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Chapter 8

HEALTH AND DISEASE IN CANADIAN REPTILE POPULATIONS

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Abstract.—Diseases are becoming an important issue in the decline of certain reptile populations and they have been incriminated in some dramatic epidemic events around the world. Emerging infectious diseases are also of concern, some having been associated with the introduction or translocation of species. Unfortunately, information on diseases in wild reptile populations is rather limited. We reviewed the existing international literature for reports on abnormalities, diseases, and mortalities in reptiles. This literature includes 120 published reports concerning Canadian reptile populations. The Canadian accounts include 1 lizard, 11 turtle, and 16 snake species. Information was fragmentary and consisted mostly of reports of internal parasitism, colour mutations and variations, and road mortality events. Extremely little information was available on the prevalence of infectious agents and their impact at the population level. Considering the precarious status of most Canadian reptile species, there is an urgent need for baseline information on the health of these animals in order to establish sound conservation programs. Such information will allow improved population management of reptile species by diminishing the risk of disease propagation in vulnerable populations.

Résumé.—Les maladies deviennent une préoccupation majeure dans le déclin de certaines populations de reptiles. Elles ont été incriminées dans des cas d'épidémies sévères à travers le monde. Les maladies infectieuses émergentes sont également préoccupantes, certaines ayant été associées avec l'introduction ou la relocalisation de certaines espèces. Malheureusement, l'information disponible sur les maladies des populations sauvages de reptiles est plutôt limitée. Nous avons passé en revue la littérature internationale portant sur les anomalies, les maladies et les mortalités de reptiles. Cette littérature inclut 120 rapports publiés sur des populations de reptiles au Canada. Ces publications concernaient une espèce de lézard, 11 de tortues et 16 de serpents. L'information rassemblée était fragmentaire et comprenait principalement des rapports sur des parasites internes, des mutations et variations pigmentaires, et des cas de mortalité routière. Très peu d'information était disponible sur la prévalence d'agents infectieux et sur leurs impacts au niveau des populations. Considérant la situation précaire de la plupart des espèces de reptiles au Canada, il y a un besoin urgent de données de base sur la santé de ces animaux afin de mettre en place des programmes de conservation judicieux. Ces informations nous permettront d'améliorer la gestion des populations de reptiles en diminuant le risque de propagation de maladies dans des populations vulnérables.

Reptile populations are facing a global decline (Gibbons et al. 2000; Klemens 2000). Although habitat loss and degradation have been cited as the primary factors, disease has also been mentioned as one of the potential causes. Abundant literature is available on the diseases of reptiles in captivity. However, little information is available on the occurrence, prevalence, and virulence of infectious agents in wild reptile populations (George 1997; Crawshaw 2000; Flanagan 2000). This is particularly true for Canada, where reptiles are largely understudied compared with other vertebrate groups. During the relatively recent implementation of Canadian policies and legislation at both provincial and federal levels for the conservation of threatened and endangered species of wildlife, the lack of information for most of the 46 native Canadian reptile species (6 lizards, 26 snakes, 10 turtles, and 4 marine turtles) has been emphasized. Many of these reptile species are in a precarious situation, and there is only limited knowledge of their ecology and population dynamics with which to establish sound conservation programs (Shank 1999; Alvo and Oldham 2000).

Identification of diseases and understanding their role in population dynamics are of primary importance for conservation. Diseases and parasites have often been neglected and are often considered to have a limited role in reptile ecology, but there is increasing evidence of effects on individual and population biology (Spalding and Forrester 1993). Recent epidemic events have been documented in various chelonian populations in the United States. Fibropapillomatosis in marine turtles and upper respiratory tract disease in tortoises are well-documented examples in which a disease quickly affects large numbers of individuals and causes dramatic population declines (Jacobson et al. 1991b, 1995; Herbst 1994; Williams et al. 1994; Brown et al. 1999; McLaughlin et al. 2000). Fibropapillomas were found on up to 85% of captured Green Seaturtles, *Chelonia mydas*, in Florida and the Hawaiian Islands in the 1980s and early 1990s (Williams et al. 1994). Upper respiratory tract disease (mycoplasmosis) became epidemic in a population of Desert Tortoises, *Gopherus agassizii*, from Las Vegas Valley in Nevada and appeared to cause widespread mortality; the number of captured individuals dropped from 204 to 13 individuals in 10 yr (Jacobson et al. 1995). In other situations, different chelonian species were affected by shell disease but the primary cause of the condition was not determined (Dodd 1988a; Jacobson et al. 1994; Lovich et al. 1996; Garner et al. 1997; Ernst et al. 1999). A population of *G. agassizii* in California experienced a 70% mortality rate over 6 yr concomitant with shell disease (Jacobson et al. 1994). Diseases subsequently have been recognized as a potential threat for some North American chelonian species (Ernst 1995; Jacobson et al. 1995).

The increasing global exchange of goods, humans, and live reptiles in the pet and food trade has facilitated the spread of exotic species within and between continents (Pendlebury 1977; Carlton and Geller 1993; Allen et al. 1994; McCallum and Dobson 1995; Harvell et al. 1999; Ruiz et al. 2000). In the United States, several reptile species introduced to new areas from outside or within the continent are already established (Conant 1961, 1977), particularly in Florida and California (Bury and Luckenbach 1976; Wilson and Porras 1983). Alien plants and animals can disrupt ecosystems and introduce diseases (Allen et al. 1994; Gibbons et al. 2000). An increase in the alteration of the environment through anthropogenic activities in past decades has been accompanied by an increase in detection of emerging infectious diseases in wildlife (Harvell et al. 1999; Carey 2000; Daszak et al. 2000). Upper respiratory tract disease in *G. agassizii* is an example of a disease spread through pet trade and incidental release (Jacobson 1994; Jacobson et al. 1995). Ophidian paramyxovirus infection and the boid inclusion body disease are examples of diseases spread worldwide by movement of captive animals in the past 2 decades (Jacobson 1993a,b).

Some factors may increase the susceptibility of Canadian reptile populations to dramatic epidemic events. Reptile species found in Canada are not exclusively endemic to this country, but rather they are at the northern limit of their more southerly ranges. Climate may serve as a natural stress on many species regardless of their biological adaptations (Gregory 1977, 1982). Diseased and injured individuals with suppressed immune systems are more at risk of dying during hibernation (Metcalf and Metcalf 1979; Willis et al. 1982). Some populations are naturally isolated from the species, main range, for example Blanding's Turtles, *Emydoidea blandingii*, in Nova Scotia, Spiny Softshells, *Apalone spinifera*, in Québec's Lake Champlain, and Sharp-tailed Snakes, *Contia tenuis*, on Gulf Islands in British Columbia. Habitat loss and fragmentation resulting from human activities increase isolation of populations, particularly in the southern part of Canada where most of the reptile species are found (Cook 1984; McKenney et al. 1998). This geographical and genetic isolation, and low population densities, may reduce the capacity of these populations to endure, and recover from, epidemic disease events.

To better appreciate the role of diseases in wild reptiles, we reviewed the existing literature up to 2006 for information on disease in chelonians, snakes, and lizards. We focused on published reports from Canada, but also surveyed the international literature for reports on species generally present in Canada. Peer-reviewed and published material has been considered almost exclusively. Our main objective was to gather knowledge on reptilian diseases and assess their potential impact upon natural population dynamics. Our review is not intended to be an exhaustive list of diseases and their clinical signs in captive and laboratory animals, for which abundant veterinary literature is available. We considered infectious and non-infectious agents such as bacteria, viruses, fungi, internal and external parasites, neoplasms, deformities, mutations, traumatic injuries, and toxicoses. Finally, we indicate important areas for future research on the health of wild reptile populations in Canada.

Infectious Agents

Diverse infectious agents are pathogenic for reptiles. Reptilian immune system response is dependent upon extrinsic factors, particularly environmental temperature, nutritional state, age, population density, season of the year, and other ecological factors (Kollias 1984; Frye 1991c). Reptiles generally show seasonal lymphoid cycles which affect the humoral immune response according to the season (Frye 1991c). Reptiles are also host to numerous opportunistic microorganisms which are harmless under normal conditions, but may become pathogenic in stressful conditions that may suppress their immune system, such as injuries, concomitant infectious processes, chemical contaminant exposures, and captivity (Kollias 1984; Klingenberg 1996). These infectious agents may overwinter in their reptile host and may be transmitted to other species.

Bacterial Diseases

A wide variety of bacteria are involved in superficial and deep lesions, abscesses, or diseases. The most common pathogens belong to the genera *Aeromonas*, *Arizona, Citrobacter, Klebsiella, Mycobacterium, Pseudomonas*, *Salmonella*, *Staphylococcus*, and *Streptococcus* (Reichenbach-Klinke and Elkan 1965; Hoff et al. 1984; Frye 1991c). Reviews of bacterial infections and their pathogenesis in wild and captive reptiles, either in general or on a species-specific basis, have been published (Reichenbach-Klinke and Elkan 1965; Cooper 1981; Hoff et al. 1984; Frye 1991c; Mader 1996). Bacteria may be transmitted from other organisms or the environment, or may spread intra-organismally from diseased sites or lesions. They often are not pathogenic under normal conditions but may become detrimental, even fatal, as secondary invaders following another infection or immunosuppression (Jacobson 1984; Shotts 1984). For example, *Salmonella* are opportunistic organisms present naturally in most reptile gastrointestinal tracts, and under normal conditions do not cause disease in their host (Chiodini 1983; Hoff and Hoff 1984; Frye 1991c). However, *Salmonella* can cause severe intestinal inflammation with electrolyte loss, and death following systemic infection, if the immune system of the host is stressed. The level of *Salmonella* is particularly high in turtles associated with human sewage waters and animal wastes (Frye 1991c). A die-off of American Alligators, *Alligator mississippiensis*, and several turtle species from *Aeromonas* septicemia followed a decrease of water levels in a Florida lake (Shotts et al. 1972). Water level declines resulted in eutrophication and an increase in the bacterial level associated with the sewage present in the lake. Tangredi and Evans (1997) reported ocular, nasal and otic infections in wild Eastern Box Turtles, *Terrapene carolina*, in New York, speculating that environmental exposure to organochlorine pesticides precipitated these opportunistic infections.

Different body systems may be more or less affected by bacterial infections. In particular, reptiles are prone to severe respiratory infections because of their simple respiratory system, the absence of a functional diaphragm, the lack of coughing or possible expulsion of mucus, and a single lung in most snakes (Frye 1991c; Perry 1998; Wallach 1998). However, reptiles, particularly chelonians and snakes, can sometimes survive chronic respiratory infections, because they use respiratory mechanisms other than lungs. These auxiliary respiratory mechanisms include cloacal bursae and skin, and the capacity for muscular anaerobiosis, all of which allow reptiles to withstand prolonged low levels of oxygen (hypoxia) or even absence of oxygen (anoxia) (Frye 1991c; Wang et al. 1998). Reptiles may also be asymptomatic carriers of bacterial agents for several years before developing any symptoms, as with *Mycoplasma agassizii*, the causative agent of the upper respiratory tract disease of tortoises (Jacobson 1993a; M.B. Brown et al. 1994, 1999; Homer et al. 1998; McLaughlin et al. 2000). The release of captive tortoises is hypothesized to be the origin of the disease in free-ranging tortoises (Jacobson et al. 1995) and may be leading to the decline of some tortoise populations in the United States (Brown et al. 1999; McLaughlin et al. 2000).

Bacteria isolated from reptiles are rarely host-specific and are often pathogenic to non-reptilian organisms. The bacterium *Yersinia enterocolitica* is widely distributed in wild, domestic, and zoo animals around the world. This bacterium and related species can be pathogenic to birds and mammals, including humans (Johnson-Delaney 1996). In Canada, this bacterium was isolated for the 1st time from a snake in the wild when it was discovered in 1 of 201 living Common Gartersnake, *Thamnophis sirtalis*, specimens examined in Saskatchewan (Table 1; Kwaga and Iversen 1993). The bacterium was isolated from the intestinal contents without any evidence of clinical significance.

Rickettsial microorganisms are intracellular bacteria, distributed worldwide, which can be parasites of vertebrates and arthropods. They are the pathogenic agents of epidemic typhus and spotted fever in humans. Arthropods such as ticks serve as vectors (Holt et al. 1994). These bacteria have been found in the blood of different reptiles, which may serve as reservoir hosts for the transmission of, for example, *Coxiella burnetii*, a rickettsia causing the Q fever in mammals (Johnson-Delaney 1996). In Canada, rickettsia have been reported in amphibians (Desser and Barta 1984; Bonin et al. 1997) but not in reptiles.

Viral Diseases

Different viruses have been isolated from both sick and asymptomatic wild and captive reptiles. These include arbovirus, herpesvirus, iridovirus, oncovirus (C-type), paramyxovirus, parvovirus, picorno virus, pox virus, reovirus, retrovirus, rhabdovirus, and syncytial virus (Clark and Lunger 1981; Hoff et al. 1984; Frye 1991c; Jacobson 1993b; Schumacher 1996; Westhouse et al. 1996). Pathological findings vary with the virus and host species and include necrosis of the liver, respiratory and digestive tracts, plus papillomas (Schumacher 1996). In North America, herpesviruses have been isolated from marine turtles with fibropapillomatosis (Jacobson et al. 1991a; Herbst 1994; Herbst et al. 1998; Quackenbush et al. 1998; Lackovich et al. 1999). The isolation and identification of viruses are often difficult due to the lack of appropriate cell lines. For example, the taxonomic position of *Pirhemocyton* and *Toddia* intraerythrocytic particles observed in different reptile species was unclear for many years before it was confirmed that they were viruses (Daly et al. 1980; Telford 1984; Smith et al. 1994a). This difficulty in isolating and identifying viruses has probably led to underestimating their potential prevalence and effects in reptile health. The icosahedral virus *Toddia* sp. was prevalent in 58% of Northern Watersnakes, *Nerodia sipedon*, sampled in Ontario (Table 1) by Smith et al. (1994a), thus suggesting that the viral infection was unlikely to be clinically significant. Reptiles can also be asymptomatic reservoirs for some viruses (Page 1966; Clark and Lunger 1981). The western equine encephalitis virus was isolated from Terrestrial Gartersnakes, *Thamnophis elegans*, Plains Gartersnakes, *T. radix*, and *T. sirtalis* in Saskatchewan (Table 1), confirming these snakes as reservoir hosts (Spalatin et al. 1964; Burton et al. 1966).

Fungal Diseases

Fungi are pathogens causing both superficial and deep infections (Austwick and Keymer 1981). Some of the most common fungi belong to the genera *Aspergillus*, *Candida*, *Fusarium*, *Prototheca*, *Schizangiella*, and *Trichoderma* (Frye 1991c; Kostka et al. 1997). Fungi commonly affect the integumentary, digestive, and respiratory systems. Many mycoses have been described in captive reptiles (Austwick and Keymer 1981; Migaki et al. 1984; Frye 1991c; Jacobson 1994). Superficial fungal infections are the most prevalent and are often secondary to infection by other pathogens (Rosenthal and Mader 1996). Hulse (1976) reported a fungal infection on the plastron of wild populations of Sonora Mud Turtles, *Kinosternon sonoriense*; the fungal colonies expanded in summer and decreased during the winter with no apparent detrimental effects on the turtles. We could not find published reports on the prevalence and potential impact of fungal infections on Canadian reptile populations.

Table 1. *Published reports of abnormalities, diseases, and mortalities in Canadian wild reptile populations*.

Species	Diagnosis	Number of individuals/ Stage of development	Date	Prov-ince	References
Apalone spinifera (Spiny Softshell; Tortue-molle à épines)	Mortality: boat propeller, unknown causes	3 / Adult M, F	1996-1999	QC	Galois et al. 2002
Caretta caretta (Loggerhead Seaturtle; Caouane)	Mortality: entanglement and debris ingestion	2 / Adult F	June 1964, July 1965	NS	Bleakney 1967
Chelonia mydas (Green Seaturtle; Tortue verte)	Mortality: bacterial infection, unknown causes	6 / Adult	1996-2002	BC	McAlpine et al. 2004
Chelydra serpentina (Snapping Turtle; Tortue serpentine)	Internal parasitism: trematodes *Auridistomum chelydrae*, *Polystomoidella oblongum*	-	-	-	Stafford 1900, 1905
	Internal parasitism: trematodes *Heronimus chelydrae*	1 / -	Summer 1897	ON	MacCallum 1902
	Road mortality	>1 / -	-	ON	Toner and Edwards 1938
	Colour mutation: albinism	1 / Immature	-	ON	Hensley 1959
	Colour mutation: albinism	1 / Immature	September 1970	ON	Judd 1971
	Internal parasitism: protozoa *Haemogregarina* sp.	37 / -	-	ON	Desser 1973
	Internal parasitism: protozoa *Haemogregarina balli*; External parasitism: leeches *Placobdella ornata*, *P. parasitica*	57 / Adult F	June-July 1972-1974	ON	Paterson and Desser 1976
	Internal parasitism: nematodes *Falcaustra chelydrae*, *F. wardi*	-	-	ON	Baker 1986a
	External parasitism: leeches *Placobdella parasitica*	173 / Adult M, F, immature	May-August 1987-1989	ON	Brooks et al. 1990
	Mortality: drowning, unknown causes; Road mortality	10 / Adult M, F, immature	1972-1989	ON	Brooks et al. 1991
	External parasitism: leeches *Placobdella parasitica*	>1 / -	April 1990	QC	Ricciardi and Lewis 1991
	Internal parasitism: protozoa *Haemogregarina balli*	84 / Adult M, F, immature	1989, May-July 1990	ON	Siddall and Desser 1992b

Table 1. *Continued.*

Species	Diagnosis	Number of individuals/ Stage of development	Date	Province	References
C. serpentina	Internal parasitism: protozoa *Haemogregarina balli* External parasitism: leeches *Placobdella ornata, P. parasitica*	28 / Adult F	1990-1991	ON	G.P. Brown et al. 1994
	Epibiont: algae *Basicladia* sp.	-	May-August 1993	ON	Colt et al. 1995
	Road mortality	272 / Adult M, F, immature	1979-1980, 1992-1993	ON	Ashley and Robinson 1996
	Anomaly: male feminization	115 / Adult M	1986-1991, 1994-1995	ON	de Solla et al. 1998
	Colour mutation: albinism	1 / Immature	September 1995	QC	Saumure and Rodrigue 1998
	Road mortality	86 / Adult M, F, immature	May-July 1993-1995	ON	Haxton 2000
	Mortality: hyperthermia	2 / Adult F	June 1999	ON	de Solla et al. 2001
	Traumatic injury: limb mutilations	2 / Adult M, F	June 1994, August 1995	QC, ON	Saumure 2001b
	Road mortality	23 / Adult M, F, immature	June-July 2003	QC	Desroches and Picard 2005
	Road mortality	1 / Adult M	May 2004	QC	Ouellet et al. 2005
	Traumatic injury: fishing tackle ingestion	1 / Adult M	June 1994	QC	This chapter (Fig. 4)
Chrysemys picta (Painted Turtle; Tortue peinte)	Internal parasitism: trematodes *Polystomoidella oblongum*, *Protenes angustus*	-	-	-	Stafford 1900, 1905
	Road mortality	1 / Adult F	-	BC	Thacker 1924
	Internal parasitism: protozoa *Entamoeba invadens*	1 / Adult	-	QC	Meerovitch 1958
	Mortality: unknown causes	56 / Adult M, F, immature	May 1954	ON	Bleakney 1966
	Internal parasitism: protozoa *Trypanosoma chrysemydis*	13 / -	1965-1967	ON	Woo 1969b
	Congenital defect: carapacial abnormalities, deformed plastron	20 / -	May-July 1974	ON	Whillans and Crossman 1977
	Internal parasitism: nematodes *Serpinema trispinosus*	-	-	ON	Baker 1979

Table 1. *Continued.*

Species	Diagnosis	Number of individuals/ Stage of development	Date	Prov-ince	References
C. picta	Internal parasitism: cestodes *Proteocephalus* sp., nematodes *Serpinema trispinosus*, *Spiroxys contortus*, trematodes *Crepidostomum* sp., *Eustomos chelydrae*, *Microphallus opacus*, *Polystomoides pauli*, *Protenes angustus*, *Spirorchis parvus*, *S. scripta*, *Telorchis attenuatus*, *T. corti*.	31 / -	May-September 1976, July-August 1977	MB	Timmers and Lewis 1979
	External parasitism: leeches *Placobdella parasitica*	62 / Adult M, F, immature	May-August 1979	SK	MacCulloch 1981a
	Colour variation: reticulate melanism	49 / Adult M, F, immature	May-September 1978-1979	SK	MacCulloch 1981b
	Congenital defect: divided, extra and missing scutes, scoliosis				
	Colour variation: reticulate melanism	21 / Adult M	-	BC, MB, SK	Schueler 1983
	Internal parasitism: nematodes *Falcaustra affinis*	-	-	ON	Baker 1986a
	Mortality: freezing, unknown causes	>88 / Adult, embryo, immature	1988-1989	BC	St. Clair and Gregory 1990
	External parasitism: leeches *Placobdella parasitica*	>1 / -	April 1990	QC	Ricciardi and Lewis 1991
	Internal parasitism: protozoa *Haemogregarina balli*	45 / Adult M, F	1989, May-July 1990	ON	Siddall and Desser 1992b
	Epibiont: algae	-	May-August 1993	ON	Colt et al. 1995
	Road mortality	341 / Adult M, F, immature	1979-1980, 1992-1993	ON	Ashley and Robinson 1996
	Internal parasitism: protozoa *Haemogregarina balli*	6 / -	July 1990	ON	Siddall and Desser 2001
	Road mortality	45 / Adult M, F	June-July 2003	QC	Desroches and Picard 2005
	Traumatic injury: limb amputation	1 / Immature	August 2000	QC	This chapter (Fig. 2)

Table 1. *Continued.*

Species	Diagnosis	Number of individuals/ Stage of development	Date	Prov-ince	References
Clemmys guttata (Spotted Turtle; Tortue ponctuée)	Internal parasitism: nematodes *Hedruris pendula*	-	May 1984	ON	Baker 1986b
	Epibiont: algae	-	May-August 1993	ON	Colt et al. 1995
	Road mortality	17 / -	1979, 1992-1993	ON	Ashley and Robinson 1996
	Mortality: unknown causes	8 / Adult M, F, immature	1977-2000	ON	Litzgus 2006
Crotalus oreganus (Northern Pacific Rattlesnake; Crotale du Pacifique nord)	Road mortality	>1 / -	July 1928	BC	Logier 1931b
Crotalus viridis (Western Rattlesnake; Crotale de l'Ouest)	Congenital defect: dicephalism	1 / Immature	1949	AB	Klauber 1972
	Congenital defect: gross abnormalities	3 / Embryo, immature	September 1974	AB	Pendlebury 1976
	Road mortality	20 / Adult M, F	May-October 1997	AB	Hill et al. 2001
Dermochelys coriacea (Leatherback Seaturtle; Tortue luth)	Mortality: entanglement	1 / Adult	August 1946	NL	Squires 1954
	Mortality: entanglement	1 / Adult	July 1957	BC	MacAskie and Forrester 1962
	Mortality: entanglement	6 / Adult M, F	1961-1964	NB, NL, NS	Bleakney 1965
	Epibiont: cirripeds *Stomatolepas* sp.	2 / Adult M, F	1955, 1965	NS	Zullo and Bleakney 1966
	Mortality: entanglement	1 / Adult	September 1972	NL	Steele 1972
	Internal parasitism: trematodes *Calycodes anthos*, *Cymatocarpus* sp., *Pyelosomum renicapite*	2 / Adult M, F	1973	NL	Threlfall 1979
	Epibiont: barnacles *Conchoderma virgatum*	1 / Adult M	September 1981	QC	D'Amours 1983
	Mortality: entanglement	4 / Adult	1982-1985	NL	Goff and Lien 1988
	Mortality: unknown causes	2 / -	May 1997, Spring 1998	BC	McAlpine et al. 2004
	Mortality: entanglement	15 / -	1997-2003	NS	James et al. 2005
	Mortality: unknown causes	1 / Adult	July 2004	QC	Ouellet et al. 2006
Diadophis punctatus (Ring-necked Snake; Couleuvre à collier)	Colour mutation: partial albinism	1 / Adult M	1997	NS	Gilhen 1999

Table 1. *Continued.*

Species	Diagnosis	Number of individuals/ Stage of development	Date	Prov-ince	References
Elaphe gloydi (Eastern Foxsnake; Couleuvre fauve)	Internal parasitism: nematodes *Rhabdias eustreptos*	3 / -	-	ON	Baker 1978
	Road mortality	24 / -	1979-1980, 1992-1993	ON	Ashley and Robinson 1996
	Internal parasitism: protozoa *Hepatozoon* sp.	3 / -	-	ON	Smith 1996
	Internal parasitism: protozoa *Hepatozoon* sp.	-	May 1992-July 1996	ON	Smith et al. 1999
Elaphe spiloides (Eastern Ratsnake; Couleuvre obscure)	Mortality: traumatic injury, unknown causes	3 / Adult M, F	April-May 1994	ON	Prior and Shilton 1996
	External parasitism: burying beetles *Nicrophorus pustulatus*	77 / Eggs	1998-1999	ON	Blouin-Demers and Weatherhead 2000
Elgaria coerulea (Northern Alligator Lizard; Lézard-alligator boréal)	External parasitism: ticks *Ixodes californicus*	2 / -	October 1934	BC	Gregson 1934, 1942
Emydoidea blandingii (Blanding's Turtle; Tortue mouchetée)	Mortality: unknown causes	3 / Adult M, F	May 1954	ON	Bleakney 1966
	Internal parasitism: nematodes *Hedruris pendula*	-	May 1984	ON	Baker 1986b
	External parasitism: leeches *Placobdella ornata, P. parasitica*	1 / Adult	July 1988	ON	Saumure 1990
	Epibiont: algae	-	May-August 1993	ON	Colt et al. 1995
	Road mortality	61 / -	1979-1980, 1992-1993	ON	Ashley and Robinson 1996
	Road mortality; Traumatic injury: limb amputations, shell mutilations	>1 / Adult, immature	1994-1996	NS	Standing et al. 1999
	Congenital defect: shell abnormalities, paralysis, edema; Road mortality	36 / Embryo, immature	1994-1996	NS	Standing et al. 2000a,b
	Road mortality	2 / Adult	June-July 2003	QC	Desroches and Picard 2005
Glyptemys insculpta (Wood Turtle; Tortue des bois)	Road mortality	2 / Adult F	June 1940	ON	Brown 1947
	Abnormality: neck excrescence; Road mortality	2 / Adult M, immature	October 1965, May 1969	NS	Gilhen and Grantmyre 1973

Table 1. *Continued.*

Species	Diagnosis	Number of individuals/ Stage of development	Date	Prov-ince	References
G. insculpta	External parasitism: leeches *Placobdella parasitica*	>1 / -	1990	QC	Ricciardi and Lewis 1991
	Road mortality; Traumatic injury: limb and tail amputations, shell mutilations	39 / Adult M, F, immature	1987-1990	ON	Brooks et al. 1992
	Internal parasitism: protozoa *Haemogregarina balli*	17 / Adult M, F	1989, May-July 1990	ON	Siddall and Desser 1992b
	External parasitism: leeches *Placobdella ornata*, *P. parasitica*	13 / Adult M, F	June 1994	QC	Saumure and Bider 1996
	Traumatic injury: limb and tail amputations, shell mutilations	50 / Adult M, F	May-July 1994-1995	QC	Saumure and Bider 1998
	Traumatic injury: limb amputation, shell mutilations	1 / Immature	August 2001	NS	Gräf et al. 2003
	External parasitism: leeches *Placobdella* sp.; Traumatic injury: limb and tail amputations	65 / Adult M, F, immature	1996-1997	QC	Walde et al. 2003
	Road mortality	3 / Adult F, immature	June-July 2003	QC	Desroches and Picard 2005
Graptemys geographica (Northern Map Turtle; Tortue géographique)	Internal parasitism: protozoa *Trypanosoma chrysemydis*	3 / -	1965-1967	ON	Woo 1969b
	External parasitism: leeches *Placobdella ornata*	2 / Adult, immature	May, August 1993	ON, QC	Saumure and Livingston 1994
	Epibiont: algae	-	May-August 1993	ON	Colt et al. 1995
	Road mortality	25 / -	1979-1980, 1992-1993	ON	Ashley and Robinson 1996
Heterodon platirhinos (Eastern Hog-nosed Snake; Couleuvre à nez plat)	Road mortality	1 / -	-	ON	Evans and Roecker 1951
	Colour mutation: melanism	3 / -	-	ON	Edgren 1957
Lampropeltis triangulum (Milksnake; Couleuvre tachetée)	Internal parasitism: nematodes *Rhabdias fuscovenosa*, trematodes *Alaria* sp.	9 / -	Spring-Summer 1976	QC	Rau et al. 1978; Rau and Gordon 1980
	Road mortality	1 / -	1980	ON	Ashley and Robinson 1996
	Internal parasitism: protozoa *Hepatozoon* sp.	1 / -	-	ON	Smith 1996
	Internal parasitism: protozoa *Hepatozoon* sp.	-	May 1992-July 1996	ON	Smith et al. 1999

Table 1. *Continued.*

Species	Diagnosis	Number of individuals/ Stage of development	Date	Prov-ince	References
Nerodia sipedon (Northern Watersnake; Couleuvre d'eau)	Internal parasitism: nematodes *Kalicephalus agkistrodontis*, protozoa *Eutrichomastix serpentis*, *Hepatozoon* sp., *Trichomonas* sp., trematodes *Plagiorchis* sp., *Pneumatophilus variabilis*	2 / Adult M, immature	-	QC	Fantham and Porter 1954
	Colour variation: aberrant pattern Congenital defect: aberrant scale number	250 / Adult M, F, immature	1956	ON	Bleakney 1958
	Mortality: unknown causes	12 / Adult	May 1959	ON	Lindsay 1966
	Internal parasitism: cestodes *Proteocephalus perspicua*, trematodes *Alaria* sp., *Dasymetra nicolli*, *Pneumatophilus variabilis*	5 / -	Spring-Summer 1976	QC	Rau et al. 1978; Rau and Gordon 1980
	Infectious agent: virus *Toddia* sp.	15 / -	May 1992	ON	Smith et al. 1994a
	Internal parasitism: protozoa *Hepatozoon sipedon*	18 / -	May 1992, July 1993	ON	Smith et al. 1994b; Smith and Desser 1997b
	Road mortality	8 / -	1979-1980, 1993	ON	Ashley and Robinson 1996
	Internal parasitism: protozoa *Hepatozoon sipedon*	3 / -	-	ON	Smith and Desser 1998
	Mortality: unknown causes	>1 / -	1993-1996	ON	Brown and Weatherhead 1999
	Mortality: unknown causes	5 / Immature	October 1994	QC	This chapter (Fig. 5)
Opheodrys vernalis (Smooth Greensnake; Couleuvre verte)	Internal parasitism: cestodes *Oochoristica* sp., nematodes *Aplectana* sp., *Physaloptera* sp.	18 / Adult M, F	May-September 1957	ON	Judd 1960
Sistrurus catenatus (Massasauga; Massasauga)	Colour variation: striped pattern	1 / Adult	July 1979	ON	Oldham 1985
Sternotherus odoratus (Stinkpot; Tortue musquée)	Internal parasitism: trematodes *Polystomoidella oblongum*	1 / -	-	-	Wright 1884

Table 1. *Continued.*

Species	Diagnosis	Number of individuals/ Stage of development	Date	Prov-ince	References
S. odoratus	Congenital defect: kyphosis	1 / Adult M	July 1984	ON	Saumure 2001a
Storeria dekayi (DeKay's Brownsnake; Couleuvre brune)	Internal parasitism: nematodes *Cosmocercoides dukae*, *Rhabdias fuscovenosa*	12 / -	Spring-Summer 1976	QC	Rau et al. 1978; Rau and Gordon 1980
Thamnophis butleri (Butler's Gartersnake; Couleuvre à petite tête)	Colour mutation: melanism	3 / Adult M, F	May-June 1976	ON	Catling and Freedman 1977
Thamnophis elegans (Terrestrial Gartersnake; Couleuvre de l'Ouest)	Infectious agent: western equine encephalitis virus *Alphavirus* sp.	1 / -	1961-1963	SK	Spalatin et al. 1964
Thamnophis radix (Plains Gartersnake; Couleuvre des Plaines)	Infectious agent: western equine encephalitis virus *Alphavirus* sp.	12 / -	1961-1963	SK	Spalatin et al. 1964
	Infectious agent: western equine encephalitis virus *Alphavirus* sp.	14 / -	May 1964	SK	Burton et al. 1966
Thamnophis sauritus (Eastern Ribbonsnake; Couleuvre mince)	Internal parasitism: protozoa *Eimeria bitis*, *Eutrichomastix serpentis*, trematodes *Lechriorchis* sp.	1 / Adult F	-	ON	Fantham and Porter 1954
	Road mortality	1 / -	1993	ON	Ashley and Robinson 1996
	Internal parasitism: protozoa *Hepatozoon* sp.	-	May 1992-July 1996	ON	Smith et al. 1999
	Road mortality	1 / Adult	August 2003	QC	Desroches and Laparé 2004
Thamnophis sirtalis (Common Gartersnake; Couleuvre rayée)	Congenital defect: dicephalism	1 / -	August 1866	ON	Johnson 1901; Whiteaves 1902
	Internal parasitism: trematodes *Lechriorchis primus*, *Zeugorchis aequatus*	-	-	-	Stafford 1902, 1905
	Colour mutation: melanism	5 / Adult M, F, immature	Summer 1913	ON	Patch 1919
	Colour mutation: melanism	1 / Adult F	July 1920	ON	Logier 1925
	Colour mutation: melanism	59 / Adult F, immature	1927	ON	Logier 1929, 1931a
	Colour mutation: melanism	44 / Adult M, F, immature	July 1929	ON	Logier 1930, 1931a

Table 1. *Continued.*

Species	Diagnosis	Number of individuals/ Stage of development	Date	Prov-ince	References
T. sirtalis	Colour mutation: melanism	>2 / Adult M, F	Spring 1937, 1938	ON	Blanchard and Blanchard 1940
	Colour mutation: melanism	9 / Adult F, immature	Fall 1940	ON	Blanchard 1942
	Colour mutation: melanism	6 / Adult M, F, immature	June 1948, July 1949	ON	Evans and Roecker 1951
	Internal parasitism: cestodes *Proteocephalus grandis*, nematodes *Physaloptera abjecta*, protozoa *Dactylosoma* sp., *Eimeria bitis*, *Entamoeba invadens*, *Eutrichomastix serpentis*, *Trichomonas* sp., *Trypanosoma* sp., trematodes *Lechriorchis primus*, *Leptophallus* sp.	6 / Adult M, F, immature	-	QC	Fantham and Porter 1954
	Colour mutation: melanism	95 / -	1956	ON	Adams and Clark 1958
	Colour mutation: albinism	1 / -	August 1956	BC	Hensley 1959
	Infectious agent: western equine encephalitis virus *Alphavirus* sp.	32 / -	1961-1963	SK	Spalatin et al. 1964
	Infectious agent: western equine encephalitis virus *Alphavirus* sp.	43 / -	May 1964	SK	Burton et al. 1966
	Colour mutation: melanism	14 / Adult F	July, August 1972	ON	Gibson and Falls 1975
	Colour mutation: melanism	29 / M, F	April-May 1972	ON	Schueler 1975
	Mortality: drowning, freezing	>1 000 / Adult M, F, immature	Winter 1972-Spring 1973	MB	Aleksiuk 1977
	Internal parasitism: nematodes *Rhabdias fuscovenosa*	33 / -	-	ON	Baker 1978
	Internal parasitism: cestodes *Cylindrotaenia* sp., nematodes *Rhabdias fuscovenosa*, trematodes *Alaria* sp., *Lechriorchis primus*, *Pneumatophilus variabilis*, *Zeugorchis aequatus*	115 / Adult, immature	Spring-Summer 1976	QC	Rau et al. 1978; Rau and Gordon 1980

Table 1. *Continued.*

Species	Diagnosis	Number of individuals/ Stage of development	Date	Prov-ince	References
T. sirtalis	Internal parasitism: cestodes *Cylindrotaenia* sp., nematodes *Rhabdias* sp., trematodes *Alaria* sp., *Lechriorchis primus*, *Zeugorchis aequatus*	29 / -	October 1976, March 1977	QC	Rau and Gordon 1978
	Colour mutation: albinism	2 / Immature	August 1970	ON	Weller 1983
	Road mortality	>1 / -	May-August 1984-1985	AB	Larsen 1987
	Colour mutation: melanism	440 / Adult M, F, immature	1980-1985	ON	King 1988
	Colour mutation: aberrant pattern, melanism	>1 / -	1986-1990	MB	Mason et al. 1991
	Road mortality	42 / Adult M, F, immature	September 1991	MB	Krivda 1993
	Infectious agent: bacteria *Yersinia enterocolitica*	1 / Adult	Spring 1988	SK	Kwaga and Iversen 1993
	Internal parasitism: protozoa *Hepatozoon* sp.	3 / -	May 1992, July 1993	ON	Smith et al. 1994b
	Colour mutation: melanism	101 / -	1989-1992	ON	Lawson and King 1996
	Road mortality	114 / -	1979-1980, 1992-1993	ON	Ashley and Robinson 1996
	Internal parasitism: protozoa *Hepatozoon* sp.	5 / -	-	ON	Smith 1996
	Internal parasitism: protozoa *Hepatozoon* sp.	8 / -	July 1993-September 1995	ON	Smith et al. 1996
	Internal parasitism: protozoa *Hepatozoon* sp.	-	May 1992-July 1996	ON	Smith et al. 1999
	Mortality: suffocation, unknown causes	443 / Adult M, F, immature	May 1997	MB	Shine et al. 2001
	Mortality: drowning, freezing; Road mortality	>10 000 / Adult M, F, immature	1998-2002	MB	Shine and Mason 2004
	Congenital defect: scale asymmetries	699 / Adult M, F, immature	May 2003	MB	Shine et al. 2005
	Road mortality	1 / Adult F	May 1994	ON	This chapter (Fig. 3)
	Congenital defect: kyphoscoliosis	1 / Immature	July 1995	QC	This chapter (Fig. 1)

Parasites

A large number of parasites have been described in reptiles. Internal parasites include organisms such as protozoans, helminths, and pentastomes; external parasites such as leeches and arthropods have also been recorded. The life cycle of these organisms may vary from simple, with the infectious form being passed directly between host individuals from the same species, to complex, with one or several intermediate hosts associated with different developmental stages of the parasite. Although parasites are relatively easy to find, their association with a disease is often difficult to confirm. Pathogenicity is generally considered limited as parasites may be present without noticeable effects on the host, including disease, even in the final host. The impact of these parasites on wild reptile populations has not been well documented and actual knowledge of their effects stems mainly from studies with captive animals.

Internal Parasites

Protozoans.—Protozoans are single-celled eukaryotes. Protozoan parasites found in reptilian species are categorized into 4 phyla: Apicomplexa, Ciliophora (ciliates), Microspora, and Sarcomastigophora (amoebo-flagellates) (Barnard and Upton 1994). However, systematic classification is continually changing (Barnard and Upton 1994; Siddall et al. 1995), particularly in the phylum Apicomplexa (Barta 1989; Siddall and Desser 1991; Siddall 1995; Smith 1996; Smith and Desser 1997a). Protozoan parasites are well documented in reptiles, but their life cycle and pathogenicity are often unclear or unknown. A synopsis of protozoan parasites of turtles from North America is provided by Ernst and Ernst (1979) and non-hemoparasitic protozoans were reviewed by Frank (1984). General reviews for reptiles may be found in Reichenbach-Klinke and Elkan (1965), Hoff et al. (1984), and Barnard and Upton (1994).

Coccidian (Apicomplexa) parasites in reptiles include a large number of genera. The significance of coccidiosis in reptile species is still poorly understood (Lane and Mader 1996) and little is known about these pathogenic organisms partly because of difficulty in identification (Cranfield and Graczyk 1996; Smith et al. 1999). Different species may infect the same individual, and the same species may infect different host species (Deeds and Jahn 1939; Telford 1970; Wacha and Christiansen 1974, 1976, 1977). For example, *Cryptosporidium* is a protozoan infecting the gastrointestinal and, occasionally, the respiratory and biliary tracts. Reptiles with cryptosporidiosis may show no clinical signs of disease. Upton et al. (1989) examined the intestinal contents and feces in 75 species of wild and captive reptiles and found *Cryptosporidium* spp. in only 6 North American species. Jacobson (1993a) suggested that a virus may compromise the immune system thereby allowing this protozoan to cause cryptosporidiosis. *Eimeria* is the most frequently reported genus of coccidia in apparently healthy chelonians (McAllister and Upton 1989).

Other coccidian genera commonly reported in reptiles are *Caryospora*, *Cyclospora*, *Isospora*, and *Sarcocystis* (Levine and Tadros 1980; Frank 1984; Upton et al. 1986; Frye 1991a; Lane and Mader 1996). In 1987, an intranuclear coccidian, *Isospora manchacensis*, was reported for the 1st time in a North American reptile, the Little Brown Skink, *Scincella lateralis*, from Louisiana (Atkinson and Ayala 1987). McAllister and Upton (1989) emphasized in a review that only 30 coccidian species had been described in turtles worldwide and that most of the coccidia infecting turtles were still to be discovered. More research is certainly needed to identify reptile coccidian parasites, establish their life cycles, and assess their role in reptile health (Smith 1996).

Hemogregarines (Apicomplexa) are common blood parasites of reptiles including *Haemogregarina* sp. found in turtles, and nearly 200 *Hepatozoon* sp. have been described in lizards and snakes (Marquardt 1966; McAuliffe 1977; Telford 1984; Siddall 1995; Smith 1996; Smith et al. 1996, 1999; Telford et al. 2001). Invertebrate organisms, which include leeches (Siddall and Desser 1990, 1991, 2001), mosquitoes (Oda et al. 1971; Smith et al. 1994b, 1996), and tabanid flies (DeGiusti et al. 1973), are potential vectors of the parasite. Reptiles can also be infected through ingestion of infected intermediate hosts such as frogs and lizards (Lowichik and Yaeger 1987; Smith 1996; Smith et al. 1996). In Texas, Wang and Hopkins (1965) found *Haemogregarina* sp. in 8 freshwater turtle species with 75% of the 44 turtles infected. In Algonquin Park, Ontario, Desser (1973) examined 37 Snapping Turtles, *Chelydra serpentina*, and found all turtles parasitized with hemogregarines (Table 1). *Haemogregarina* was found in 3 turtle species and *Hepatozoon* was found in 4 snake species in Canada (Table 1). These common parasites are rarely associated with clinical diseases (Campbell 1996). For example, G.P. Brown et al. (1994) found that hemogregarine parasites had no effect on the reproductive success of female *C. serpentina* from a site in Ontario.

The amoeba (Sarcomastigophora) *Entamoeba invadens* is one of the most clinically important parasites infecting captive and wild reptiles (Lane and Mader 1996). Geiman and Ratcliffe (1936) described the different stages of the life cycle of *Entamoeba invadens* in naturally and artificially infected Eastern Racers, *Coluber constrictor*, Mississippi Green Watersnakes, *Nerodia cyclopion*, Diamond-backed Watersnakes, *N. rhombifer*, and *N. sipedon*. There were no characteristic clinical signs and death was either sudden or following long debilitation. In Canada, different *Entamoeba* species have been reported in apparently healthy turtles and snakes (Table 1). Meerovitch (1958) suspected that *Entamoeba invadens* was a commensal in turtles but pathogenic in snakes.

Trypanosomes (Sarcomastigophora) are flagellate protozoa found in the blood and require blood-sucking invertebrate hosts such as leeches and mosquitoes for their transmission (Woo 1969a; Siddall and Desser 1992a; Campbell 1996). They are often seen in the blood of reptiles but most are not considered pathogenic. In Canada, trypanosomes have been reported in 1 snake and 2 turtle species (Table 1). Woo (1969b) found trypanosomes in 2 of 4 turtle species examined in Ontario with a prevalence of 8 to 20% of animals infected in 3 different sites.

Helminths.—Many helminths, which include nematodes, cestodes and trematodes, are parasites of reptiles (Reichenbach-Klinke and Elkan 1965; Ernst and Ernst 1977; Hoff et al. 1984). Helminth species of the same group (Phylum, Class, Order, Family), or from different groups, can be found simultaneously in the same individual or population, and the helminth community composition can differ between host populations and habitats (Judd 1960; Esch and Gibbons 1967; Telford 1970; Esch et al. 1979a,b; Timmers and Lewis 1979; Rau and Gordon 1980; Goldberg et al. 1998). Factors such as host age, diet, thermoregulatory behaviour, and season have been shown to influence the helminth community in chelonians (Esch et al. 1990) and snakes (Rau and Gordon 1978, 1980).

Nematodes or roundworms (Phylum Nematoda) are found in various organs of wild reptiles, but particularly in the intestines and lungs (Reichenbach-Klinke and Elkan 1965). More than 1000 species of nematodes have been reported in amphibians and reptiles (Baker 1984, 1987). The majority are monoxenous, i.e., do not require an intermediate host (Anderson 2000). Nematode parasites of reptiles include members of the following orders: Ascaridida, Oxyurida, Rhabditida, Spirurida, and Strongylida. Nematodes are rarely harmful in healthy adults, but may become detrimental in juveniles, or under conditions of stress (Reichenbach-Klinke and Elkan 1965). Ascarids are large nematodes that generally develop via an intermediate host such as a frog or rodent. *Ophidascaris* is a well-known parasite of snakes with *O. labiatopapillosa* found particularly in North American watersnakes (Lane and Mader 1996). Oxyurid nematodes (pinworms) are common parasites of reptiles except crocodilians (Lane and Mader 1996), and are usually monoxenous and host specific (Frank 1981b; Anderson 2000). Their pathogenicity is generally low but they can be debilitating when they occur in exceptionally large numbers (Frank 1981b). Rhabditid nematodes (lungworms) of the family Rhabdiasidae are widely distributed in amphibians and reptiles. These small nematodes are characterized by free-living and parasitic phases. They can cause respiratory diseases in snakes (Brannian 1984), although many individuals show no clinical signs or only a light inflammatory response to these worms (Lane and Mader 1996). Spirurid nematodes use invertebrates as intermediate hosts, and reptiles as intermediate or final hosts. For example, nematodes from the *Physaloptera* genus are commonly found in reptiles with arthropods as obligate intermediate hosts (Frank 1981b). Reptiles may serve as final host or as a paratenic host (a paratenic host is an organism which serves to transfer a larval stage or stages from one host to another but in which little or no development takes place (Anderson 2000)). *T. sirtalis* may be a paratenic host for *Physaloptera maxillaris* for which the final hosts are carnivorous mammals. In this case, the snake host remains asymptomatic (Cawthorn and Anderson 1976). Strongyloid nematodes of the family Diaphanocephalidae are mostly found in the digestive tract of snakes and feed mainly on blood (Schad 1956, 1962; Anderson 2000). They have low host specificity. Different species of *Kalicephalus* (Diaphanocephalidae) can be found in the same host but spaced throughout the gut (Anderson 2000). In large numbers, they induce hemorrhagic lesions which facilitate bacterial invasion of the intestine (Frank 1981b). In Michigan, Esch and Gibbons (1967) examined the seasonal incidence of parasitism in Painted Turtles, *Chrysemys picta*, and identified 4 nematode species. They observed a high parasite load during the warm months and a decline in winter in adult turtles. Species from 9 different genera, and representing the 5 orders described above, were reported in Canada in 6 snake and 4 turtle species (Table 1).

Cestodes or tapeworms (Phylum Platyhelminthes) are often found as adults in the intestine or peritoneal cavity of reptiles that generally are associated with aquatic habitats, the intermediate hosts often being a crustacean (Brooks 1978, 1984). Reptiles may be host to both larval and adult stages. They become infected by ingesting other animals parasitized by larval cestodes (Reichenbach-Klinke and Elkan 1965). The diversity of cestode species in turtles is very limited (Ernst and Ernst 1977; Timmers and Lewis 1979; Esch et al. 1990). Acholonu (1970) found few reports of cestodes in North American turtles and observed only 1 species (*Proteocephalus testudo*) infecting 1 of 12 turtle species examined in Louisiana. Host animals and their cestode parasites usually co-exist with no significant impact on the host under normal conditions (Brooks 1984). In Canada, 4 cestode species were reported in 3 snake species and 1 turtle species (Table 1) but their impact on their hosts was not documented.

Trematodes or flukes (Phylum Platyhelminthes) are common parasites in reptiles and belong mostly to the order Digenea. These digenetic trematodes require an intermediate host, usually a snail, and sometimes a secondary intermediate host, such as an amphibian, to complete their life cycle. The adults are generally found in the host intestinal tract, but they can also be found in the bladder, uterus, kidneys, and peritoneal cavity (Reichenbach-Klinke and Elkan 1965; Brooks 1984). Reptiles become infested by larvae after ingesting the secondary intermediate host. Trematodes of the family Spirorchidae, or turtle blood flukes, are restricted to chelonians (Smith 1972). *Spirorchis* is found in the liver and the circulatory system. Pathological effects of *Spirorchis parvus* consisted of debilitation and death in heavily infested captive *C. picta* (Holliman and Fisher 1968; Holliman et al. 1971). Trematodes usually do not pose a major threat in natural situations (Brooks 1984). Esch and Gibbons (1967) identified 8 trematode species in a population of *C. picta* from Michigan. Twenty-one trematode species were reported in 4 snake and 4 turtle species from Canada (Table 1).

Pentastomes.—Pentastomids (Phylum Pentastomida) are parasitic arthropods found mostly in reptiles. They are also called tongue worms or linguatulids. Adult pentastomids are internal parasites found in the respiratory tract and other tissues of snakes, lizards, and crocodilians (Self 1969; Frank 1981b; Lane and Mader 1996). The life cycle includes an intermediate host, often a herbivorous vertebrate such as a rodent (Reichenbach-Klinke and Elkan 1965; Page 1966; Self 1969; Klauber 1972; Johnson-Delaney 1996). The larvae can cause tissue lesions through migration and encystment (Cosgrove et al. 1984). Nymphs are present mostly in the liver and lungs of intermediate hosts such as amphibians, snakes, lizards, fish, and mammals. The adult worms may induce hemorrhagic perforations and infection of the lungs, leading to anemia, anoxia, or hypoproteinemia (Cosgrove et al. 1984). Since pentastomes are usually reported in southern latitudes, they are unlikely to cause clinical health problems in Canadian reptile populations.

External Parasites

Leeches.—Leeches (Class Hirudinea) are mostly found on turtles and crocodilians. The presence of leeches on freshwater turtles is frequent and regularly reported (Ernst and Barbour 1972). Leeches may transmit bacteria, protozoans, and viruses to turtles, but little is known about their real impact on freshwater turtles (Woo 1969a; Frank 1981a; Siddall and Desser 1992a). The seasonal occurrence of leeches varies; they can remain on their host throughout the year or only during the summer (Ernst 1971b; Koffler et al. 1978; Brewster and Brewster 1986; Dodd 1988b; Brooks et al. 1990; Farrell and Graham 1991; Graham et al. 1997). Two species of leeches, *Placobdella parasitica* and *P. ornata*, were identified in Canada on 5 freshwater turtle species (Table 1). G.P. Brown et al. (1994) found that leech parasitism had no effect on the reproductive success of female *C. serpentina* in Algonquin Provincial Park, Ontario.

Ozobranchius sp. leeches are common ectoparasites of marine turtles (Lauckner 1985). They are abundant on turtles afflicted with fibropapillomatosis, but their possible role in this disease is unknown (Aguirre et al. 1994). They appear to have a preference for external tumours probably because these tumours are typically highly vascularized (Lauckner 1985). Marine hirudineans tend to bury in soft skin tissues and may cause severe lesions to their host when they occur in high densities on a small area (Lauckner 1985).

Mites and Ticks.—Mites (Order Acarina) are common arthropods. In reptiles they are usually found under the scales of the axillar and inguinal regions, near the proximal part of the tail, and around the eyes. Mites may be a threat as parasites, and as vectors of diseases. They can be species-specific or may affect several host species (Reichenbach-Klinke and Elkan 1965). Some mite species infest the lungs (Turk 1945) and the cloacal tissue of turtles (Camin et al. 1967; Frank 1981a; Pence and Wright 1998). One of the most common mites, *Ophionyssus natricis*, is suspected of transmitting the virus responsible for the boid inclusion body disease, which causes high mortality in captive boids around the world (Jacobson 1993a; Schumacher et al. 1994; Wozniak and DeNardo 2000).

Ticks (Order Acarina) generally inflict minor inflammatory responses of the skin, but may sometimes inflict serious damage to their host (Barnard and Durden 2000). For example, they were suspected to be the cause of tail loss in Trans-Pecos Ratsnakes, *Bogertophis subocularis* (Degenhardt and Degenhardt 1965). More important, ticks are vectors of infectious agents and are pathogen reservoirs. Ticks can transmit microorganisms, such as *Cowdria ruminantium* (rickettsia), which was found in ticks attached to tortoises, and which causes heartwater disease in ruminants (Burridge et al. 2000; Mahan et al. 2000). Ticks can also host viruses like tick-borne encephalitis virus and the Russian spring-summer encephalitis virus (Frank 1981a; Johnson-Delaney 1996). Goldberg and Bursey (1991) suggested that infestation of mites and ticks occurred during hibernation of Californian lizards, and that the level of infestation varied annually in relation to weather conditions. The prevalence of *Ixodes californicus* ticks on Northern Alligator Lizards, *Elgaria coerulea*, was documented in British Columbia (Gregson 1934, 1942).

Flesh Flies and Burying Beetles.—Sarcophagid flies can parasitize reptiles and their larvae occasionally cause the death of adults of various turtle and tortoise species (Muller 1921; Knipling 1937; Peters 1948; Rainey 1953; Beane and Zappalorti 1997). Larvae from sarcophagid and phorid flies also parasitize the eggs of reptiles (Vogt 1981; Acuña-Mesén and Hanson 1990; Trauth and Mullen 1990; Iverson and Perry 1994). The impact of fly larvae at the population level has not been documented. Larvae of the burying beetle *Nicrophurus pustulatus* were found to parasitize eggs of Gray Ratsnakes, *Elaphe spiloides*, in Ontario (Blouin-Demers and Weatherhead 2000). This association is a parasitoid-host relationship in which only the beetle larva is parasitic and always kills the host. *N. pustulatus* may be an important factor in the population biology of some oviparous snakes.

Epibionts

Epibionts or epizoophytes are organisms (either animals or plants), attached to the surface of a host, but which are not classified as parasites. In reptiles, they are mostly found on the shell and skin of turtles. Algae are generally observed in semi-aquatic and aquatic turtles, snakes, and lizards (Frye 1991c). The most common taxa involved are *Basicladia chelonum*, *B. crassa*, and *Chlorella* sp. (Edgren et al. 1953; Neill and Allen 1954; Moski 1957a,b; Proctor 1958; Belusz and Reed 1969). Hunt (1958) observed algal penetration under the epidermal laminae in turtles, opening the way for bacterial and fungal infections. Proctor (1958), however, concluded that algal growth has no effect on turtles. In a population of *C. picta* in Michigan, the amount of carapace covered by algae varied with season and was controlled by annual scute shedding (Gibbons 1968). Algae from the genus *Basicladia* were 1st reported in Canada by Colt et al. (1995), and 2 species were identified on 5 different turtle species from Ontario and Québec (Table 1).

Marine turtles can host a large number of diverse organisms from this group. On nesting Loggerhead Seaturtles, *Caretta caretta*, 90 different species of epibionts were identified, and included mostly algae and barnacles, plus amphipods, bivalves, bryozoans, crabs, gastropods, hydroids, polychaete worms, sponges, and tunicates (Frick et al. 1998; Frick and Slay 2000). Encrusting barnacles have little effect on their carriers, but burrowing forms may penetrate the shell, inflicting serious wounds (Lauckner 1985). The relationship between the turtles and their epibionts remains poorly understood even though they play a possible role in disease and parasite transmission (Aguirre et al. 1994; Frick et al. 1998). Barnacles and cirripeds have been found on Leatherback Seaturtles, *Dermochelys coriacea*, foraging in Canadian Atlantic waters during the summer (Zullo and Bleakney 1966; D'Amours 1983).

Neoplasia

A neoplasm, or tumour, is a new, often uncontrolled growth of abnormal tissue and may be benign or malignant. Neoplasms have been reported in all reptile groups (Jacobson 1981; Machotka 1984; Done 1996). Genetic or environmental factors may be at the origin of malignant tumours or cancers, or they can be triggered by infectious agents. Fibropapillomatosis in marine turtles is an example in which different etiologic agents are suspected, although a herpesvirus is known to be associated with the disease (Jacobson et al. 1991a; Herbst et al. 1998; Quackenbush et al. 1998; Lackovich et al. 1999). These herpesviruses are suspected to initiate tumours and to operate in conjunction with cofactors such as toxins from algae or chemical contaminants (Landsberg et al. 1999). The prevalence of these tumours in different marine turtle species has been documented since the 1980s, with sometimes up to 85% of the individuals in a population being affected (Herbst 1994; Williams et al. 1994; Aguirre et al. 1999). Neoplasms are regularly reported in captive reptiles but their prevalence in the wild is poorly documented. Neoplasia has not been reported in Canadian reptile populations.

Deformities and Mutations

Deformities have attracted the attention of humans for centuries (Ouellet 2000). Two-headed (dicephalic) reptiles and partially fused (dichotomic) twins have been extensively reported in the past. In 1761, a dicephalic Milksnake, *Lampropeltis triangulum*, was found near Lake Champlain in the so-called Double-headed Snake Bay (Bancroft 1769; Smith and Chiszar 1988). Three dicephalic *C. constrictor* from New York were examined in 1823 by Mitchill (1826), and another one, from Massachusetts, was reported in 1862 (Dexter 1976). The oldest Canadian record of dicephalism is a *T. sirtalis* collected in Ontario in 1866 (Johnson 1901; Whiteaves 1902). Various degrees of dichotomy may affect the anterior and posterior part of the body (with fusion of the axial body), and internal organs may be duplicated (Smith and Pérez-Higareda 1987; Frye 1991b). Dichotomic adults are rare in the wild since malformed individuals are often stillborn or die shortly after birth (Klauber 1972; Smith and Pérez-Higareda 1987; Wallach 1995). The prevalence of such abnormalities and of other types is not well documented in newborns and hatchlings in the wild (Fig. 1). Kyphosis, an abnormal backward curvature of the spine, and other spinal deformities have been regularly reported in turtles (Smith 1947; Ernst 1971a; Plymale et al. 1978; Rhodin et al. 1984; Burke 1994). In Pennsylvania, Ernst (1971a) observed 5 (0.5%) turtles with kyphosis after examining 929 *C. picta*. MacCulloch (1981b) discovered 2 (1.5%) scoliotic *C. picta* of 128 individuals captured in Saskatchewan (Table 1). These abnormalities are rare in nature, and are likely insignificant to turtles since some were adults when captured.

Other reported abnormalities relate to aberrant scutellation. These include additional, divided, missing, or unaligned scutes. In turtles, these types of shell abnormalities have been regularly observed. Zangerl and Johnson (1957) examined 2220 individuals from a museum collection; 951 (42.8%) exhibited one or more aberrant variations in the shell pattern. In Pennsylvania, 125 (13.4%) *C. picta* from a study site exhibited shell abnormalities (Ernst 1971a). In Canada, scute abnormalities have also been reported in *C. picta* (Table 1). Twenty turtles out of 51 (39.2%) examined in Ontario had shell abnormalities (Whillans and Crossman 1977), while 22% of a Saskatchewan population also exhibited shell abnormalities (MacCulloch 1981b). Scale abnormalities such as partial or total absence of scales are also reported in snakes (Stickel 1942; Klauber 1972; Murphy et al. 1987; Bechtel and Bechtel 1991; Frye 1991b). These scale abnormalities are not detrimental to the individual and are seen as natural morphological variations in the species.

Colour mutations and variations, including albinism, melanism, and aberrant patterns, are also regularly reported in reptiles. Albinism in North American reptiles was reviewed by Hensley (1959) and Dyrkacz (1981). Klauber (1972) reviewed colour variations in rattlesnakes. The mode of inheritance of colour pattern and the maintenance of variability in populations were addressed particularly in snakes (Blanchard and Blanchard 1940; Camin and Ehrlich 1958; Bechtel and Bechtel 1981; King 1987, 1993a; King and Lawson 1995; Lawson and King 1996; Zweifel 1998). Various cases of albinism and melanism have been reported in Canadian snakes and turtles (Table 1). Some aberrant scale pigment patterns may have a negative impact on survival of *N. sipedon* by making individuals more conspicuous to predators (Bleakney 1958; King 1992, 1993b). Albinistic individuals may also be more prone to predation because of heightened visibility. On the other hand, melanism was suspected to reduce conspicuousness of adult male Pond Sliders, *Trachemys scripta*, during terrestrial movements (Lovich et al. 1990). Melanism has also been suggested to play a role as a thermoregulatory adaptation (Schaefer 1969; Gibson and Falls 1979; Schueler 1983; Lovich et al. 1990; Bittner et al. 2002).

Morphological anomalies of reptiles may have environmental or genetic causes (Lynn and Ullrich 1950; Bellairs 1981; Murphy et al. 1987). Temperature and humidity during incubation are important factors in reptiles with external egg development. Abnormal incubation conditions may induce abnormalities in embryos and hatchlings (Bellairs 1981; Frye 1991b). Chemical contaminants cause developmental abnormalities, and their potential effects have been addressed in a few reptile species, principally *A. mississippiensis*, *C. serpentina*, *Nerodia* spp., and marine turtles (Meyers-Schöne and Walton 1994; Campbell and Campbell 2000, 2001; Guillette 2000; Guillette et al. 2000; Sparling et al. 2000). In Canada, studies have concentrated on *C. serpentina* eggs and adults around the Great Lakes and along the St. Lawrence River (Bishop and Gendron 1998). In some polluted areas, eggs may be affected by chemical contaminants, resulting in unhatched eggs, abnormal development, and deformities in hatchlings (Bishop et al. 1998). A positive relationship has been established between environmental contaminants and feminization of male external morphology in *C. serpentina* (de Solla et al. 1998). The precloacal length, defined as the distance between the posterior margin of the plastron and the cloaca, which is normally larger, was smaller in males at contaminated sites and overlapped female precloacal length. Determining sex of adults using this criterion was therefore erroneous in these turtles.

Traumatic Injuries and Mortalities

Figure 1. *Congenital defect in a newborn Eastern Gartersnake,* Thamnophis s. sirtalis. *This kyphoscoliotic individual died within a few hours of birth. Specimen from L'Île-Perrot (45°23′ N, 73°57′ W), Île Perrot, Québec, July 1995. Photo by Martin Ouellet.*

Traumatic injuries are often caused by failed predation attempts. Limb and tail amputations are quite common in wild reptiles (Fig. 2). Tail autotomy is a natural defence mechanism observed in a few snakes and in many lizards (Arnold 1984, 1988; Bellairs and Bryant 1985). Traumatic injuries can also be inflicted through diverse human activities. Hartup (1996) examined 586 reptiles and amphibians brought to a rehabilitation centre in Illinois. Automobile-induced trauma was the most frequent source of injuries (55%), followed by ingestion of fishing gear (19%), and attacks by domestic animals (8%). Brown and Sleeman (2002) obtained similar results in Virginia, with 66% of 515 reptile traumas caused by motor vehicles. Wildlife can be affected by roads in many different ways including mortality during construction, trauma by vehicles, and alterations of the physical and chemical environment (Findlay and Houlahan 1997; Trombulak and Frissell 2000). Diurnal reptiles are prone to road accidents as traffic is more intense during daylight hours (Gregory 1977; Dalrymple and Reichenbach 1984; Larsen 1987; Ashley and Robinson 1996). Snakes are especially vulnerable because they often use roads for thermoregulation (Fig. 3). Female turtles searching for nesting sites increase their susceptibility to road mortality (Ashley and Robinson 1996; Haxton 2000). Agricultural machinery and lawnmowers can also inflict serious injuries and death (Mitchell 1988; Dodd 1997; Saumure and Bider 1998; Brown and Sleeman 2002).

Recreational and commercial activities also have impacts on reptiles. Motorboats inflict shell injuries in turtles (Burger and Garber 1995; Galois et al. 2002), and fishing activities result in injuries or drowning from ingestion of gear or entanglement in lines, nets, and traps (Bleakney 1965; Ogren et al. 1977; Lazell 1980; Bishop 1983; Cochran and McConville 1983; Henwood and Stuntz 1987; Goff and Lien 1988; Lutcavage et al. 1997; Renaud et al. 1997; Roosenburg et al. 1997; Brown and Sleeman 2002; James et al. 2005). Turtles caught on fishing lines are sometimes released by cutting the line and leaving the hook (Hartup 1996; Borkowski 1997) which can inflict further injuries to the mouth and digestive tract of the turtle (Fig. 4). Ingestion of the monofilament line causes perforations and necrosis of the digestive tract, and lead poisoning can arise from lead sinkers (Borkowski 1997). Debris and garbage can entrap reptiles, inflicting injuries or death (Groves and Groves 1972; Herrington 1985; Stuart et al. 2001). Pieces of fishing line and human trash are often ingested by marine turtles (Bleakney 1967; Mrosovsky 1981; Fritts 1982; Carr 1987; Starbird and Audel 2000), potentially obstructing the intestinal tract, and inflicting serious injuries.

Reptiles may survive severe injuries such as spinal fractures (Smith and Fitzgerald 1983; Montgomery and Mackessy 1999), limb amputations, and shell mutilations (Burger and Garber 1995; Dodd 1997; Saumure and Bider 1998; Saumure 2001b). However, the growth and survivorship of the individual may be negatively affected (Harding 1985; Congdon et al. 1993; McLeod 1994; Saumure and Bider 1998), even in the case of the tail autotomy adaptation (Ballinger and Tinckle 1979; Vitt and Cooper 1986; Wilson 1992; Niewiarowski et al. 1997). Open wounds provide opportunities for infectious agents or parasites to invade the individual. Tail injuries to young of the year *T. sirtalis* may result in their death during the 1st hibernation because of post-traumatic physiological stress (Willis et al. 1982). Recapture rates of Wood Turtles, *Glyptemys insculpta*, were lower in those individuals with at least 1 amputated limb (Harding 1985). Injuries may also impinge on breeding. Male *T. sirtalis* with shorter tails have lower mating success in mating balls (Shine et al. 1999). Burger and Garber (1995) observed in *G. insculpta* that 3-legged males and males with a large part of the tail missing usually cannot mate.

The effect of traumatic injuries at the population level has not been documented for most reptile species. Burger and Garber (1995) observed a 15% increase in shell injuries and death from motorboats in female Diamond-backed Terrapins, *Malaclemys terrapin*, between the 1970s and 1990s. The ingestion of debris, particularly plastic resembling jellyfish, by large numbers of marine turtles likely has a serious impact at the population level (Mrosovsky 1981). Fritts (1982) found plastic bags and films in the intestinal tract of 19 (13.5%) of 140 *D. coriacea* examined. Shell injuries in *G. insculpta* were twice as common in agricultural areas when compared to forest habitats, mostly due to the presence of cattle and agricultural machinery (Saumure and Bider 1998). Ashley and Robinson (1996) looked specifically at road mortality in Long Point, Ontario, and found an enormous increase in mortality between the early 1980s and the 1990s. In 4 years, they collected 864 dead turtles and snakes along a 3.6-km causeway crossing a major wetland area. Haxton (2000) examined road mortality of *C. serpentina* in central Ontario and collected 86 turtles dead on the road, representing 30.8% of the 279 turtles observed in 3 yr on or near a road. If traumatic injuries are important in the dynamics of reptile populations, it is likely to be in populations most closely associated with urban and agricultural development.

Conclusion and Final Remarks

This review represents a survey of the literature on abnormalities, diseases, and mortalities in reptiles, including 120 published reports for Canadian reptiles (Table 1). Many of these latter accounts were purely

Figure 2. *Wild juvenile female Midland Painted Turtle,* Chrysemys picta marginata, *with a traumatic amputation of the right hindlimb at the proximal level of the tibiofibula. Specimen from Lac des Deux Montagnes (45°25′ N, 74°00′ W), Vaudreuil, Québec, August 2000. Photo by Martin Ouellet.*

Figure 3. *An adult female Eastern Gartersnake,* Thamnophis s. sirtalis, *killed on the road. Specimen from the Long Point Causeway (42°35′ N, 80°27′ W), Lake Erie, Ontario, May 1994. Photo by Martin Ouellet.*

descriptive; they involved 1 lizard, 11 turtle, and 16 snake species. Common species such as *C. serpentina*, *C. picta*, and *T. sirtalis* have received the most attention. A larger number of reports concerned internal parasites in both snakes and turtles (Table 2). The remaining reports dealt mainly with colour mutations in snakes, and traumatic mortality in snakes and turtles. There was almost no information on infectious agents in Canadian reptiles.

Considering the limited information available on the health of wild reptile populations in Canada, we recommend using every opportunity to gain such information (Ouellet et al. 2006). In any studies dealing with wild reptiles, general data on pathology and pathological agents should be more systematically gathered in order to document the distribution and the prevalence of infectious agents and parasites in these animals (Fig. 5). In various die-offs of the past, the opportunity to collect information was missed because of the delay in investigation and the lack of involvement of wildlife health and veterinary specialists (Bleakney 1966; Metcalf and Metcalf 1979). Recently published guidelines may be useful to herpetologists interested in developing protocols to assist in health evaluation of wild reptiles (Divers 1999; Redrobe and MacDonald 1999; Arvy and Fertard 2001; Berry and Christopher 2001; Herbst and Jacobson 2003).

Anthropogenic factors are having an increasing impact on wildlife health. Chemical contaminants are found even in remote areas (Blais et al. 1998). Monitoring for contaminants and the assessment of their impact on reptiles require more research and should be included in any population health assessment (Gibbons et al. 2000; Guillette 2000; Hopkins 2000; Pauli and Money 2000). More research is also needed on disease etiologies and parasite life cycles, and on the role of parasites in reptile population dynamics. *Koch's postulates* should be used to identify the causative agent of any particular infectious disease: 1) the pathogen must be present in all cases of the disease; 2) the pathogen must be isolated from the diseased host and grown in pure culture; 3) the pathogen from the pure culture must cause the disease when inoculated into a healthy susceptible laboratory animal; 4) the pathogen must be isolated from the new host and shown to be the same as the original pathogen.

Figure 4. *Wild adult male Eastern Snapping Turtle,* Chelydra s. serpentina, *with ingested fishing tackle. Left: radiograph; above: the monofilament line and the lures were removed by surgery and the turtle was released a few weeks later after a successful recovery. Specimen from Mont Bélair (46°49′ N, 71°30′ W), Val-Bélair, Québec, June 1994. Photos by Martin Ouellet.*

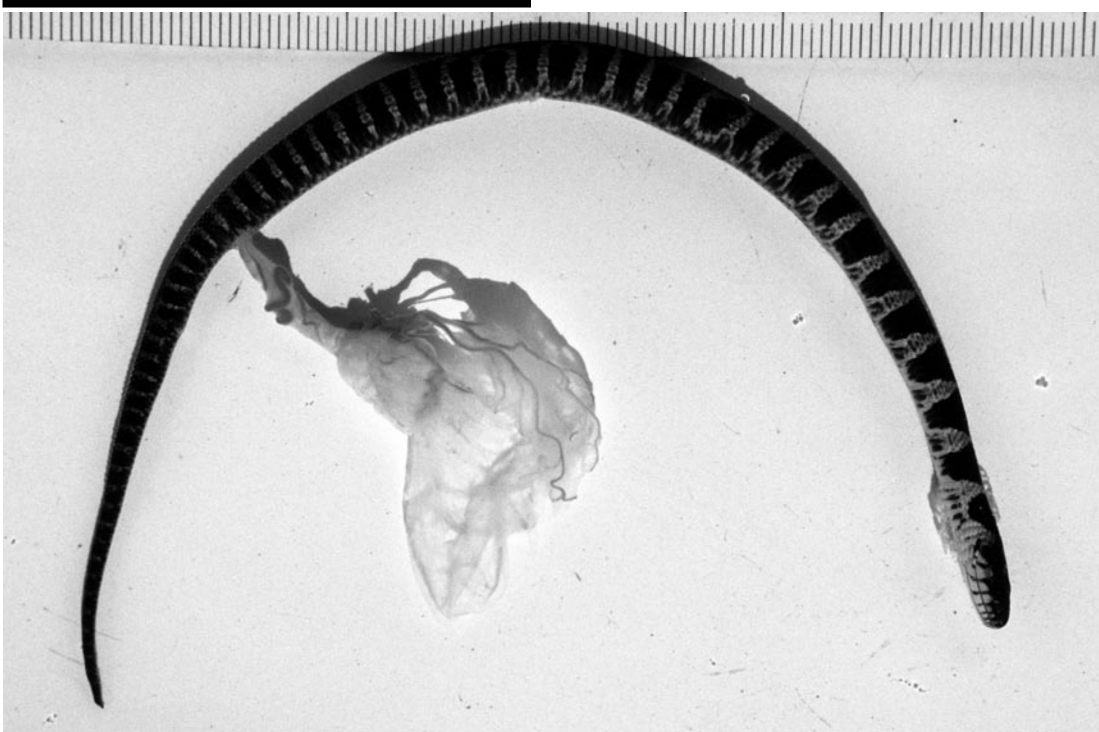

Figure 5. *A stillborn Northern Watersnake,* Nerodia s. sipedon. *Five of 15 offspring were stillborn from unknown causes. Specimen from L'Île-Perrot (45°23′ N, 73°57′ W), Île Perrot, Québec, October 1994. Photo by Martin Ouellet.*

Translocations and reintroductions are conservation tools that have been widely used for vertebrates in the past (Griffith et al. 1993; Fisher and Lindenmayer 2000), but occasionally with only limited or no success in reptiles (Dodd and Seigel 1991; Reinert 1991). Protection of large patches of natural habitat must be a priority to maintain populations in the long term and allow them to recover from disease outbreaks (Hess 1996; Findlay and Houlahan 1997; Rivard et al. 2000). However, the increasing loss and degradation of habitat mean that translocations or reintroductions will continue to be used for conservation efforts. These management practices have not always been used with caution relative to the potential risk of disease transmission (Griffith et al. 1993; Jacobson 1993a; Jacobson et al. 1995). To minimize this risk, all individuals must be checked thoroughly for disease prior to being transferred, and the health of the receiving population has to be assessed and monitored in order to investigate any mortality (Spalding and Forrester 1993; Jacobson 1994; Harvell et al. 1999; Jacobson et al. 1999; Daszak et al. 2000; Berry and Christopher 2001).

Concern should be raised about the introduction of exotic species, even if the climate in Canada may limit the success of many of the introduced reptile species and infectious agents. In future years, climate change and global warming may weaken this natural cold barrier (Harvell et al. 1999; Patz and Lindsay 1999; Daszak et al. 2000). Non-native Red-eared Sliders, *T. scripta elegans*, commonly sold in Canadian pet stores, are often released and are able to survive the winter in southern Canada (Cook 1984; Bider and Matte 1991). The Common Wall Lizard, *Podarcis muralis*, which was introduced to Vancouver Island, is established in the wild and able to reproduce (Allan et al. 2000). A stricter and more systematic veterinary screening for diseases and parasites of pet trade reptiles, which are marketed and shipped inside and outside the country, is required, preferably before their shipping. This screening could target mites and ticks (Wozniak and DeNardo 2000; Burridge 2001), and some protozoans (Wozniak et al. 1996; Graczyk and Cranfield 2000). It should also include a microbiological survey in order to detect known threatening infectious agents of reptiles (Schumacher 1996; Berry and Christopher 2001).

Some emerging diseases like fibropapillomatosis of marine turtles and mycoplasmosis of tortoises are currently receiving much needed attention in the United States because of their increasing prevalence in the wild. This recent effort came in response to severe morbidity and mortality events. Establishing a systematic assessment of the health of reptile populations might help prevent or limit the impact of such diseases. Many Canadian reptile populations are now extremely small and isolated so that

Table 2. *Number of published reports of abnormalities, diseases, and mortalities in Canadian wild reptile populations.*

	Lizards		Snakes		Turtles	
Diagnosis	Reports	Species	Reports	Species	Reports	Species
Infectious agents	-	-	4	4	-	-
Internal parasites	-	-	14	7	16	8
External parasites	2	1	1	1	9	5
Epibionts	-	-	-	-	3	6
Neoplasia	-	-	-	-	-	-
Deformities and mutations	-	-	26	7	9	4
Traumatic injuries and mortalities	-	-	13	9	31	10

recovery from such epidemics is unlikely. We strongly encourage an immediate effort to collect baseline health data of reptiles in Canada to ensure, or at least facilitate, the survival of these populations. Non-invasive techniques, collection of road mortalities, and examination of preserved museum specimens should be favoured in order to limit any impact on the remaining reptile populations.

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