Status, distribution, and nesting ecology of Snapping Turtle (*Chelydra serpentina*) on Cape Breton Island, Nova Scotia, Canada

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Abstract
Based on current knowledge of the ecology and distribution of Snapping Turtle (*Chelydra serpentina*), both in eastern Canada and elsewhere, we conclude this species is native to Cape Breton Island. Seventy-two reports of Snapping Turtle from Cape Breton (1999–2017) indicate a range centred in the area south of Bras d'Or Lake. Date of oviposition ranged from 19 June to 10 July (median = 26 June) among 26 nests observed during 2012–2014. Clutch size for these nests was 23–65 eggs (mean = 46) and among 25 protected nests average rate of hatchling emergence was 21.5%. Time from oviposition to emergence of hatchlings (n = 256) was 75–120 days (mean = 87.2; SD = 9.0) among 20 nests. First emergence ranged from 9 September to 20 October (75–114 nest days; mean = 90) and last emergence ranged from 13 September to 28 October (86–120 nest days; mean = 100). Duration of emergence ranged from one day (i.e., synchronous emergence; five nests) to 37 days (mean = 11 days). The number of days on which hatchlings emerged at a nest ranged from one to nine days (mean = 4 days). Maximum carapace length was 25.0–31.8 mm (mean = 29.0 mm) and maximum carapace width was 23.5–30.0 mm (mean = 27.0 mm) for 256 hatchlings that emerged from 20 protected nests. Mass of hatchlings was 4.9–9.9 g (mean = 7.8 g).

Key words: Snapping Turtle; *Chelydra serpentina*; status; distribution; nesting ecology; clutch size; hatching success; Cape Breton Island; Nova Scotia; Canada

Introduction
Snapping Turtle (*Chelydra serpentina*) is native to mainland Nova Scotia and was first recorded present on Cape Breton Island in 1953 when a large adult was reported from the ocean beach at Port Hood, Inverness County (Bleakney 1958; Gilhen 1984). However, until 1984, Snapping Turtle was known to be present in Cape Breton from only three widely scattered locations that were believed to be the result of released/escaped captive turtles (Gilhen 1984) and this view of the species' status has remained up until the present (COSEWIC 2008; Environment and Climate Change Canada 2016). Our observations, together with reports received from the public by both Nova Scotia Department of Natural Resources (NSDNR) and the Nova Scotia Museum (NSM) within the past two decades, indicate Snapping Turtle is much more widely distributed than earlier believed. Beginning in 1999, detailed investigation of all reports of Snapping Turtle was undertaken to better understand the status and distribution of this species in Cape Breton. On 12 July 2006, we excavated the first documented nest of Snapping Turtle in Cape Breton at Intervale Road, Huntington, Cape Breton County (Gilhen and Power 2018). From 2012 to 2014, we investigated the nesting ecology of this species at this site.

Snapping Turtle was assessed Special Concern by the Committee on the Status of Endangered Wildlife in Canada in 2008 (COSEWIC 2008) and is listed as Special Concern under the Canadian *Species at Risk Act* in 2011 (SARA Registry 2018) with a proposed Management Plan drafted in 2016 (Environment and Climate Change Canada 2016). Snapping Turtle was listed Vulnerable under the Nova Scotia *Endangered Species Act* in 2013, but to date, the presence of a naturally occurring population has not been recognized on Cape Breton Island (COSEWIC 2008; Environment and Climate Change Canada 2016). This paper discusses the status of Snapping Turtle on Cape Breton Island, summarizes known distribution based on personal observations as well as records from NSDNR and NSM (n = 75; 1953–2017), and presents data on time of nesting, location of nests, clutch size, time of emergence of hatchlings, survivorship to emergence, and size of hatchlings for nesting areas located at Huntington, Cape Breton County, Nova Scotia.

Study Area
Cape Breton Island is located off northeastern mainland Nova Scotia, Canada, (approximately. 45.5–47.0°N, 59.5–61.5°W) separated from the mainland by the Strait of Canso, an approximately 2 km wide stretch of ocean connecting the Gulf of St. Lawrence to the north with the Atlantic Ocean to the south (Figure 1). A permanent land connection between Cape Breton Island and main-

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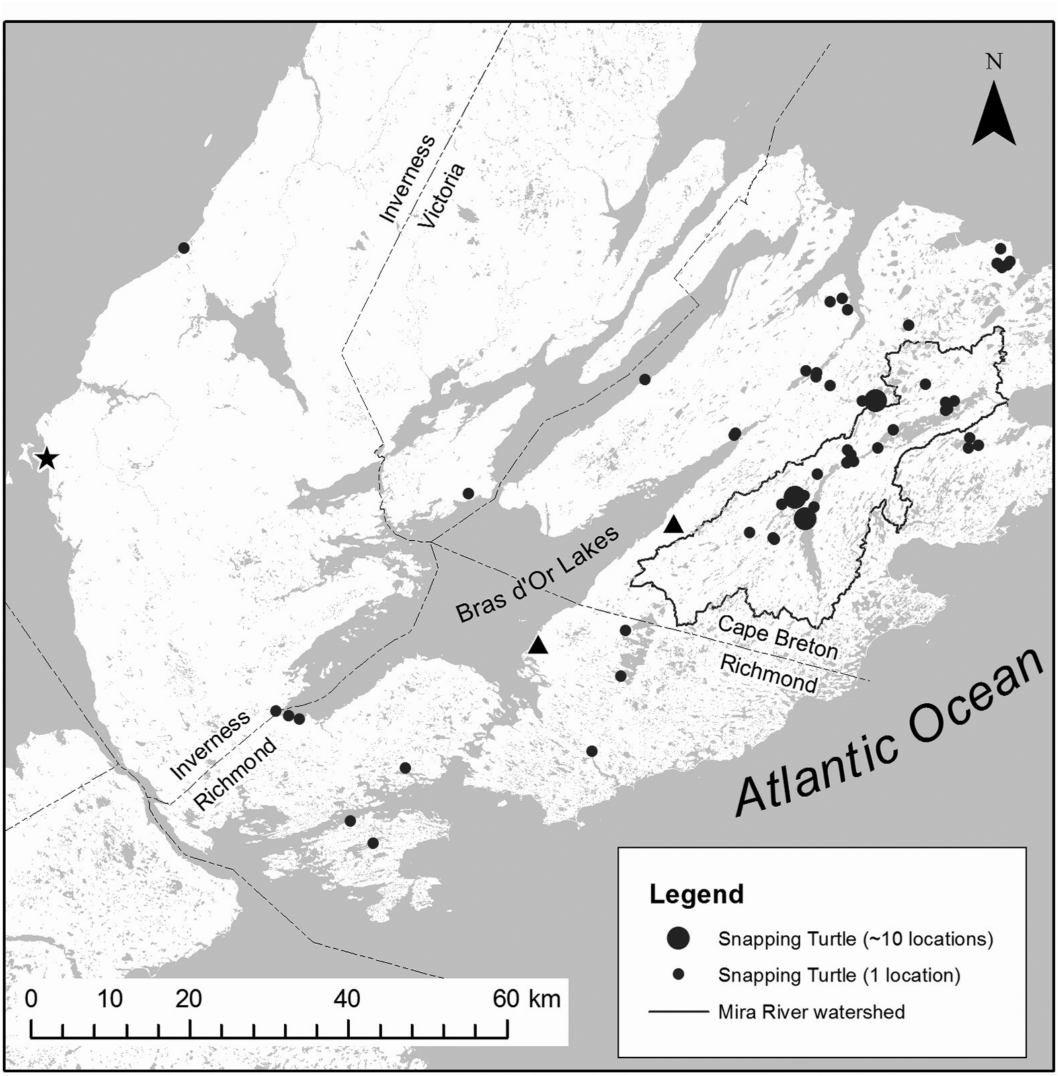

FIGURE 1. Distribution of records for Snapping Turtle (*Chelydra serpentina*) on Cape Breton Island, Nova Scotia, Canada 1953–2017 (n = 75) including a single record for 1953 (black star; Bleakney 1958; Gilhen 1984), two records for 1977 (black triangles; Gilhen 1984), and 72 records from 1999–2017 (black dots; this study). Contains information licensed under the Open Government License, Nova Scotia.

land Nova Scotia was completed in 1955 with the construction of the Canso Causeway. This narrow connection is a busy thoroughfare and a hostile environment with approaches through industrial lands, affording almost no opportunities for migration of freshwater turtles to or from Cape Breton Island.

Methods

All reports of Snapping Turtles for Cape Breton Island received from the public by NSDNR and NSM, as well as observations by NSDNR staff, between 1999 and 2017 were investigated and recorded. Interviews, correspondence, photographs, and site visits were used to verify reports and collect accurate location data. Historical records by Bleakney (1958; one record) and Gilhen (1984; three records) were also reviewed. All locations were collated into NSDNR's Biodiversity Investigation Report system and exported to ArcMap GIS (Esri, California, USA) for mapping.

Surveys of known nesting areas at Huntington, Cape Breton County were conducted in June and July 2012–2014 to determine onset and duration of nesting and to locate nests. Three localized nesting areas were surveyed including two roadside nesting areas and one natural riverine nesting area located on a gravel bar (island) in Salmon River near Intervale Road. Surveys were conducted on almost all days in the early part of the nesting season and more opportunistically thereafter. All visible nest attempts were global positioning system mapped and examined to determine if a nest was present. All nests discovered were immediately excavated, eggs were removed and carefully placed in the upright position, counted and returned to the nest in the same upright position, and the nest was re-buried. All nests were covered with 1 cm mesh galvanized hardware cloth screen fastened to 60 cm × 60 cm square wooden frames constructed of 38 × 89 mm wood and fixed to the ground using 16 mm rebar stakes, to prevent predation and to retain emerged hatchlings.

Beginning about 70 days after date of oviposition, all nests were surveyed daily to observe emerged hatchlings. Care was taken to replace each nest screen and fasten with rebar stakes to ensure that emerging hatchlings were not able to escape from under the screen undetected. All fully emerged hatchlings (Figure 2) were removed from under the protective screen. Maximum carapace length and width were measured to the nearest 0.1 mm using calipers, and weight measured to the nearest 0.1 g using Pesola® spring scales (Medio-Line No. 20010; Baar, Switzerland). Surveys were continued until mid-October 2012 and 2013, and mid-November 2014 and discontinued only after approximately two weeks of no further emergence of hatchlings and onset of cooler temperatures (2012 = 17 days; 2013 = 15 days; 2014 = 13 days). With one exception, no turtles emerged from a nest after two weeks of no emergence. One or two nests were excavated each year after the emergence period to examine condition of eggs and determine if live hatchlings were still present in the nest. All nest screens were removed for the winter and replaced again in May of the following year to monitor potential spring emergence.

FIGURE 2. Hatchling Snapping Turtle (*Chelydra serpentina*) emerged from a roadside nest on Intervale Road, Huntington, Cape Breton County, Nova Scotia, Canada, 11 September 2013. Photo: T. Power.

Results

Between 1999 and 2017 we investigated and verified 72 reports of Snapping Turtle on Cape Breton Island received from both the public and from the observations of NSDNR staff (Table 1). Except for two records for Inverness County (Inverness and West Bay), and one record for Victoria County (Jamesville), all records for Snapping Turtle on Cape Breton Island were in Cape Breton and Richmond Counties. These records indicate a distribution centred on an area of Cape Breton Island south of the Bras d'Or Lakes, with a notable concentration of records from tributaries of Mira River, Cape Breton County (Figure 1). The large number of observers ($n = 60$) submitting reports over an 18-year period and over a wide geographical area suggests there is no significant reporting bias. Within this larger area, many of the records are centred near the confluence of the Salmon River and Mira River and indicate that although Snapping Turtle nests widely across Cape Breton and Richmond Counties, the area of convergence of Salmon and Mira Rivers is the most important known nesting area. Only two records were located on Mira River which is tidal water: one a failed nest attempt and another a turtle carcass, both observed at Juniper Mountain on the southern shore of the Mira River.

Among 72 records of Snapping Turtle, 62 observations were made within the June–July nesting season and many of these were of confirmed (egg-laying observed) or probable (nest attempt without confirmed egg-laying) nesting females (Table 1). Among all records, only two were confirmed juvenile turtles based on carapace growth rings: one observation of a 13-year old turtle at Petersfield Provincial Park in Westmount, Cape Breton County, and one report of a juvenile turtle (estimated 14 years old from photograph) from near Camp Lake, Cape Breton County.

Snapping Turtles in Cape Breton nested in the gravel shoulder of a paved road ($n = 12$ nests), a natural riverine gravel bar ($n = 12$ nests), a semi-vegetated gravel quarry (one nest), and within a child's sandbox (one nest). Other reports of nesting turtles that were investigated ($n = 31$) showed nest attempts and probable nests located in other areas modified by development, including lawns, laneways, a horse paddock, and other areas cleared of vegetation (Table 1). Among 26 Snapping Turtle nests observed during three years (three in 2012; 10 in 2013; 13 in 2014), date of oviposition ranged from 19 June to 10 July (median = 26 June; Table 2). Dates of nesting for those nests monitored ($n = 26$) were 26–27 June 2012, 19–28 June 2013, and 25 June–10 July 2014. In addition, incidental observations of nesting activity (turtles nesting or making a nest attempt) on Cape Breton Island from 1999–2017 ($n = 31$) occurred as early as 17 June 2010 and as late as 26 July 2011 (Table 1). Onset of nesting in each year appeared to be synchronous but the length of the nesting season appeared to vary somewhat from year to year.

TABLE 1. Record number, location, date, sex, age, and behaviour for 75 records of Snapping Turtle (*Chelydra serpentina*) on Cape Breton Island, Nova Scotia, Canada 1953–2017.

Record	Date	Sex	Age	Location	Co.*	Map grid	UTME	UTMN	Behaviour
1013922	1/8/1953	U	A	Port Hood†, ‡	IN	11F5Z5	613478	5095301	unknown
1013923	18/5/1977	F	A	Campbells Brook‡	RI	23X5E3	675488	5071818	unknown
1013924	18/5/1977	M	A	Breac Brook‡	CB	23Z2G5	692560	5087013	unknown
207324	16/6/1999	U	A	Cow Bay Road	CB	14Y3F3	722238	5111961	unknown
214219	25/6/2001	U	A	Glace Bay	CB	43D3F16	730546	5110726	terrestrial movement
997633	22/5/2002	F	A	Glace Bay	CB	15V1C5	733818	5121662	terrestrial movement
225250	8/7/2002	F	A	Big Hill Road	CB	24Z1G2	731018	5096882	nest attempt
233014	6/7/2004	F	A	Grand Mira North	CB	24W2H5	709060	5087549	nest attempt
243552	7/7/2004	F	A	Huntington	CB	24W2G2	707971	5090500	nest attempt
243746	9/7/2004	F	A	Grand Mira North	CB	24W2H2	708959	5090533	nesting
997431	26/6/2005	F	A	Loch Lomond	RI	34Y1G2	685914	5067725	nesting
250324	4/7/2005	F	A	Grand Mira North	CB	24W2H5	709060	5087549	nesting
271432	28/6/2006	F	A	Huntington	CB	24W2H2	708959	5090533	nest attempt
271189	12/7/2006	U	E	Huntington	CB	24W2G2	707819	5090404	nest with eggs
252800	30/6/2007	U	A	Inverness	IN	12W1H2	630729	5121730	terrestrial movement
997428	2/7/2007	U	A	Huntington	CB	24W2G2	708024	5090142	unknown
231973	5/7/2007	F	A	New Boston	CB	24Z1F2	729723	5096524	nest attempt
231972	12/7/2007	U	A	Marion Bridge Hwy.	CB	14X5H1	716349	5102459	terrestrial movement
264421	20/7/2007	U	A	Glace Bay	CB	15V2C2	733968	5119246	terrestrial movement
264435	1/8/2007	U	A	Marion Bridge	CB	24X1F3	714949	5095684	terrestrial movement
231975	7/8/2007	F	A	Marion Bridge	CB	24X1B5	710697	5093166	terrestrial movement
257032	27/6/2008	F	A	Grand Mira North	CB	24W2H5	709164	5087477	nest attempt
997435	15/6/2009	U	A	Caribou Marsh Rd.	CB	14Y5B1	717992	5102587	terrestrial movement
401761	19/6/2009	F	A	Howie Centre	CB	14X4D5	712288	5104344	terrestrial movement
401830	19/6/2009	U	A	Caribou Marsh Rd.	CB	14Y5B2	718143	5101975	terrestrial movement
401831	9/7/2009	U	A	Caribou Marsh Rd.	CB	14Y5B1	718108	5102970	terrestrial movement
401834	17/7/2009	U	A	Albert Bridge	CB	14Z5C2	726867	5102290	terrestrial movement
403805	17/6/2010	F	A	Caribou Marsh Rd.	CB	14Y5B1	718108	5102970	nest attempt
407600	18/6/2010	F	A	Huntington	CB	24W2G2	707807	5090407	nest attempt
997444	18/6/2010	F	A	Huntington	CB	24W2G2	707947	5090382	nest attempt
407598	22/6/2010	F	A	Albert Bridge	CB	14Y1C2	718337	5096531	nest attempt
257122	26/6/2010	F	A	Huntington	CB	24W2G2	707971	5090500	nest attempt
257123	29/6/2010	F	A	Huntington	CB	24W2H2	708959	5090533	nest attempt
407597	2/7/2010	U	E	Huntington	CB	24W2G2	707818	5090394	nest with eggs
997425	8/7/2010	U	A	Jamesville	VI	23W2D1	666628	5090740	terrestrial movement
409130	16/7/2010	U	A	Marion Bridge	CB	24X1F2	714542	5096287	terrestrial movement
997426	17/7/2010	U	A	Marion Bridge	CB	24X1G3	715256	5094805	terrestrial movement
407668	20/7/2010	F	A	Blacketts Lake	CB	14X4A3	709264	5106233	terrestrial movement
997820	15/6/2011	U	A	Sydney Forks	CB	14X4B4	710503	5105510	terrestrial movement
257121	22/6/2011	F	A	Huntington	CB	24W2G2	707971	5090500	nest attempt
407738	26/7/2011	F	A	Huntington	CB	24W2G2	707875	5090395	nest attempt

TABLE 1. (*Continued*)

Record	Date	Sex	Age	Location	Co.*	Map grid	UTME	UTMN	Behaviour
992491	27/6/2012	U	A	Martinique	RI	33Z4A2	651691	5049953	terrestrial movement
997422	28/6/2012	F	A	Grand Mira South	CB	24X2B5	710044	5087747	nest attempt
997423	25/7/2012	F	A	Grand Mira South	CB	24X2A3	710232	5089030	nesting
997574	12/9/2012	U	A	Edwardsville	CB	14X2E6	712290	5114983	terrestrial movement
997395	24/5/2013	U	A	Glace Bay	CB	15V2D2	735003	5120006	terrestrial movement
997389	2/6/2013	U	A	Edwardsville	CB	14X2F5	713824	5115384	terrestrial movement
997397	18/6/2013	U	A	Salmon River Rd.	CB	24W3D2	705267	5084990	terrestrial movement
997402	18/6/2013	F	A	Northside East Bay	CB	14V5G5	700320	5098373	nest attempt
997404	24/6/2013	U	A	Albert Bridge	CB	14Z4A5	724333	5104525	terrestrial movement
997405	24/7/2013	U	J	Westmount	CB	14X3G1	714500	5113959	terrestrial movement
997473	20/8/2013	U	J	Camp Lake	CB	24W3A1	702104	5085865	terrestrial movement
997821	15/9/2013	U	U	Sydney Forks	CB	14X4C3	710598	5106014	aquatic basking
1000594	26/6/2014	U	A	Salmon River Rd.	CB	24W3D2	705103	5085177	terrestrial movement
1000563	10/7/2014	F	A	Albert Bridge	CB	14Z5C3	727142	5101410	nesting
1001650	15/7/2014	F	A	Grand Mira North	CB	24W2H5	709155	5087790	nest attempt
1004867	30/6/2015	F	A	Grand Mira South	CB	24X1F4	714428	5094636	nest attempt
1004878	3/7/2015	U	A	Loch Lomond	RI	23Y5H2	686496	5073463	terrestrial movement
1004875	12/7/2015	F	A	Grand River	RI	34Y2D6	682248	5058236	nest attempt
1004877	13/7/2015	U	A	New Boston	CB	24Z1F1	729948	5097763	terrestrial movement
1004601	16/7/2015	U	A	Albert Bridge	CB	14Z5C2	727932	5102430	terrestrial movement
1007091	13/5/2016	U	A	Marion Bridge	CB	14Y5D5	720295	5098817	terrestrial movement
1007090	26/5/2016	M	A	Glace Bay	CB	15V2C1	733415	5119801	terrestrial movement
1013868	27/6/2016	F	A	Grandique Road	RI	33Z4G5	654606	5046639	nesting
1007694	28/6/2016	F	A	Northside East Bay	CB	14V5G5	700156	5098137	nest attempt
1007749	29/6/2016	F	A	MacDonald Road	CB	24W2E3	706221	5089388	nest attempt
1013869	2/7/2016	F	A	Beaver Cove	CB	13Z4C4	688930	5105128	nesting
1008245	10/8/2016	U	A	Glace Bay	CB	15V2D2	734688	5119633	dead
1008261	12/8/2016	U	A	Grand Mira South	CB	24X1C6	714385	5094632	dead
1013853	18/6/2017	U	A	Dundee	RI	33Y2F1	645312	5062297	terrestrial movement
1012655	24/6/2017	U	A	Albert Bridge	CB	14Z5C3	726886	5101227	terrestrial movement
1013787	30/6/2017	F	A	Salmon River Rd.	CB	24W2G4	708343	5088116	nest attempt
1012894	9/7/2017	U	A	Cannes	RI	34V3D2	658712	5056118	terrestrial movement
1013851	10/9/201	U	A	Dundee	RI	33Y1D6	643968	5062718	terrestrial movement
1013854	2/7/2017	U	A	West Bay	IN	33Y1C5	642343	5063326	terrestrial movement

*CB (Cape Breton County), IN (Inverness County), RI (Richmond County), VI (Victoria County).
†Bleakney (1958).
‡Gilhen (1984).

TABLE 2. Date of oviposition, clutch size, number of hatchlings emerged, dates, duration of hatchling emergence, and hatchling size for 25 protected nests (256 hatchlings) of Snapping Turtle (*Chelydra serpentina*) in a study area at Huntington, Cape Breton County, Nova Scotia.

Nest ID	Nest date	Clutch size	Intact clutch size*	No. of hatchlings emerged	Hatch success (%)	First emergence date	Min. nest days	Last emergence date	Max. nest days	Duration of emergence (days)	No. of days hatchlings emerged	Mean hatchling carapace length (mm) (SD)	Mean hatchling carapace width (mm) (SD)	Mean hatchling mass (g) (SD)
2012-06-27-1	25/6/2012	42	42	est. 20	est. 47.6	est. 7-Sep-12								
2012-06-26-3	25/6/2012	40	40	0	0.0	N/A								
2012-06-26-2	25/6/2012	47	37	24	51.1	11/9/2012	78	28/9/2012	95	17	4	28.3 (0.6)	26.7 (0.9)	7.0 (0.6)
2013-06-19-1	19/6/2013	51	51	40	78.4	11/9/2013	84	25/9/2013	98	14	9	28.6 (0.9)	26.7 (1.0)	8.3 (0.5)
2013-06-19-2	19/6/2013	51	51	9	17.6	13/9/2013	86	13/9/2013	86	1	1	29.4 (0.8)	27.1 (0.8)	7.8 (0.4)
2013-06-19-3	19/6/2013	44	43	16	36.4	13/9/2013	86	22/9/2013	95	9	5	29.8 (0.7)	27.4 (0.8)	8.2 (0.3)
2013-06-19-4	19/6/2013	55	52	11	21.2	14/9/2013	87	23/9/2013	96	9	3	28.1 (0.8)	26.0 (1.3)	7.0 (0.6)
2013-06-19-5	19/6/2013	44	44	11	25.0	14/9/2013	87	23/9/2013	96	9	5	30.3 (0.9)	27.7 (1.3)	8.7 (0.5)
2013-06-24-1	24/6/2013	60	59	3	5.0	24/9/2013	92	24/9/2013	92	1	1	28.4 (0.6)	25.3 (0.9)	7.4 (0.5)
2013-06-24-2	24/6/2013	49	49	4	8.2	17/9/2013	85	20/9/2013	88	3	3	29.4 (0.5)	26.7 (0.8)	7.3 (0.3)
2013-06-28-1	28/6/2013	23	23	0	0.0	N/A	N/A		N/A	N/A	N/A	N/A		
2013-06-28-2	28/6/2013	45	45	2	5.0	20/10/2013	114	20/10/2013	114	1	1	27.9 (0.0)	25.3 (0.4)	5.8 (0.1)
2013-06-28-3	28/6/2013	52	52	24	46.2	14/9/2013	82	26/9/2013	94	12	7	28.7 (0.8)	26.8 (0.9)	7.6 (0.5)
2014-06-25-1	25/6/2014	37	37	20	54.1	14/9/2014	81	21/10/2014	118	37	7	29.2 (0.9)	27.7 (0.6)	8.2 (0.7)
2014-06-26-1	26/6/2014	64	63	24	37.5	9/9/2014	75	25/9/2014	91	16	7	29.0 (1.0)	27.8 (1.1)	7.4 (0.6)
2014-06-26-2	26/6/2014	42	37	3	7.1	22/9/2014	88	16/10/2014	112	24	3	29.8 (1.1)	27.6 (1.5)	7.7 (0.8)
2014-06-26-4	26/6/2014	40	40	28	70.0	19/9/2014	85	5/10/2014	101	16	9	30.1 (0.9)	27.4 (0.8)	9.0 (0.5)
2014-06-26-5	26/6/2014	40	40	1	2.5	30/9/2014	96	30/9/2014	96	1	1	N/A		
2014-06-30-1	30/6/2014	55	55	5	9.1	5/10/2014	97	21/10/2014	113	16	3	26.6 (0.6)	24.9 (0.2)	5.8 (0.4)
2014-06-30-2	30/6/2014	65	64	6	9.2	18/10/2014	110	28/10/2014	120	10	5	27.2 (0.3)	25.9 (0.4)	6.5 (0.4)
2014-06-30-3	30/6/2014	57	55	15	26.3	27/9/2014	89	12/10/2014	104	15	6	29.4 (0.5)	26.9 (0.9)	7.4 (0.5)
2014-06-30-4	30/6/2014	37	35	8	21.6	30/9/2014	92	3/10/2014	95	3	3	30.7 (1.1)	27.7 (0.6)	8.7 (0.6)
2014-07-03-1	3/7/2014	61	61	0	0.0	N/A	N/A		N/A	N/A	N/A	N/A		
2014-07-04-1	4/7/2014	36	36	2	5.6	11/10/2014	99	11/10/2014	99	1	1	25.8 (0.3)	23.7 (0.3)	5.2 (0.4)
2014-07-04-2	4/7/2014	28	28	0	0.0	N/A	N/A		N/A	N/A	N/A	N/A		
2014-07-10-1	10/7/2014	30	30	0	0.0	N/A	N/A		N/A	N/A	N/A	N/A		
Mean		46.0	45.0	10.2	21.5		90		100	11	4	2.9	2.7	7.8
SD		11.0	10.9	10.9	23.1		10		10	9	3	0.1	0.1	0.9
Min		2323	0	0.0		75		86	1	1	2.5	2.4	4.9	
Max		6564	40	78.4		114		120	37	9	3.2	3.0	9.9	
Count		2626	25	25		20		20	20	20	256.0	256.0	256.0	

*The number eggs left intact following oviposition, excavation, and replacement of the clutch (occasionally eggs were destroyed during oviposition or excavation of the nest).

Clutch size for 26 nests protected from predation with wire screen was 23–65 eggs (mean ± SD: 46 ± 11; Table 2). Hatchlings emerged from 20 of 26 protected nests (76.9%); five nests did not produce hatchlings. An additional riverine nest was flooded during hatchling emergence but appeared to have had partial hatchling emergence. Among the 25 protected nests with a known outcome, the number of hatchlings that emerged ranged from 0 to 40 (10 ± 11). The proportion of a clutch that produced emerged hatchlings was 0–78.4% (21.5 ± 23.1).

Among 20 protected nests from which hatchlings emerged during 2012–2014, time from oviposition to emergence of a hatchling (n = 256; Table 2) was 75–120 days (87.2 ± 9.0). Time of first emergence ranged from 9 September to 20 October (75–114 nest days; 90 ± 10) and date of last emergence ranged from 13 September–28 October (100 ± 10). Duration of emergence at a nest ranged from one day (i.e., synchronous emergence; five nests) to 37 days for one nest (mean = 10 days). Among 20 protected nests, number of days on which hatchlings emerged ranged from one to nine (mean = 4).

A total of 256 hatchlings emerged alive from 20 protected nests (Table 2). An additional one and 12 hatchlings, respectively, were excavated and released alive from two of these nests on 11 October 2013. These 13 hatchlings were initially torpid within the nest due to cool temperatures late in the season but became active once removed from the nest, placed in the sun, and were subsequently released. These hatchlings may not have been able to emerge on their own, had the nest not been excavated. However, the latest date of hatchling emergence in 2013 was 11 days later (20 October) when two hatchlings emerged from one nest.

For 256 hatchlings that emerged from protected nests (n = 20), maximum carapace length was 25.0–31.8 mm (29.0 ± 1.2) and maximum carapace width was 23.5–30.0 mm (27.0 ± 1.1). Mass of hatchlings ranged from 4.9 to 9.9 g (7.8 ± 0.9).

Discussion

Snapping Turtle is native to mainland Nova Scotia (Bleakney 1958; Gilhen 1984) but the occurrence of this species on Cape Breton has been uncertain. Bleakney (1958) provides the first record for Snapping Turtle on Cape Breton Island, that of a large adult reported from the beach at Port Hood, Inverness County in 1953. Gilhen (1984) includes this record and two additional occurrences: one at Campbells Brook, Richmond County and another at Breac Brook, Cape Breton County, both observed on 18 May 1977. These three widely scattered locations were believed to be the result of released/escaped captive turtles (Gilhen 1984) and for 22 years, no further observations were recorded for this species on Cape Breton Island. Beginning in 1999, an effort was made to investigate all sightings received from the public by NSDNR and NSM. In addition, NSDNR staff were encouraged to actively record sightings. The accumulated reports began to suggest the species was much more widely distributed than earlier believed and several nesting areas were identified.

Seventy-two verified reports of Snapping Turtle on Cape Breton Island from 1999–2017, together with personal observations, indicate a distribution centred on the area of Cape Breton and Richmond Counties south of the Bras d'Or Lakes (45.5–46.0°N), with a notable concentration of records from tributaries of Mira River, Cape Breton County. Within this larger area, most of the records are centred near the confluence of Salmon River and Mira River. The presence of an important nesting area here, including both riverine and roadside nests, on Salmon River and Intervale Road at Huntington, may largely account for the increased number of reports from this area as Snapping Turtle is highly aquatic, and most reported sightings are of females on land during the nesting season.

The current widespread occurrence and relative abundance of Snapping Turtle on Cape Breton suggests this species is likely native to the Island. The absence of records from 1953 to 1977 and again from 1977 to 1999 is troubling but may simply reflect gaps in searching for and reporting on this species. In this context, Bleakney (1958) discusses similar historical anomalies in documentation of herpetofauna in eastern Canada and elsewhere. The accumulation of reports of Snapping Turtle in Cape Breton since 1999 reflects an effort by the authors to search for reports for this species, to verify all reports received, and to encourage further reporting from observers including both the public and NSDNR staff. Snapping Turtle occurs widely in adjacent mainland Nova Scotia, New Brunswick, and Maine at similar latitudes to that of Cape Breton, so its presence here is not unexpected. Two species of herpetofauna with wide distributions on mainland Nova Scotia which are not native to Cape Breton, are Northern Painted Turtle (*Chrysemys picta*) and American Bullfrog (*Lithobates catesbeianus*). In contrast, Wood Turtle (*Glyptemys insculpta*) is native to both the mainland and Cape Breton Island (Gilhen 1984; Gilhen and Power 2018), even though the presence of this species here was not recognized earlier (Bleakney 1958). Bleakney (1958) discussed the postglacial immigration of amphibians and reptiles into eastern Canada and, based on isostatic land movements and seawater levels, concluded that Cape Breton Island was connected by a land bridge to the adjacent mainland of Nova Scotia between 16 000 and 10 000 years ago. Gilhen (1984) elaborates on the timing, connection, and isolation of geographic features in the Maritime provinces during the postglacial period and resultant impacts on present distributions of herpetofauna. More recently, Shaw *et al.* (2002) present evidence, based on isobase maps and a digital terrain model, to show a land connection from Cape Breton Island to mainland Nova Scotia from about 13 000–8000 years before present (BP) with peak emergence of Cape Breton Island at about 9000 years BP. Snapping Turtle is recognized as one of the dominant turtles within North American glacial age faunas and one of the first to invade following glacial retreat at the end of the Wisconsin (Holman and Andrews 1994).

Bleakney (1958) did not recognize the presence of turtles on Cape Breton, even though he reports on a visual sighting of Snapping Turtle by A.W. Cameron at Port Hood Beach, Inverness County in 1953. Bleakney (1958) suggested that turtles may have arrived too late to take advantage of a land bridge to Cape Breton (as well as Prince Edward Island) and presented a range map for the northern limit for freshwater turtles that excludes Cape Breton Island. However, Bleakney (1958) calculated an "Environmental Temperature Index" to estimate the northern limit for Snapping Turtle that includes Cape Breton Island. The approximate northern limit of distribution of Snapping Turtle in Cape Breton (46.0°N) is well within the range of populations studied elsewhere (e.g., 45.5°N in Ontario [Congdon *et al.* 2008]; 46.0°N in Michigan and 47.2°N in Minnesota [Ewert *et al.* 2005]; 53.0°N in Manitoba [Holman and Andrews 1994]). The tolerance of Snapping Turtle and its eggs to brackish water conditions, including habitation in coastal saltmarshes (Pope 1961; Kinneary 1992; Klemens 1993; Hunter *et al.* 1999), would enhance the ability of this species to colonize Cape Breton Island along a prehistoric land bridge with mainland Nova Scotia. Based on current knowledge of the ecology and distribution of Snapping Turtle, both in Eastern Canada and elsewhere, we conclude this species is native to Cape Breton Island and arrived here along with Wood Turtle via a land connection to mainland Nova Scotia about 10 000 years BP.

Snapping Turtle is known to nest in a variety of natural and disturbed substrates (Congdon *et al.* 2008). In Cape Breton, we recorded the species nesting on natural riverine gravel bars as well as a variety of sites modified by development, including gravel road verges, lawns, laneways, a horse paddock, a child's sand box, and other semi-vegetated areas. Turtles here appeared to choose unshaded nest sites, open to the sun, which may reflect an adaptation to hasten embryogenesis in this northern population, as suggested by Ewert *et al.* (2005). Within its extended range in North America, Snapping Turtle nests earlier in the south than further north (Iverson *et al.* 1997; Congdon *et al.* 2008). Warmer springs result in more rapid follicular development and egg maturation, and earlier onset of nesting (Congdon *et al.* 1987). Date of first observed nesting in Cape Breton (17 June) was somewhat later than in Nebraska (1–12 June; Iverson *et al.* 1997) and southeastern Michigan (22 May–12 June) where first nesting varied annually by 22 days and was significantly correlated with the amount of heat available in March, April, and May (Congdon *et al.* 1987). Obbard and Brooks (1987) used accumulation of heat units in a lake to predict onset of nesting and reported that even though date of first nesting in north-central Ontario varied by 15 days over six years, variation in accumulation of heat units varied by only 7.5%. Nesting in Cape Breton (17 June–26 July), also near the northern limit of the species range (46.0°N), may be somewhat later than that reported for Algonquin Park, Ontario (26 May–7 July; Congdon *et al.* 2008), at a similar latitude (45.5°N).

Clutch size of Snapping Turtles in Cape Breton is large but within the range reported from locations elsewhere in the species range (Iverson *et al.* 1997; Congdon *et al.* 2008). Clutch size of eight nests at Grafton Lake, Queens County, in southwestern mainland Nova Scotia, was 19–41 eggs (Gilhen 1984). Hatchlings in Cape Breton emerged from 76.9% of protected nests. Total nest failure (failure of hatchlings to emerge = 19.2%) appears higher than reported for southeastern Michigan (egg infertility or failure of embryos to develop = 11.8%; Congdon *et al.* 1987). Hatching success among protected nests in Cape Breton (21.5%) was much lower than in north-central Ontario, at a similar latitude (73.2–85.2%: Riley and Litzgus 2013). Probability of survival in protected nests in Cape Breton was 0.215, whereas the probability of survival of unprotected nests (including a 70% predation rate) was 0.22 in Michigan (Congdon *et al.* 1987). Nest predation losses in the Michigan population over 17 years averaged 77% (Congdon *et al.* 1994). Clearly, the already low survivorship to emergence in protected nests in Cape Breton (comparable to that of unprotected nests in Michigan) would be much further reduced by predation. In nests of Snapping Turtle in Cape Breton, an average of 35 eggs in protected nests failed to produce hatchlings whereas in southeastern Michigan, an average of four eggs or embryos died in nests that escaped predation (Congdon *et al.* 1987). High nest failure and low hatchling survivorship to emergence, due to factors other than predation, suggest recruitment may be low in this northern population of Snapping Turtle in Cape Breton. Predated nests were observed in Cape Breton during both nesting and hatchling emergence. Often extended duration of emergence at nests in Cape Breton coupled with observed peaks in predation late in incubation elsewhere (Riley and Litzgus 2014) may facilitate increased predation pressure here.

Snapping Turtle in Cape Breton emerged in September and October, and as generally reported elsewhere (Congdon *et al.* 1987, 2008; Carroll and Ultsch 2007; Baker *et al.* 2013), no spring emergence was observed. Scattered reports of confirmed (Obbard and Brooks 1981; Parren and Rice 2004) or suspected (Bleakney 1963; Congdon *et al.* 1987) spring emergence are recorded for this species and have been linked to the insulating effects of unusually deep snow cover (Obbard and Brooks 1981) and an unusually mild winter (Parren and Rice 2004). Snapping Turtle hatchlings in Cape Breton were observed to emerge later (9 September–28 October) than reported further south (5–24 September in New Hampshire [Carroll and Ultsch 2007]; late August to early October in southeastern Michigan [Congdon *et al.* 1987]). Mean number of days from egg-laying to hatchling emergence in Cape Breton (mean = 87.2, range 75–120) was slightly lower than that reported for north-central Ontario at a similar latitude (~93 days; Riley and Litzgus 2013), and also for Michigan, further to the south (mean = 93.2, range 73–117; Congdon *et al.* 1987). Mean time to first emergence in Cape Breton was slightly shorter (90 days) than in a more southerly population in Indiana (94 days, range 90–97 days; Baker *et al.* 2013). Duration of emergence at a nest in Cape Breton, (mean = 11 days) may be longer than reported elsewhere. In Indiana, mean duration of emergence at a nest was eight days (range 1–20 days) and synchronous emergence occurred occasionally (Baker *et al.* 2013). Synchronous emergence in nests (25%) was much lower in Cape Breton than in southeastern Michigan (65%; Congdon *et al.* 1987).

Emergence of Snapping Turtle hatchlings in Cape Breton appears to be characterized by a high proportion of asynchronous emergence, a protracted duration of emergence at some nests (up to 37 days) as well as emergence on numerous days within the emergence period. Despite this, however, average time from oviposition to emergence may be shorter in Cape Breton than has been reported elsewhere. Both high and low incubation temperatures compromise survival and growth rates of Snapping Turtle hatchlings (Brooks *et al.* 1991). Bobyn and Brooks (1994) found that lower incubation temperature increased mortality and compromised growth and survival of hatchling Snapping Turtles and suggest this is an important determinant of the northern limit of this species, through reduced recruitment. Summer temperatures are thought to be the dominant factor limiting the northern distribution of herpertofauna in Canada (Bleakney 1958; Brooks 2007) and Snapping Turtle approaches the northern limit of its range in Cape Breton.

The relatively large and deep nests of Snapping Turtles likely contribute to the observed temperature differences within nests with depth which has been reported (Packard *et al.* 1985). Packard *et al.* (1987, 1998, 1999) discuss the importance of variation in thermal and to a lesser extent, hydric, conditions of incubating eggs of Snapping Turtle to both size and physiological condition of hatchlings. The high proportion of asynchronous emergence and extended duration of emergence for individual nests in Cape Breton may reflect differing hydric and, especially, temperature conditions within nests, exaggerated by already marginal incubation conditions experienced by this northern population.

Size of Snapping Turtle hatchlings in Cape Breton (*n* = 256; mean carapace length = 29.0 mm, range 25.0–31.8 mm; mean carapace width = 27.0 mm, range 23.5–30.0 mm; mean mass = 7.8 g, range 4.9–9.9 g) was similar to that of hatchlings in southeastern Michigan (mean carapace length = 29.1 mm, range 23.0–33.0 mm; mean mass = 8.9 g, range 5.0–11.0 g; Congdon *et al.* 1987) and north-central Ontario (carapace length = 27.84 mm [males] and 29.47 mm [females]; mean mass = 9.03 g [males] and 9.68 g [females]; Riley *et al.* 2014). Within nests in Cape Breton, size of emerged hatchlings appears to decrease with both clutch size and date of hatchling emergence but further exploration of this relationship is needed.

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