entering or leaving the study area. One-quarter of turtles captured in the Wildlife Research Area in Algonquin Park between 1972 and 2005 were observed only once, suggesting that they may have been moving through the area on their way up or down the Madawaska River (R. Brooks, unpublished data). Nevertheless, population estimates based on the minimum number of individuals known to be alive can be useful for identifying population trends. Between 1986 and 1989, the minimum number of resident adults known to be alive in Lake Sasajewun decreased by approximately 65% (Brooks *et al.* 1991a). Although no recent analyses have been performed on the same population, observational data and detailed nesting records indicate that the population of Snapping Turtles in Lake Sasajewun has not increased or has possibly decreased further since that time (R. Brooks, pers. comm. 2008). The population size at Point Pelee National Park was estimated to be 1385 individuals based on 322.1 ha of suitable habitat and 4.3 Snapping Turtles/ha (Browne 2003). The estimated relative abundance of Snapping Turtles to Painted Turtles in 2001 was not significantly different from data for 1972-1973 (Browne and Hecnar 2007).

A static life table created for female Snapping Turtles in the Wildlife Research Area using data collected between 1972 and 1987 showed that despite high adult survivorship, reproductive output and recruitment into the population were insufficient to sustain the population in the long term (Brooks *et al.* 1988, Galbraith *et al.* 1997). Based on the data from Algonquin Park, the minimum estimate of generation time for that population would be 17 + 1/0.07 = 31 years (Galbraith and Brooks 1987b). Another life table created for a population of Snapping Turtles in the E.S. George Reserve, Michigan, resulted in a cohort generation time of approximately 25 years and a doubling time of approximately 2,000 years (Congdon *et al.* 1994). In an effort to simulate the effect of harvesting on Snapping Turtle populations, Congdon *et al.* (1994) artificially reduced annual adult survivorship by 0.1 and found that the population would be reduced by half in less than 20 years. Even if harvesting is restricted to only those adults older than 29 years, population half life is only 30 years (Congdon *et al.* 1994). The population of Snapping Turtles in the Wildlife Research Area appears not to have recovered from the increased adult mortality in 1987 and 1988, and these long-term data indicate that Snapping Turtle populations in general cannot recover from sustained decreases in adult survival. This conclusion is reinforced by application of a stage-based model which indicates that in Snapping Turtles, adult survivorship is critical to population persistence and almost any level of chronic increase in rates of adult mortality will produce a decline in the population (Cunnington and Brooks, 1996). Moreover, the greater age of maturity in the Algonquin population relative to the Michigan population makes the former much more sensitive to changes in adult survivorship.

At the Royal Botanical Gardens in Hamilton, adult population size of West Pond was estimated using a modified Petersen estimate and data collected from 1992 to 1995 (S. de Solla, unpublished data). West Pond is a 9-ha eutrophic pond connected to a larger wetland along the shore of Lake Ontario and artificially enriched by effluent from an upstream sewage treatment plant (Galbraith *et al.* 1988). Densities in West Pond were estimated at 66/ha in 1984-85 with a biomass >330 kg/ha. Petersen estimates suggest that the population of Snapping Turtles in West Pond is decreasing (Table 1), although there were no significant differences between years (S. de Solla, unpublished data) and many assumptions of population closure were violated. Another area of wetland at Royal Botanical Gardens had an estimated population of 21 Snapping Turtles with a density of 0.5 turtles/ha (T. Theysmeyer, pers. comm. 2007), a density 120 times less than in West Pond. The high density of turtles in West Pond is attributed to unusually high primary productivity, which is expected to decrease as effluent runoff into the wetland is deliberately reduced in future (S. de Solla, pers. comm. 2007). In general, the Snapping Turtle population at Royal Botanical gardens has not shown a marked change in population size, but more intensive study is required to substantiate this statement (T. Theysmeyer and S. de Solla, pers. comm. 2007).

Table 1. Estimates of population size of Snapping Turtles in West Pond, Hamilton, Ontario. Values in parentheses are 95% confidence limits of estimates.

	1984-1985†	1992-1994	1994-1995
Population Size	592.2	431.6	372.6
	(394.8 - 930.6)	(287.5 - 512.0)	(274.1 - 489.4)

† from Galbraith *et al.* 1988

Outside Ontario, it is estimated that Snapping Turtle populations are abundant and stable throughout Nova Scotia (M. Elderkin, J. Gilhen, pers. communication 2006). A population in Grafton Lake was estimated to have 147 turtles (95% C.I. 112-211) with no observable increase or decrease over three years of study (Hurlburt *et al.* 1997; Whynot 1996). Approximately 80% of observational records in the Atlantic Canada Conservation Data Centre database are from the past 10 years, which makes comparison with historic abundance difficult. In the past, the Snapping Turtle was reported to be rare, with a limited distribution in New Brunswick (Bleakney 1958). Insufficient data are available to determine if the species' abundance in the province is increasing or decreasing (McAlpine and Godin 1986, New Brunswick Museum Herp database 2006). In Quebec, the Snapping Turtle is relatively abundant in the south and up to 47 N latitude (S. Giguere, pers. communication 2005). On the nearby Akwesasne First Nation Reserve, the Snapping Turtle was far less abundant than the Painted Turtle (*Chrysemys picta*) with only 11 individuals captured relative to 103 Painted Turtles (S. Giguere, pers. communication 2005). No Snapping Turtles were captured during surveys of 7 other National Wildlife Areas in Quebec, although the species' presence is suspected in Iles-de-la-Paix NWA where traces of digging were observed during the nesting season (S. Giguere, pers. communication 2006).

An historic record for Manitoba states that the Snapping Turtle was abundant in the rivers and lakes of Southern Manitoba in the earlier half of the 20th century (Norris-Elye 1949). Currently the Snapping Turtle is ranked S3 provincially, indicating 100 or fewer occurrences of the species in Manitoba. No abundance estimates are available for Saskatchewan, although the species is rarely encountered (D. Secoy, pers. communication 2006). Scientists working frequently in the watersheds of southeastern Saskatchewan do not observe Snapping Turtles during field work (A. Didiuk, pers. communication).

Rescue effect

The possibility of Snapping Turtle populations in Saskatchewan and Manitoba being bolstered by migrants from the United States is limited given that the species is ranked S3 in neighbouring Montana and Minnesota (unranked in North Dakota; NatureServe website 2006). Populations of the Snapping Turtle in Ontario, Quebec, New Brunswick and Nova Scotia that are eliminated could be recolonized by nearby populations in the northeastern USA. However, given that the greatest risks to population persistence are habitat loss and decreased adult survivorship due to accidental or deliberate mortality (see Limiting Factors and Threats below), it is unlikely that declining populations will benefit greatly from an influx of new individuals that face similar threats.

LIMITING FACTORS AND THREATS

“Slow” life histories (late maturity, long lifespan, low recruitment, and reliance on low adult mortality) and vulnerability to human exploitation have made turtles and tortoises one of the most threatened major taxa globally with ~70% of assessed species being listed as Extinct, Critically Endangered, Endangered or Vulnerable (IUCN Red List 2007). Most of the remaining species are Conservation Dependent/Near Threatened and fewer than 0.5% are ranked as Least Concern. The Snapping Turtle has not been not assessed by IUCN.

Like all native turtle species in Canada, Snapping Turtles exist under two major natural constraints; a “slow” life history (See Biology, Life History) and cool, relatively short, active seasons. These limiting factors are not in themselves threats to turtles, but in concert with anthropogenic activities, these factors make turtles unusually vulnerable to a host of threats. This combination of life history, temperature constraints and interactions with people has led to all nine other Canadian species of turtles being listed by COSEWIC. The Snapping Turtle is the lone exception to date.

Although Snapping Turtles remain widespread and somewhat numerous, the species will inevitably decline under current circumstances for precisely the same reasons that other turtles have declined. Indeed, Livaitis and Tash (2008) argue that life-history information be used to rank animals along a continuum of vulnerability. On their scale (Fig. 7 in their paper), turtles are most vulnerable among a diverse sample of species native to the United States. Because of climate, high human densities and habitat alteration over most of their Canadian range, Snapping Turtle populations in Canada are particularly vulnerable to stochastic mortality events and to chronic increases in mortality rates of both juveniles and adults. The recovery period compensating for this increased mortality is likely to be extremely long (Congdon *et al.* 1994, Brooks *et al.* 1988, Cunnington and Brooks 1996, Galbraith *et al.*1997, Heppell 1998), because of low rates of recruitment, extended juvenile periods (late maturity), and lack of any apparent density-dependent responses (i.e., low density, increased food availability, etc., do not lead to increases in survival, growth rate, egg or clutch size in Snapping Turtles. Brooks *et al.* 1991a). For the Snapping Turtle population in Michigan, Congdon *et al.* (1994) estimated that at the existing rate of population increase, doubling time is 2000 years.

Thermal constraints on turtles in Canada are most important through their effects on incubating embryos. Development rates of turtle embryos have a strong positive correlation with ambient temperatures (Yntema 1976, Holt 2000, Ewert 2008) and this relationship means that if temperatures are not high enough the embryos will not complete development before winter, and will not survive (Obbard and Brooks 1981b, Holt 2000, unpublished data). Similarly, if the eggs hatch late in fall they cannot emerge if temperatures are low, and again they will not survive winter (Obbard, 1983). Even if incubation is completed and hatchlings do emerge, they will have poor growth and viability if exposed to low temperatures during incubation (Brooks *et al.* 1991a, Bobyn and Brooks 1994). Like those of many plants, turtle distributions follow isotherms of heat units (for example, see agricultural maps showing "corn heat units"). As a result, turtles are confined to the more southern parts of Canada, the areas occupied by most Canadians and subject to the nation's most intensive agriculture, the latter being dictated by the same thermal constraints that limit turtle distribution. Therefore, Snapping Turtles face high densities of people and their roads, urban areas and intensive farming activities over most of their range. At the northern limits of the turtle's range, threats from human activities are reduced, but turtle densities are low, maturity is exceptionally delayed (Galbraith et al, 1997, Moll and Iverson 2008) and egg and hatchling survival is unusually poor (Brooks *et al.* 1991b). Hence, recruitment into the breeding population is exceptionally low and stochastic in the more northern populations.

Population persistence is critically dependent on high adult survivorship; thus the greatest limitations to the Snapping Turtle's persistence in Canada are any events that increase adult mortality. With annual harvesting (or road mortality) rates as low as 0.1, a population of Snapping Turtles could be halved within 20 years in southern Michigan (Congdon *et al.* 1994). Whereas, in the Michigan population females mature at ~ 12 years, in central Ontario, age at maturity is 16-19 years (Galbraith and Brooks 1989). This longer delay is likely typical of most Snapping Turtle populations in Canada, except those in southern Ontario (which would be more similar to southeast Michigan). Those at the species' northern and climatic limits may take even longer to mature (Moll and Iverson 2008). The later age at maturity in Canada means that these populations are even more vulnerable to additional unnatural mortality than are turtles in Congdon's study (Cunnington and Brooks 1996, Stearns 1992, Roff 2002). The average annual survival required by Algonquin turtles from ages 1-18 yr to produce a replacement rate of one is 83% (Galbraith *et al.* 1997).

Anthropogenic threats

Mortality on roads

Roads are a widespread and significant threat to a variety of wildlife species (Trombulak and Frissell 2000), particularly many turtle species (Beaudry *et al.* 2008, Litvaitis and Tash 2008). Considering southern Ontario alone, the primary road network increased from roughly 7000 km to over 35000 km of roads from 1935-1995 (Fenech *et al.* 2001). Concomitant with these increases there have been demonstrated increases in both traffic volume and speed, both of which increase mortality of wildlife including turtles (Farmer, 2007). Significant annual mortality of most turtle species occurs as a result of traffic mortality, especially on roads located through or adjacent to wetlands. Furthermore, roads fragment and isolate populations, either by forming impassable physical barriers or by selection against those genotypes that use the roads. Snapping Turtles are most vulnerable to mortality from vehicular collisions during the reproductive season as females cross roads frequently in search of nesting sites, but also because soft gravel road shoulders make attractive nesting sites (Haxton 2000, Aresco 2005). If females do manage to complete a nest, the hatchlings are often killed (e.g. Ashley and Robinson 1996) as they leave the nest or because eggs fail to hatch due to compaction of the nest chamber, desiccation or increased access to mammalian predators. Gravel or dirt roads and shoulders may provide a nesting environment for turtles, but they also are population “sinks” because of the added mortality from vehicles (Haxton 2000). Modelling studies predict that populations of freshwater turtles experience annual traffic mortality rates that may exceed 5% in areas with high road densities (Gibbs and Shriver 2002). Snapping Turtle populations will decline with an increase in annual mortality of this magnitude (Congdon *et al.* 1994). Another threat to roadside nests is routine road maintenance such as gravelling and grading, which often destroy or seriously damage nests by exposing or crushing the eggs (R. Brooks unpublished data).

Perhaps as a result of increased mortality to females, turtle population sex ratios become increasingly skewed towards males in areas with higher road densities (Aresco 2005). For example, males made up 95% of adult Snapping Turtles caught in wetlands surrounded by a high density of roads (Steen and Gibbs 2004) suggesting that females are experiencing high levels of road mortality. If road mortality is causing the male-biased sex ratio then this trend should be observable over time. A meta-analysis of 165 turtle population estimates from the USA spanning 1928-2003 revealed a significant increase in the percentage of males over time (Gibbs and Steen 2005). Sex ratios became more male-biased in states with higher road densities and in species that were more aquatic. Higher rates of female mortality are also reflected in the fact that there is a larger fraction of female turtles in studies close to roads (61%) compared with studies away from roads (41%; Steen *et al.* 2006), presumably because females nesting on roadsides are more readily encountered. These overall results also hold true for the Snapping Turtle specifically, with 64% of the adults found on roads confirmed as females. This is likely a significant underestimate (R. Brooks unpublished data).

Mortality from fishing

Recreational and sport fishing are another source of mortality for Snapping Turtles. These turtles can accidentally ingest fishing hooks after consuming dead fish with imbedded hooks in them, or can be hooked directly by the anglers. Dead turtles with fishing hooks embedded in mouth, throat and stomach have been collected from Rondeau Provincial Park, Long Point NWA and the Thames River (S. Gillingwater, pers. comm. 2006). Approximately 5% of Snapping Turtles brought to the Wildlife Center of Virginia that were associated with trauma were due to fishing related gear (Brown and Sleeman 2002). A few cases of mortality and injury to Snapping Turtles due to the ingestion of lead sinkers and jigs have been reported (Borkowski 1997, Scheuhammer *et al.* 2003); however, it is likely that this source of mortality is under-reported. Finally, many people kill Snapping Turtles because the turtles eat fish hanging on “stringers” from boats or docks.

Mortality from persecution

Vandals also target Snapping Turtles for violent purposes. Snapping Turtles have been found deliberately starved to death, nailed to trees, shot, beaten or dismembered (R. Bolton, R. Brooks and S. Gillingwater, pers. comm. 2008). For example, "Photographs of slain and often mutilated Snapping Turtles have been observed at a private waterfowl hunt club in southern Ontario. It is unknown whether these turtles were killed for consumptive use, persecuted due to the concern that they negatively affect waterfowl populations, or some other reason. Additionally, it is unknown whether the turtles depicted in some photographs were alive or dead prior to having their heads and limbs removed. Other photographs depicted Snapping Turtles with their heads still attached, but seemingly only to provide a point of attachment for when nailed to a tree." (R. Bolton, email comm. Sept. 25 2008). Snapping Turtles are especially targeted for persecution because of their reputation for aggression, their large size and fearsome visage and their reputation as voracious predators of waterfowl and sport fish. These views are enhanced by apocryphal tales that exaggerate these traits.

Although road mortality in turtles may primarily be the result of accidental collisions with automobiles, recent research has demonstrated that a significant proportion of drivers deliberately target turtles on roads. An average of 2.7% of drivers (one per 40 vehicles) intentionally drove over decoy turtles placed at the centre of a road adjacent to Big Creek NWA and leading to Long Point Provincial Park (Ashley *et al.* 2007). Although this percentage sounds relatively minor, given known traffic volumes and periods of increased road activity by turtles during nesting season, it was estimated that a reptile (turtle or snake) is deliberately targeted by an automobile driver every 15 minutes (Ashley *et al.* 2007).

Unnaturally high rates of nest predation

Predation of turtle nests is natural. However, unnaturally high rates of nest predation are associated with areas of high human populations and are also a threat to Snapping Turtle population persistence. Unnaturally high rates of nest predation have been well documented in several Ontario parks (see Biology, Reproduction). Nest predation is exacerbated in many parts of southern Canada by elevated populations of egg-eating predators (the so-called “subsidized predators”) such as Raccoons, Striped Skunks, Opossums and Coyotes. Raccoon density at Point Pelee National Park is four times the average for rural Ontario (Phillips and Murray 2005). Raccoon densities are also high in suburban areas with densities >100/km^2 reported from one location in southern Ontario (Rosatte 2000). It is estimated that Ontario has approximately one million Raccoons (Rosatte 2000). Such predator densities can lead to complete nest failure: Examples include:

- 100% of roadside turtle nests were depredated at Point Pelee National Park (Browne 2003).
- 99% of 697 Snapping Turtles nests were depredated in 2000 and 100% of 784 nests were depredated in 2001 at Rondeau Provincial Park (Gillingwater 2001).
- 100% of Snapping Turtle nests were depredated along the Simcoe Rail Trail in 2006 (Bowles *et al.* 2007).

Intense nest predation often occurs in or near parks, because high levels of food available from tourists, campers and other park visitors increase populations of Raccoons and their pressure on turtle populations (Phillips and Murray, 2005). Unnaturally high densities of mammals are the primary cause of nest failure in southern parts of the species’ range, and it is unlikely that predator densities will decrease in future. Although turtle life histories have evolved to compensate for high nest mortality, multiple years of 100% mortality of eggs will lead to declines in abundance.

Legal and illegal harvesting

Turtles have had a long history of exploitation by humans, perhaps more than any other reptiles (Carr 1952, Klemens and Thorbjarnarson 1995, Klemens 2000). Virtually every group of turtles (tortoises, marine turtles, river turtles, pond turtles) has been harvested historically for eggs, meat, pets, or decorations, and such harvesting not only continues today, but is increasing globally particularly to supply a growing Asian market (Klemens 2000, Gamble and Simons 2004, Caputo *et al.* 2005, Schlaepfer et al 2005), IUCN 2007, Herpdigest 2008). The staggering size of the reptile trade in the USA has been described in detail by Christy (2008) in a recent book.

Legal and illegal harvesting is an ongoing source of mortality for the Snapping Turtle. Although Ontario has tightened its hunting restrictions, the daily bag limit for Snapping Turtles is two and the possession limit is five (Ontario Ministry of Natural Resources 2007). At a rate of capture of two Snapping Turtles per day during the legal hunting season (July 15 to September 15 in central and southern Ontario), two individuals harvesting from the same population could potentially remove about 250 adults in a single summer. In more northern regions with a longer "open" season, many more could be taken. Although there is some monitoring of this "harvest" by conservation officers, there is no tracking of the "harvest" so there are no quantitative long-term data from which to assess impacts. Nova Scotia has recently (Sept. 2008) banned commercial harvest of Snapping Turtles, but personal harvest continues (S. Boates pers. comm. Sept 2008). There is no commercial harvest in Quebec or Ontario.

A new, rapidly increasing and far more serious threat is the illegal wildlife trade (V. Miller pers. comm. Nov. 2007, Herpdigest 2008). There is a highly organized trade in turtles (and other reptiles) for food, medicine, pets and trinkets (Christy, 2008). This trade involves not just adult/juvenile turtles, but eggs and hatchlings that are coveted because they can be grown on Asian turtle farms. Systematic trapping of all turtle species, including Snapping Turtles, is increasing to meet overseas demand (China) and to satisfy a growing clandestine market in Canada, especially in large cosmopolitan sophisticated centres like Toronto and Montreal. From 1996-2006, over 1500 shipments including >1,100,000 Snapping Turtles were recorded by LEMIS (Law Enforcement Unit of US Fish and Wildlife). Few of these shipments involved Canada, but many transactions are not reported (Ernie Cooper, ecooper@wwfcanada.org).

Data from Canada on population trends are nearly non-existent, outside long-term research cited earlier. However, in the mid-1980s, a commercial trapper in southern Ontario petitioned the Ontario government to curb harvesting because of his perception that Snapping Turtles were vanishing from his favoured sites (R. Brooks, pers. comm. Sept. 2008). Subsequently, Ontario banned commercial harvest, but cited human health concerns from consumption of high levels of contamination in turtle meat, rather than disappearance of turtles as the reason for the decision. Recently, Georgia has discussed banning harvest and cited similar reports of plunging Snapping Turtle numbers as revealed in the following quote, "The most compelling result of this meeting was the testimony of two turtle farmers who provided anecdotal information on the decline of common Snapping Turtles from sites they trapped for 15 years, prior to shifting to farming to protect the wild resource. These former trappers indicated that they witnessed little change in populations after five years, but after 15 years their catch per unit effort dropped from an average of 4000 lbs/week (early on) to only 400-600 lbs/week" (Herpdigest 8:44, 2008).

Effects of contaminants

Long-term threats to the persistence of the Snapping Turtle in Canada include decreases in reproductive success due to environmental contamination. Chemical pollutants accumulate in such high concentrations in Snapping Turtles that the species has become an established indicator of localized environmental and geographic trends in contamination of polychlorinated hydrocarbons, inorganic compounds and radionuclides (deSolla *et al.* 2008). Organochlorine contaminant concentrations in Snapping Turtles vary across their distribution in southern Ontario and with the age of the turtle (Hebert *et al.* 1993). The maximum concentrations of total PCBs in Snapping Turtle clutches near Cornwall, Ontario were extremely high (up to 737 683 ng/g, wet weight, or > 730 ppm) and are among the highest recorded in any tissue of a free-ranging animal (de Solla *et al.* 2008). Organochlorine contaminant concentrations in some Snapping Turtle eggs in Canadian Lake Erie Areas of Concern exceed guidelines for human consumption (based on guidelines for fish consumption) and Environmental Quality Guidelines (de Solla *et al.* 2008). The external morphology of Snapping Turtles at some contaminated sites in Ontario differed from reference sites that had lower degrees of environmental contamination (de Solla *et al.* 1998). High concentrations of contaminants can also have long-term effects on the reproductive success of populations (Rowe 2008). Reduced hatching success and increased deformity rates in Snapping Turtles have been reported in a number of Ontario studies (Bishop *et al.* 1991, Bishop *et al.* 1998, de Solla *et al.* 2008). As noted above, these contaminant concentrations were a primary reason that commercial harvest was banned in Ontario.

Miscellaneous causes of mortality by humans

Local population extinctions are possible when Snapping Turtle habitat is eliminated directly by urban development, or indirectly when ponds, lakes, agricultural drains and stormwater management facilities are dredged to “improve” fish habitat or increase stormwater capacity (Aresco and Gunzberger 2004). Snapping Turtles are also deliberately killed or removed from ponds and other such sites as they are perceived to be a threat to ducks, geese, swans, dogs, and humans (R. Brooks, pers. comm. Sept. 2008; S. Hecnar, pers. comm 2008).

Turtles floating at or near the surface of the water are at risk of being struck and killed by propellers of boats (Galois and Ouellet 2007). Nine Snapping Turtles were found dead, apparently killed by propeller strikes during a 2-year study in southern Ontario (Gillingwater 2001).

SPECIAL SIGNIFICANCE OF THE SPECIES

The Snapping Turtle is Canada's largest terrestrial or freshwater reptile, and has a lifespan similar to or greater than humans. Its primitive appearance is familiar to Canadians, many of whom have personal stories (often exaggerated) about the enormous size, jaw strength or ferocity of the species. In nutrient-rich wetlands in Ontario, it can occur at densities as high as 66 turtles/ha, with a total biomass exceeding 330kg/ha, which is higher than most other vertebrate species in wetlands (Galbraith *et al.* 1988), and at least an order of magnitude higher than is typical of endotherms (Iverson 1992). It is, therefore, likely that healthy populations of Snapping Turtles play significant ecological roles in wetland ecosystems, consuming dead fish and other vertebrates, reducing plant biomass, and creating channels in wetlands that fish, amphibians and other reptiles use. Their eggs provide a significant source of nutrients to mammalian mesocarnivores at a critical time when these mammals are raising their young, and at other times of year juveniles and hatchlings are consumed by a wide range of vertebrate predators. This process redistributes nutrients from aquatic to terrestrial habitats. Also, Snapping Turtles probably have coevolved with other species and become, for example, important vectors of algae, plants, and leeches and other invertebrates (Congdon and Gibbons 1989). Given that there has been little investigation of the influences on ecosystems of this or any other turtle, it is likely that snappers perform other functions at the ecosystem level that are as yet undiscovered. Snapping Turtles are of considerable scientific interest as they possess significant adaptations to anoxia, and occupy a wide range of habitats, Furthermore, they display many unique behavioural and morphological traits, including environmental sex determination (see Syeyermark *et al.* 2008 for a comprehensive survey of research on the Snapping Turtle). Snapping Turtles have become a useful species in environmental education through organizations, such as the Kawartha Turtle Trauma Centre in Peterborough Ontario, that rehabilitate turtles injured on roads. Many children have participated in these programs and learn about the impact people are having on turtles and other wildlife. Last, but not least, the Snapping Turtle also has great significance for First Nations' people. ATK evaluation of this report supports the status of Special Concern and agrees that the Snapping Turtle is a species in decline in Canada.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The Snapping Turtle is ranked S5 (demonstrably widespread, abundant, and secure) in Nova Scotia, while in Ontario, New Brunswick and Quebec the species is ranked S4, apparently secure (NatureServe website 2006). In both Manitoba and Saskatchewan, the Snapping Turtle is ranked S3, due to its restricted range and relatively few populations (NatureServe website 2006, J. Duncan, pers. communication 2006). The general status ranking of the species is Sensitive in Saskatchewan and Manitoba, and Secure in Ontario, Quebec, New Brunswick and Nova Scotia (Wildspecies 2005).

The species is legally protected in all Provincial and National Parks, although illegal trapping has been observed in Ontario Parks (S. Gillingwater, pers. comm.) including Point Pelee National Park (S. Hecnar, pers. comm 2008). The Snapping Turtle is protected from hunting in Manitoba, Quebec and New Brunswick, but may be hunted with a licence in Ontario (during restricted periods) and Nova Scotia (Canadian Amphibian and Reptile Conservation Network 2007). In Saskatchewan, the Snapping Turtle may be hunted without a licence (Canadian Amphibian and Reptile Conservation Network 2006).

TECHNICAL SUMMARY

Chelydra serpentina
Snapping Turtle — Tortue serpentine
Range of Occurrence in Canada : SK, MN, ON, QC, NB, NS

Demographic Information

Generation time (average age of parents in the population)	Gen time=age at maturity+1/annual mortality rate. 17 +1/0.07=31yrs
Observed percent reduction in total number of mature individuals over the last 3 generations.	Unknown, but likely to be substantial over that part of its range south of the Shield
Suspected percent reduction in total number of mature individuals over the next 3 generations.	Unknown; likely to be significant future decline without protection
Estimated percent reduction in total number of mature individuals over any 3-generations period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible?	No
Are the causes of the decline understood?	Yes
Have the causes of the decline ceased?	No
Inferred trend in number of populations	Decline
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	No

Extent and Area Information

Estimated extent of occurrence	~1,455,000 km²
Observed trend in extent of occurrence	Decline
Are there extreme fluctuations in extent of occurrence?	No
Index of area of occupancy (IOA)	Estimated to be approximately 858,000 km²
Observed trend in area of occupancy	Decline
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No
Number of current locations	Estimated at > 1000
Trend in number of locations	Decline
Are there extreme fluctuations in number of locations?	No
Observed trend in area of habitat	Decline

Number of mature individuals in each population

Population	**N Mature Individuals**
Number of adults is not known, but in the thousands	Unknown
Grand Total	Unknown

Quantitative Analysis

Not applicable.	

Threats (actual or imminent, to populations or habitats)

- exceptional vulnerability to even minor increases in adult mortality - constraints on distribution by effects of low temperatures on viability and growth of embryos and hatchlings - road mortality from collisions with vehicles - illegal wildlife trade - hunting (licensed and unlicensed) - persecution, deliberate killing including with vehicles - increased nest predation by predators (raccoons, skunks, foxes, opossums) in or near urban areas, parks, etc. - incidental mortality from fishing activities - boat propeller strikes - chemical contamination reducing reproductive success - habitat degradation and loss

Rescue Effect (immigration from an outside source)

Status of outside population(s)? USA:	
Is immigration known?	Likely
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Likely
Is rescue from outside populations likely?	Unlikely

Current Status

COSEWIC: Special Concern (November 2008)

Status and Reasons for Designation

Status: **Special Concern**	**Alpha-numeric code:** Not applicable
Reasons for designation: Although this species is widespread and still somewhat abundant, its life history (late maturity, great longevity, low recruitment, lack of density-dependent responses) and its dependence on long warm summers to complete incubation successfully make it unusually susceptible to anthropogenic threats. When these threats cause even apparently minor increases in mortality of adults, populations are likely to decline as long as these mortality increases persist. There are several such threats and their impacts are additive. Aboriginal Traditional Knowledge generally supports the declining trend and population figures in the COSEWIC report.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Decline has occurred but amount is not quantified.
Criterion B (Small Distribution Range and Decline or Fluctuation): Declines in numbers and habitat, but index of area of occupancy and extent of occurrence exceed criteria thresholds.
Criterion C (Small and Declining Number of Mature Individuals): Population is too large.
Criterion D (Very Small Population or Restricted Distribution): Population is too large.
Criterion E (Quantitative Analysis): Not applicable

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INFORMATION SOURCES

Ashley, E.P., A. Kosloski, and S.A. Petrie. 2007. Incidence of intentional vehicle-reptile collisions. Human Dimensions of Wildlife 12(3): 137-143.

Ashley, EP and JT Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field-Naturalist 110(3):403-412.

Aresco, M.J. 2005. The effect of sex-specific terrestrial movements and roads on the sex ratio of freshwater turtles. Biological Conservation 123(1): 37-44.

Aresco, M.J. and M.S. Gunzberger. 2004. Effects of large-scale sediment removal on herpetofauna in Florida wetlands. Journal of Herpetology 38(2): 275-279.

Ashpole, S.L., C.A. Bishop, and R.J. Brooks. 2004. Contaminant residues in Snapping Turtles (Chelydra s. serpentina) eggs from the Great Lakes-St. Lawrence River Basin (1999 to 2000). Archives of Environmental Contamination and Toxicology 47: 240-252.

Beaudry, F., P.G. deMaynadier and M.L. Hunter Jr. 2008. Identifying road mortality at multiple spatial scales for semi-aquatic turtles. Biological Conservation 141: 2550-2563.

Bishop, C.A., R.J. Brooks, J.H. Carey, P. Ng, R.J. Norstrom, D.R.S. Lean. 1991. The case for a cause-effect linkage between environmental contamination and development in eggs of the Common Snapping Turtle *Chelydra serpentina* from Ontario, Canada. Journal of Toxicology and Environmental Health 33:512-547.

Bishop, C.A., G.P. Brown, R.J. Brooks, D.R.S. Lean, and J.H. Carey. 1994. Organochlorine contaminant concentrations in eggs and their relationship to body size, and clutch characteristics of the female common Snapping Turtle (Chelydra serpentina serpentina) in Lake Ontario, Canada. Archives of Environmental Contamination and Toxicology 27: 82-87.

Bishop, C.A., P. Ng, K.E. Pettitt, S.W. Kennedy, J.J. Stegeman, R.J. Norstrom, and R.J. Brooks. 1998. Environmental contamination and developmental abnormalities in eggs and hatchlings of the common Snapping Turtle (Chelydra serpentina serpentina) from the Great Lakes-St. Lawrence River basin (1989-91). Environmental Pollution 101: 143-156.

Bleakney, J.S. 1958. A zoogeographical study of the amphibians and reptiles of eastern Canada. National Museum of Canada Bulletin 155: 1-119.

Boates, S. 2008. Email correspondence to R.J. Brooks, Sept. 2008 . Manager of Biodiversity, Nova Scotia Department of Natural Resources.

Bobyn, M.L., and R.J. Brooks. 1994. Incubation conditions as potential factors limiting the northern distribution of Snapping Turtles, Chelydra serpentina. Canadian Journal of Zoology 72(1): 28-37.

Bolton, R. 2008. Email correspondence to R.J. Brooks, October 2008. PhD Candidate, Dept. of Inegrative Biol,ogy. University of Guelph, Guelph Ontario.

Borkowski R. 1997. Lead poisoning and intestinal perforations in a Snapping Turtle *Chelydra serpentina* due to fishing gear ingestion. J Zoo Wildl Med 28:109-113.

Bowles, R.L., J. Laverty, and D. Festherstone. 2007. Minesing Wetlands Biological Inventory. Unpublished report to Nottawasaga Valley Conservation Authority, Utopia, Ontario.

Britson, C.A. 1998. Predatory responses of largemouth bass (Micropterus salmoides) to conspicuous and cryptic hatchling turtles: A comparative experiment. Copeia 1998: 383-390.

Brooks, R., pers. comm. 2005, 2008. Email correspondence to S. Holt. September 2005. Professor Emeritus of Zoology, University of Guelph, Guelph, Ontario.

Brooks, R.J., M.L. Bobyn, D.A. Galbraith, J.A. Layfield and E.G. Nancekivell. 1991b. Maternal and environmental influences on growth and survival of embryonic and hatchling Snapping Turtles *Chelydra serpentina*. Canadian Journal of Zoology, 69:2667-2676.

Brooks, R.J., G.P. Brown, and D.A. Galbraith. 1991a. Effects of a sudden increase in natural mortality of adults on a population of the common Snapping Turtle *Chelydra serpentina*. Canadian Journal of Zoology 69: 1314-1320.

Brooks, R.J., D.A. Galbraith, and J.A. Layfield. 1990. Occurrence of Placobdella parasitica (Hirudinea) on Snapping Turtles, Chelydra serpentina, in southeastern Ontario. Journal of Parasitology 76(2): 190-195.

Brooks, R.J., D.A. Galbraith, E.G. Nancekivell, and C.A. Bishop. 1988. Developing management guidelines for Snapping Turtles. In R.C. Szaro, K.E. Severson, and R. David ton (eds.), Management of amphibians. reptiles and small mammals in North America; Proceedings of the symposium, pp. 174-179. U.S. Dept. Agriculture Forest Service. Gen. Tech. Rep. RM-166.

Brooks, R.J., M.A. Krawchuk, C. Stevens, and N. Koper. 1997. Testing the precision and accuracy of age estimation using lines in scutes of Chelydra serpentina and Chrysemys picta. Journal of Herpetology 31(4): 521-529.

Brown, G.P. 1992. Thermal and spatial ecology of a northern population of Snapping Turtles, Chelydra serpentina. M.Sc. dissertation, University of Guelph, Guelph, Ontario, Canada. 98 pp.

Brown, G.P., C.A. Bishop, and R.J. Brooks. 1994a. Growth rate, reproductive output, and temperature selection of Snapping Turtles in habitats of different productivities. Journal of Herpetology 28(4): 405-410.

Brown, G.P., and R.J. Brooks. 1991. Thermal and behavioural responses to feeding in free-ranging turtles, Chelydra serpentina. Journal of Herpetology 25: 273-278.

Brown, G.P., and R.J. Brooks. 1993. Sexual and seasonal differences in activity in a northern population of Snapping Turtles *Chelydra serpentina*. Herpetologica 49(3): 311-318.

Brown, G.P., and R.J. Brooks. 1994. Characteristics of and fidelity to hibernacula in a northern population of Snapping Turtles, Chelydra serpentina. Copeia 1994(1): 222-226.

Brown, G.P., R.J. Brooks, and J.A. Layfield. 1990. Radiotelemetry of body temperatures of free-ranging Snapping Turtles *Chelydra serpentina* during summer. Canadian Journal of Zoology 68: 1659-1663.

Brown, G.P., R.J. Brooks, M.E. Siddall, and S.S. Desser. 1994b. Parasites and reproductive output in the Snapping Turtle, Chelydra serpentina. Copeia 1994(1): 228-231.

Brown J.D. and J.M. Sleeman. 2002. Morbidity and mortality of reptiles admitted to the Wildlife Center of Virginia, 1991–2000. J Wildl Dis 38: 699–705.

Browne, C.L. 2003. The Status of Turtle Populations in Point Pelee National Park. M.Sc. dissertation, Lakehead University, Thunder Bay, Ontario, Canada. 112 pp.

Browne, C.L. and S.J. Hecnar. 2007. Species loss and shifting population structure of freshwater turtles despite habitat protection. Biological Conservation 138: 421-429.

Bull, W.P. 1938. From Amphibians to Reptiles. The Perkins Bull Foundation, George J. McLeod Ltd, Toronto, Ontario. 85 pp.

Canadian Amphibian and Reptile Conservation Network. 2006. Web site: www.carcnet.ca. [Accessed by M. Cameron March 2007].

Caputo, F. P., D. Canestrelli, and L. Boitani. 2005. Conserving the terecay (Podocnemis unifilis, Testudines: Pelomedusidae) through a community-based sustainable harvest of its eggs. Biological Conservation 126:84-92.

Carr, A. 1952. Handbook of Turtles. Comstock Publishing Associates, Ithaca, NY.

Christy, B. 2008. The Lizard King. 12 Hachette Book Group N.Y., N.Y.

Congdon, J.D., G.L. Breitenbach, R.C. van Loben Sels, and D.W. Tinkle. 1987. Reproduction and nesting ecology of Snapping Turtles *Chelydra serpentina* in southeastern Michigan. Herpetologica 43(1): 39-54.

Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1994. Demographics of common Snapping Turtles *Chelydra serpentina*: Implications for conservation and management of long-lived organisms. American Zoologist 34: 397-408.

Congdon, J.D. and J.W. Gibbons.1986. Biomass Productivity of Freshwater Turtles Annual Report of Ecological Research at the Savannah River Ecology Laboratory. DOE Report SRO--819-17 (1986). p 111-114.

Congdon, J.D., J.L. Greene, and R.J. Brooks. 2008. Reproductive and nesting ecology of female Snapping Turtles. In: The Biology of the Snapping Turtle. A.C, Steyermark, M.S. Finkler and R.J. Brooks. The Johns Hopkins University Press Baltimore, MD.

Congdon, J.D., R.D. Nagle, O.M. Kenney, R.C. van Loben Sels, T. Quinter and D.W. Tinkle. 2003. Testing hypotheses of aging in long-lived Painted Turtles (Chrysemys picta). Experimental Gerontology 38: 765-772.

Cook, F.R. 1984. Introduction to Canadian Amphibians and Reptiles. National Museum of Natural Sciences, Ottawa. 200 pp.

Cook, F.R. Personal communication to R. Brooks, November 2008. Curator Emeritus, National Museum of Canada.

Cringan, A.T. 1958. Waterfowl production project – Production of waterfowl in the large marshes of Prince Edward County. Report to Ontario Dept. of Lands and Forests. 112p.

Cunnington, D.C. and R.J. Brooks. 1996. Bet-hedging theory and eigenelasticity: A comparison of the life histories of loggerhead sea turtles (Caretta caretta) and Snapping Turtles *Chelydra serpentina*. Canadian Journal of Zoology 74(2): 291-296.

Davidson, K., pers. comm. 2006. Email correspondence to M. Cameron. April 2006. Endangered Species Biologist, Canadian Wildlife Service, Environment Canada, Sackville, New Brunswick.

de Solla, S., pers. comm. 2007. Email correspondence to M. Cameron. March 2007. Wildlife Conservation Biologist, Canadian Wildlife Service, Environment Canada, Burlington, Ontario.

de Solla, S.R, C.A. Bishop, H. Lickers, and K. Jock. 2001. Organochlorine Pesticides, PCBs, Dibenzodioxin, and Furan Concentrations in Common Snapping Turtle Eggs (Chelydra serpentina serpentina) in Akwesasne, Mohawk Territory, Ontario, Canada. Archives of Environmental Contamination and Toxicology 40:410-417.

de Solla, S.R., C.A. Bishop, G. Van Der Kraak, and R.J. Brooks. 1998. Impact of organochlorine contamination on levels of sex hormones and external morphology of common Snapping Turtles (Chelydra serpentina serpentina) in Ontario, Canada. Evironmental Health Perspectives 106(5): 253-260.

de Solla S.R, K.J. Fernie, S. Ashpole 2008. Snapping Turtles *Chelydra serpentina* as bioindicators in Canadian Areas of Concern in the Great Lakes Basin. II. Changes in hatching success and hatchling deformities in relation to persistent organic pollutants. Environ Poll 153: 529-536

Desroches, J.-F. and D. Rodrigue. 2004. Amphibiens et reptiles du Québec et des maritimes. Éditions Michel Quintin, 288 p.

Didiuk, A., pers. comm. 2006. Email correspondence to M. Cameron. May 2006. Wildlife Biologist, Saskatchewan Herpetology Atlas Project, Saskatoon, Saskatchewan.

Elderkin, M., pers. comm. 2006. Telephone correspondence to M. Cameron. April 2006. Species at Risk Biologist, Nova Scotia Department of Natural Resources, Kentville, Nova Scotia.

Ernst, C.H. 2008. Systematics, taxonomy, and geographic distribution of the Snapping Turtles, Family Chelydridae. In: The Biology of the Snapping Turtle. A.C, Steyermark, M.S. Finkler and R.J. Brooks. The Johns Hopkins University Press Baltimore, MD.

Ernst, C.H., R.W. Barbour, and J.E. Lovich. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington D.C. 578 pp.

Ewert, M.A. 2008. Embryos and incubation period of the Snapping Turtle. In: The Biology of the Snapping Turtle. A.C, Steyermark, M.S. Finkler and R.J. Brooks. The Johns Hopkins University Press Baltimore, MD.

Farmer, R.G. 2007. Factors associated with vertebrate roadkill in southern Ontario parks. Unpublished master's thesis, University of Guelph. 149 pp.

Fenech, A. B. Taylor, R. Hansell and G. Whitelaw. 2001. Major Road Changes in Southern Ontario 1935 – 1995: Implications for Protected Areas. In Proceedings of the Fourth International Conference on the Science and Management of Protected Areas, S. Bondrup-Nielsen, N.W.P. Munro, G. Nelson, J.H.M. Willison, T.B. Herman, and P.F.J. Eagles (eds.). University of Waterloo, Waterloo, Ontario, Canada. Pp. 365-383.

Steyermark, A.C., M.S. Finkler and R.J. Brooks. (Eds). 2008. The Biology of the Snapping Turtle. The Johns Hopkins University Press Baltimore, MD.

Fraser, D., pers. comm. 2006. Email correspondence to M. Cameron. May 2006. Endangered Species Specialist, Biodiversity Branch, Terrestrial Ecosystem Science Section, Ministry of Water, Land and Air Protection, Government of British Columbia, Victoria, British Columbia.

Frey, S., pers. comm. 2005. Email correspondence to S. Holt. August 2005. Ecosystem Data Specialist, Riding Mountain National Park, Parks Canada.

Gaffney, E.S. 1984. Historical analysis of theories of chelonian relationships. Systematic Zoology 33: 283-301.

Galbraith, D.A. 1991. Studies of mating systems in wood turtles (Clemmys insculpta) and Snapping Turtles *Chelydra serpentina* using DNA fingerprinting. Ph.D. dissertation, Queen's University, Kingston, Ontario, Canada. 182 pp.

Galbraith, D.A. 2008. Population biology and population genetics. In: The Biology of the Snapping Turtle. A.C, Steyermark, M.S. Finkler and R.J. Brooks. The Johns Hopkins University Press Baltimore, MD.

Galbraith, D.A., and R.J. Brooks. 1987a. Survivorship of adult females in a northern population of common Snapping Turtles, Chelydra serpentina. Canadian Journal of Zoology 65: 1581-1586.

Galbraith, D.A., and R.J. Brooks. 1987b. Addition of annual growth lines in adult Snapping Turtles Chelydra serpentina. Journal of Herpetology 21(4): 359-363.

Galbraith, D.A., C.A. Bishop, R.J. Brooks, W.L. Simser, and K.P. Lampman. 1988. Factors affecting the density of populations of common Snapping Turtles (Chelydra serpentina serpentina). Canadian Journal of Zoology 66: 1233-1240.

Galbraith, D.A., R.J. Brooks and G.P. Brown. 1997. Can management intervention achieve sustainable exploitation of turtles? In Proceedings: Conservation. Restoration and Management of Tortoises and Turtles – an International Conference, edited by Van Abbema, J. New York Turtle and Tortoise Society, New York. Pp. 186-194.

Galbraith, D.A., R.J. Brooks, and M.E. Obbard. 1989. The influence of growth rate on age and body size at maturity in female Snapping Turtles *Chelydra serpentina*. Copeia 1989(4): 896-904.

Galbraith, D.A., M.W. Chandler, and R.J. Brooks. 1987. The fine structure of home ranges of male Chelydra serpentina: are Snapping Turtles territorial? Canadian Journal of Zoology 65: 2623-2629.

Galois, P. and M. Ouellet. 2007. Traumatic injuries in eastern spiny softshell turtles (Apalone spinifera) due to recreational activities in the northern Lake Champlain basin. Chelonian Conservation and Biology 6:288-293.

Gamble, T., and A. M. Simons. 2004. Comparison of harvested and nonharvested painted turtle populations. Wildlife Society Bulletin 32:1269-1277.

Gibbs, J.P. and W.G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16:1647-1652.

Gibbs, J.P. and D.A. Steen. 2005. Trends in sex ratios of turtles in the United States: implications of road mortality. Conservation Biology 19:552-556.

Giguère, S., pers. comm. 2005. Email correspondence to S. Holt. August 2005. Biologiste, Environnement Canada, Sainte-Foy, Québec.

Gilhen, J. 1984. Amphibians and Reptiles of Nova Scotia. Nova Scotia Museum, Halifax NS

Gilhen, J., pers. comm. 2006. Email correspondence to M. Cameron. April 2006. Curator Emeritus, Nova Scotia Museum of Natural History, Halifax, Nova Scotia.

Gillingwater, S., pers. comm. 2007. Email correspondence to R. Brooks. July 2007, August 2008.

Gillingwater, S.D., 2001. A selective herpetofaunal survey, inventory and biological research study of Rondeau Provincial Park. Unpublished report to Rondeau Provincial Park.

Green, D.M. 2003. Herpetofaunal provinces of Canada. 5 pp. Unpublished Manuscript.

Gregory, P. 2008. Email correspondence to R. Brooks. October, 2008.

Harding, J.H. 1997. Amphibians and Reptiles of the Great Lakes Region. The University of Michigan Press, Ann Arbor, Michigan. xvi + 378 pp.

Haxton, T. 2000. Road mortality of Snapping Turtles, Chelydra serpentina, in central Ontario during their nesting period. Canadian Field-Naturalist, 114:106-110.

Hebert, C.E., V Glooschenko, GD Hafner, and R Lazar. 1993. Organic contaminants in Snapping Turtle *Chelydra serpentina* populations from southern Ontario, Canada. Archives of Environmental Contamination and Toxicology 24:35-43.

Hecnar, S. 2008..Email correspondence to R. Brooks. October 2008.

Heppell, S.S., 1998. Application of life-history theory and population model analysis to turtle conservation. Copeia 1998:367-375.

Herpdigest 2008. Herpdigest, 8:44, October 2008.

Holt, S.M. 2000. Development and evaluation of a model for turtle embryonic growth. MSc thesis. University of Guelph, Guelph, Ontario

Hurlburt, D., S. Mockford, and T.B. Herman. 1997. Grafton Watershed Ecological Restoration ..Monitoring Project Final Report (Phase III) – Reptiles. Kejimkujik National Park, Maitland Bridge, Nova Scotia. 18 pp.

IUCN 2007. 2007 IUCN Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on 15 Sept. 2008.

Iverson, J.B. 1982. Biomas in turtle populayions: a neglected subject. Oecologia, 55:69-76.

Iverson, J.B. 1992. A Revised Checklist with Distribution Maps of the Turtles of the World. John B. Iverson, Richmond, Indiana. 363 pp.

Jutras, J., pers. comm. 2006. Email correspondence to M. Cameron. April 2006. Biologiste, Coordonnateur herpétofaune, chiroptères et micromammifères, Secteur Faune, Direction du Développement de la faune, Gouvernement du Québec, Québec.

Keith, J., pers. comm. 2006. Email correspondence to M. Cameron. April 2006. Biologist, Saskatchewan Conservation Data Centre, Saskatchewan Environment, Regina, Saskatchewan.

Kiviat, E. 1980. A Hudson River tidemarsh Snapping Turtle population. Transactions of the Northeast Section of the Wildlife Society 37: 158-168.

Klemens, M.W. 2000. From information to action: developing more effective strategies to conserve turtles. In Turtle Conservation, MW Klemens (ed). Smithsonian Institution Press, Washington. Pp. 239-258.

Klemens, M.W., and J.B. Thorbjarnarson. 1995. Reptiles as a food resource. Biodiversity and Conservation 4:291-298.

Knight, T.W., J.A. Layfield, and R.J. Brooks. 1990. Nutritional status and mean selected temperature of hatchling Snapping Turtles *Chelydra serpentina*: Is there a thermophilic response to feeding? Copeia 1990(4): 1067-1072.

Lagler, K.F. 1940. A Turtle Loss? American Wildlife 29(1): 41-44.

Litzgus, J., pers. comm. 2007. Email correspondence to M. Cameron. April 2007.

Livaitis, J.A. and J.P. Tash. 2008. An approach toward understanding wildlife-vehicle collisions. Environmental Management, 2008;

Mahmood, I.Y. and A.A. Alkindi.2008. Reproductive physiology of the Snapping Turtle. In: The Biology of the Snapping Turtle. A.C, Steyermark, M.S. Finkler and R.J. Brooks. The Johns Hopkins University Press Baltimore, MD.

McAlpine, D.F. and G. Godin. 1986. New records of Snapping Turtles, Chelydra serpentina, and painted turtles, Chrysemys picta, from New Brunswick. Canadian Field-Naturalist 100(1): 63-68.

Miller, V. 2007. Personal communication, to R. Brooks Nov. 2007. Enforcement Officer Ontario Ministry of Natural Resources.

Moll, D. and J.B. Iverson. 2008. Geographic variation in life-history traits. In: The Biology of the Snapping Turtle. A.C, Steyermark, M.S. Finkler and R.J. Brooks. The Johns Hopkins University Press Baltimore, MD.

Mooi, R.D., pers. comm. 2005. Email correspondence to S. Holt. August 2005. Curator of Zoology, Manitoba Museum, Winnipeg, Manitoba.

Mosimann, J.E., and J.R. Bider. 1960. Variation, sexual dimorphism, and maturity in a Quebec population of the common Snapping Turtle, Chelydra serpentina. Canadian Journal of Zoology 95: 350-352.

Natural Resources Canada. 2004. Wetlands. Web site: http://atlas.gc.ca/site/english/learningresources/theme_modules/wetlands/index.html [Accessed by S. Holt 9 August 2005].

NatureServe. 2006. Web site: www.natureserve.org. [Accessed by M. Cameron May 2006].

New Brunswick Museum Herpetofaunal Database. 2006. Data provided courtesy of Don McAlpine.

Nordstrom, W., pers. comm. 2006. Email correspondence to M. Cameron. May 2006. Biologist, Parks and Protected Areas Division, Government of Alberta, Edmonton, Alberta.

Norris-Elye, L.T.S. 1949. The common Snapping Turtle *Chelydra serpentina* in Manitoba. The Canadian Field-Naturalist 63: 145-147.

Obbard, M.E. 1983. Population ecology of the common Snapping Turtle, Chelydra serpentina, in north-central Ontario. Ph.D. dissertation, University of Guelph, Guelph, Ontario, Canada. 184 pp.

Obbard, M.E., and R.J. Brooks. 1979. Factors affecting basking in a northern population of the common Snapping Turtle, Chelydra serpentina. Canadian Journal of Zoology 57(2): 435-440.

Obbard, M.E., and R.J. Brooks. 1980. Nesting migrations of the Snapping Turtle *Chelydra serpentina*. Herpetologica 36(2): 158-162.

Obbard, M.E., and R.J. Brooks. 1981a. A radio-telemetry and mark-recapture study of activity in the common Snapping Turtle, Chelydra serpentina. Copeia 1981(3): 630-637.

Obbard, M.E., and R.J. Brooks. 1981b. Fate of overwintered clutches of the common Snapping Turtle *Chelydra serpentina* in Algonquin Park, Ontario. The Canadian Field-Naturalist 95: 350-352.

Obbard, M.E., and R.J. Brooks. 1987. Prediction of the onset of the annual nesting season of the common Snapping Turtle, Chelydra serpentina. Herpetologica 43(3): 324-328.

Oickle, D. 1997. An assessment of predation on turtle nests in relation to the spatial ecology of raccoons (Procyon lotor) in Kejimkujik National Park, Nova Scotia. B.Sc. Honours thesis, Acadia University. 49 pp.

Oldham, M., pers. comm. 2007. Email correspondence to the author. July 2007.

Ontario Herpetofaunal Summary (OHS). 2005. Natural Heritage Information Centre (NHIC) information database for sightings of the Snapping Turtle, courtesy of Mike Oldham, Ontario Ministry of Natural Resources.

Ontario Ministry of Natural Resources. 2007. Hunting Regulations. Document obtained online from: http://publicdocs.mnr.gov.on.ca/View.asp?Document_ID=10735&Attachment_ID=20632 [Accessed online 1 Sep 07)

Pell, S.M. 1941. Notes on the habits of the common Snapping Turtle, Chelydra serpentina (Linn.), in central New York. M.Sc. dissertation, Cornell University, Ithaca, New York, USA. 85 pp.

Pettit, K.E., C.A. Bishop, and R.J. Brooks. 1995. Home range and movements of the common Snapping Turtle, Chelydra serpentina serpentina, in a coastal wetland of Hamilton Harbour, Lake Ontario, Canada. Canadian Field-Naturalist 109(2): 192-200.

Phillips, C.A., W.W. Dimmick, and J.L. Carr. 1996. Conservation genetics of the common Snapping Turtle *Chelydra serpentina*. Conservation Biology 10(2): 397-405.

Phillips, J. and D. Murray. 2005. Racoon (Procyon lotor) population demographics in Point Pelee National Park and implications for the management of turtle species at risk. Contract Report for Parks Canada.

Powell, L., pers. com. 2006. Email and fax correspondence to M. Cameron. May 2006. Biologist and Research Associate, University of Calgary, Calgary, Alberta.

Preston, W.B. 1982. The Amphibians and Reptiles of Manitoba. Manitoba Museum of Man and Nature, Winnipeg, Manitoba. 128 pp.

Quebec Atlas of Reptiles and Amphibians. 2006. Saint Lawrence Valley Natural History Society, 21 125 chemin Sainte-Marie, Sainte-Anne-de-Bellevue, Quebec, H9X 3Y7, (514) 457-9449, ecomus@total.net, coordinator David Rodrigue.

Ramsey, L., pers. comm. 2006. Email correspondence to M. Cameron. May 2006. British Columbia Conservation Data Centre, British Columbia.

Roberts, W., pers. comm. 2006. Email correspondence to M. Cameron. May 2006. Professor of Zoology, University of Alberta, Edmonton, Alberta.

Roff, D. 2002. Life History Evolution. Sinauer Associates Inc. Sunderland MA.

Rosatte, R. 2000. Management of raccoons (Procyon lotor) in Ontario, Canada: do human intervention and disease have significant impact on raccoon populations. Mammalia. 64(4):369-390.

Rowe, C.L., 2008.”The calamity of so long life”: life histories, contaminants, and potential emerging threats to long-lived vertebrates. BioScience 58:623-631.

Russell, A.P., and A.M. Bauer. 2000. The Amphibians and Reptiles of Alberta. University of Calgary Press, Calgary, Ontario. xii + 279 pp.

Shaffer, H.B., D.E. Starkey, and M.K. Fujita. 2008. Molecular insights into the systematics of the Snapping Turtles, Chelydra serpentina. In: The Biology of the Snapping Turtle. A.C, Steyermark, M.S. Finkler and R.J. Brooks. The Johns Hopkins University Press Baltimore, MD.

Scheuhammer A.M., S.L. Money, D.A. Kirk, and G. Donaldson. 2003. Lead fishing sinkers and jigs in Canada: Review of their use patterns and toxic impacts on wildlife. Occasional Paper no 108. Canadian Wildlife Service, Ottawa.

Schuett, G.W. and R.E. Gatten. 1980. Thermal preference in Snapping Turtles *Chelydra serpentina*. Copeia 1: 149-152.

Schlaepfer, M.A., C. Hoover, and C.K.D. Jr. 2005. Challenges in evaluating the impact of the trade in amphibians and reptiles on wild populations. BioScience 55:256-264.

Scott, F.W. 2002. Nova Scotia Herpetofauna Atlas Database. Acadia University, Wolfville, Nova Scotia. 8856 recs.

Secoy, D., pers. comm. 2006. Email correspondence to M. Cameron. April 2006. Professor Emeritus of Zoology, University of Saskatchewan, Saskatoon, Saskatchewan.

Shallow, M. 1998. Turtle nest predation and predator foraging patterns in Kejimkujik National Park, Nova Scotia. B.Sc. Honours thesis, Acadia University. 58 pp.

Stearns, S.C. 1992. The Evolution of Life Histories. Oxford University Press. Oxford UK.

Steen, D.A. and J.P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18:1143-1148.

Steen, D.A., M.J. Aresco, S.G. Beilke, B.W. Compton, E.P. Condon, C.K. Dodd Jr, H. Forrester, J.W. Gibbons, J.L. Greene, G Johnson, T.A. Langen, M.J. Oldham, D.N. Oxier, R.A. Saumure, F.W. Schueler, J.M. Sleeman, L.L. Smith, J.K. Tucker, and J.P. Gibbs. 2006. Relative vulnerability of female turtles to road mortality. Animal Conservation 9:269-273.

Theysmeyer, T., pers. comm. 2007. Email correspondence to M. Cameron. March 2007. Aquatic Ecologist, Royal Botanical Gardens, Hamilton, Ontario.

Tims, J., and N. Craig. 1995. Environmentally significant areas in New Brunswick (NBESA), 1st Ed. New Brunswick Department of Environment & Nature Trust of New Brunswick Inc.

Trombulak, S.C. and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Weller, W.F., and M.J. Oldham, Eds. 1988. Ontario Herpetofaunal Summary 1986. Ontario Field Herpetologists. 221 pp.

White, J.B., and G.G. Murphy. 1973. The reproductive cycle and sexual dimorphism of the common Snapping Turtle, Chelydra serpentina serpentina. Herpetologica 29: 240-246.

Whynot, D. 1996. Spatial dynamics and morphology of the Common Snapping Turtle, Chelydra serpentina, in Grafton Lake, Kejimkujik National Park, Nova Scotia. B.Sc. Honours thesis, Acadia University.

Wildspecies. 2005. Website: http://www.wildspecies.ca/wildspecies2005 [Accessed by M. Cameron 23 August 2007].

Wilhoft, D.C., M.G. Del Baglivo and M.D. Del Baglivo. 1979. Observations on mammalian predation of Snapping Turtle nests (Reptilia, Testudines, Chelydridae). Journal of Herpetology 13(4): 435-438.

Wilhoft, D.C., Hotaling, E. and P. Franks. 1983. Effects of temperature on sex determination in embryos of the Snapping Turtle, Chelydra serpentina. Journal of Herpetology 17(1): 38-42.

Wilson, R., pers. comm. 2006. Email correspondence to M. Cameron. April 2006. Head, Park System Planning, Government of Manitoba.

Yntema, C.L. 1976. Effects of incubation temperatures on sexual differentiation in the turtle, Chelydra serpentina. Journal of Morphology 150: 453-462.

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