SCIENCE, MANAGEMENT, AND POLICY IN CONSERVATION BIOLOGY: PROTECTING POST-EMERGENT HATCHLING BLANDING'S TURTLES IN NOVA SCOTIA

by

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Table of Contents

List of Tables

List of Figures

Abstract

Hatchling Blanding's turtles were radio-tracked following nest emergence to study their behaviour, movements and habitat use. Hatchlings in the study used different habitats near the nest following emergence, and travelled to nearby wetlands for overwintering. Hatchlings also used moist or saturated microhabitats with ground vegetation cover. High hatchling mortality rates, due to predation, exposure to cold and high water levels, and road mortality, were observed in the study. Risk analysis indicated that hatchlings may also be vulnerable to habitat loss/disturbance and climate change, and minimizing these risks should be an important part of conservation initiatives. Policy analysis revealed that information and economic instruments have been effective in promoting research and stewardship, while regulatory instruments have been used primarily as a safety net. This research explored the conservation of hatchling Blanding's turtles from the science, management, and policy perspectives, and highlighted the importance of all three in achieving conservation goals. Future conservation initiatives should focus on increasing current knowledge of younger age classes of Blanding's turtles, particularly the overwintering survival of hatchlings and the cues they use in selecting habitats, and on encouraging the use of other economic policy instruments and stronger regulatory instruments to help protect Blanding's turtles and their habitats in Nova Scotia.

List of Abbreviations Used

ATV	All Terrain Vehicle
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPAWS	Canadian Parks and Wilderness Society
EPA	Environmental Protection Agency
GIS	Geographic Information Systems
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature and Natural Resources
KNPNHS	Kejimkujik National Park and National Historic Site
ML	McGowan Lake
NAD	North American Datum
NGO	Non-Governmental Organization
NRC	National Research Council
NSNT	Nova Scotia Nature Trust
PR	Pleasant River
PVA	Population Viability Analysis
SCBD	Secretariat of the Convention on Biological Diversity
SLI	Straight-Line Index
UN/DESA	United Nations/Department of Economic and Social Affairs
UNEP/CBD	United Nations Environment Program/Convention on Biological Diversity
UTM	Universal Transverse Mercator
UV	Ultraviolet
VHF	Very High Frequency

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"No man is an island, entire of itself...." – John Donne

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CHAPTER 1. Introduction

It is now widely accepted among scientists and the general public that the world is currently undergoing a biodiversity crisis. There is also little doubt that this sixth mass extinction event can be directly attributed to the increase in dominance and subsequent impact of humans (Leakey and Lewin 1995). Habitat transformations, overexploitation, introduction of invasive alien species, release of nutrient associated pollutants, and climate change, all resulting from human activities, have contributed to the rapid decline of biodiversity worldwide (Millennium Ecosystem Assessment 2005). This global biodiversity loss is a great cause for concern given the significant role of biodiversity in maintaining life on earth. Aside from its intrinsic value, biodiversity provides a wide range of ecosystem goods and services that are essential for life. Biodiversity provides food, fuel, medicine, and raw materials, regulates climate, temperature, surface and ground water flow, and biogeochemical cycles, and supports primary production, carbon dioxide exchange, nutrient cycling, pollination and seed dispersal, and waste decomposition (OECD 1996; Daily 1997; Millennium Ecosystem Assessment 2005). Biodiversity also has a variety of cultural, aesthetic, scientific, educational, spiritual and recreational values that improve our quality of life (OECD 1996; Millennium Ecosystem Assessment 2005). Preservation of biodiversity is therefore crucial not only for its own sake but also to ensure our own survival as a species.

The field of conservation biology has emerged in response to the need to preserve biodiversity. Conservation biology is, in essence, the science and practice of conservation, with the goal of providing principles and tools for preserving biodiversity (Soulé 1985). It is often viewed as a "crisis discipline", with practitioners typically called upon to make decisions or take action before all the facts are known (Soulé 1985). Conservation biology also frequently takes a holistic and multidisciplinary approach, using methods and techniques from a wide variety of fields to address conservation issues (Soulé 1985).

Conservation biology is, therefore, more than just science. Scientific knowledge of biodiversity and conservation are incorporated into management decisions to improve the effectiveness of conservation activities. Reliance of human societies on the goods and services provided by biodiversity also necessitates the consideration of various social, economic, legal, and political issues in any management decision. Conservation activities are also typically set within a broader policy context that determines how conservation should proceed and what tools are available to help achieve conservation goals. The interface between science, management, and policy is therefore important for the success of biodiversity conservation initiatives. This thesis explores science, management, and policy within the context of conservation biology and how they work together to preserve biodiversity. In particular, I examine the conservation biology of Blanding's turtles (*Emydoidea blandingii*) in Nova Scotia, with particular reference to the hatchling life stage.

Blanding's Turtles in Nova Scotia

Blanding's turtles (*Emydoidea blandingii*) are freshwater turtles belonging to the family Emydidae, subfamily Emydinae (Ernst et al. 1994). They occur only in North America, ranging from southwestern Quebec and southern Ontario south and west to central Nebraska (including parts of Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Missouri and South Dakota), with isolated populations occurring further east (in New York, Massachusetts, New Hampshire, Maine and Nova Scotia) (Herman et al. 1995). Blanding's turtles often occupy productive, eutrophic habitats with abundant aquatic vegetation such as lakes, ponds, marshes, creeks, wet prairies and sloughs, and feed on crayfish, insects, fish and eggs, frogs and plant material (Ernst et al. 1994).

The Nova Scotia population of Blanding's turtles is considered to be the most isolated in the entire range of the species (Herman et al. 1995). Within the province, the population is restricted to the Mersey and Medway watersheds (Herman et al. 1995), with three genetically distinguishable sub-populations occurring in Kejimkujik National Park and National Historic Site (KNPNHS), McGowan Lake (ML), and Pleasant River (PR) (Mockford et al. 2005). Because of the small, isolated range and the uneven age structure, with low juvenile and young adult recruitment, the Nova Scotia population of Blanding's turtles has been listed as Endangered by the Committee on the Status of

Endangered Wildlife in Canada (COSEWIC) (Environment Canada 2005) and under the Nova Scotia *Endangered Species Act* (S.N.S. 1998, c.11) (*Species at Risk List Regulations* N.S. Reg. 109/2000).

The primary objectives of the recovery plan for Blanding's turtles in Nova Scotia include the determination of habitat requirements and availability for the population, and the implementation of habitat protection and management (Herman et al. 1999). Previous research on habitats of Blanding's turtles has led to the identification of many of the nesting, overwintering, spring basking and summering sites for adults and juveniles in the Kejimkujik National Park and McGowan Lake sub-populations (Blanding's Turtle Recovery Team 2002). The third sub-population in Pleasant River was discovered more recently, and research at that location has led to the identification of summer and winter sites (Blanding's Turtle Recovery Team 2002).

Despite intensive research, however, the behaviour and habitat use by hatchlings (a young turtle from the time it hatches to the onset of overwintering the following year [Blanding's Turtle Recovery Team 2002]) in all three sub-populations is still poorly understood, particularly during winter. Studies of post-emergent behaviour of hatchling turtles show no significant orientation towards water (Standing et al. 1997; McNeil et al. 2000; Smith 2004), suggesting the possibility of terrestrial overwintering (Standing et al. 1997; McNeil et al. 2000). More recent studies on the physiology of hatchlings have revealed that hatchling Blanding's turtles are freeze tolerant and able to supercool to avoid freezing (Packard et al. 1999; Dinkelacker et al. 2004; Dinkelacker et al. 2005), and can therefore potentially overwinter in some terrestrial habitats. This is supported by evidence from a radio-tracking study of three hatchling turtles in Minnesota, where radio-tagged hatchlings were tracked to overwintering sites in moist, terrestrial habitats (Refsnider 2005).

Studying the behaviour and overwintering habitats of post-emergent hatchling turtles, whether terrestrial or aquatic, is important in defining and protecting the critical habitats of this population of Blanding's turtles. Protection of hatchling turtles is especially important to the conservation and recovery of the Nova Scotia population of Blanding's turtle due to the low recruitment of juveniles and young adults and the uneven age distribution in this population (Blanding's Turtle Recovery Team 2002). Studies of the behaviour and ecology of hatchlings at overwintering sites and *en route* may also provide a greater knowledge of the vulnerabilities and potential threats faced by individual hatchlings at these locations, which can help to protect hatchling turtles more effectively in the future.

Objectives and Research Questions

The objective of this thesis is to study the behaviour, movements and habitat use of hatchling Blanding's turtles, identify their overwintering habitats, characterize the risks facing hatchlings, and discuss the policy options available to protect Blanding's turtles and their habitats. More specifically, I wish to address the following research questions:

1. What behaviours do hatchling turtles exhibit following their emergence from the nest? Are these behaviours related to environmental variables such as weather or habitat type? What types of habitats do hatchlings use? What physical characteristics describe these habitats? How do the hatchlings move through their environment on the way to overwintering sites? In what types of habitats do hatchlings overwinter?
2. What are the potential threats to hatchling survival following their emergence from the nest? How are these threats distributed in time and space? What is the likelihood that hatchlings will be exposed to these threats? What is the consequence of exposure to these threats? How can these threats be mitigated?
3. What are the different ways in which biodiversity can be protected in Nova Scotia? How have these options been implemented to protect Blanding's turtles in Nova Scotia? What specific measures can be used to protect hatchling Blanding's turtles?

A variety of different approaches, involving science, management, and policy, were used to address these research questions. Field research using radio-telemetry, behaviour observations and habitat characterization was conducted to study hatchling behaviour, habitat use, and movement patterns. Data from the field research were used in a formal risk analysis to identify threats to hatchlings and determine how those threats can be mitigated. Finally, a review of current policy for protecting biodiversity in Canada and Nova Scotia was conducted to outline the various options available to protect Blanding's turtles in Nova Scotia.

Field Study

Radio-telemetry

Previous studies on hatchling Blanding's turtles used coloured powder that fluoresces under UV light to track hatchlings newly emerged from the nest (Butler and Graham 1993; Standing et al. 1997; McNeil et al. 2000; Smith 2004). In these studies, hatchling turtles were dusted with powder upon emergence from the nest and were tracked by following powder trails at night using a hand held UV light. While this procedure is relatively inexpensive and allows the tracking of large numbers of individuals, it does not allow for tracking over longer periods of time. Using coloured powder alone for tracking individuals lasts anywhere between 1 – 11 days, with an average length of 3 days (McNeil et al. 2000). One study using diodes and a radar transmitter receiver to find hatchlings whose trails have been lost (Smith 2004) has extended the tracking time to an average length of 4 – 5 days, with a maximum of 23 days.

While radio-telemetry is more expensive and therefore used to track fewer individuals, it is a useful method of tracking individuals for longer periods and over longer distances. However, until recently, radio-transmitters have been too large to safely and effectively use on newly emerged hatchling Blanding's turtles, although they have been used in the past to study headstarted hatchlings after the first winter (Morrison 1996), juveniles and subadults (McMaster and Herman 2000), and adults (Rowe and Moll 1991) of this species. With the development of smaller and lighter radio-transmitters for amphibians and reptiles – some weigh as little as 0.39 g including the battery and antenna, and can last anywhere between 8 – 15 days (Holohil Systems Ltd. 2006) – it is now possible to use transmitters to track hatchling Blanding's turtles during their first year. With hatchling mass ranging from about 6 – 13 g (Ernst et al. 1994), the smallest transmitters come to about 3.1 – 6.6% of the biomass of hatchling turtles. The smaller size and lighter weight of these radio-transmitters may significantly reduce the potential negative impacts of transmitters, in the form of increased energy expenditure and reduced ability to escape from predation, on the individuals being tracked.

Manual radio-tracking, done by "homing-in" on the animal using a hand held antenna and receiver, is less expensive and in some ways more accurate and more appropriate for this species than aerial/satellite tracking or triangulation methods (White and Garrott 1990). Once the individual is found, its location can be recorded using a hand held GPS unit. To sample the locations of radio-tagged individuals, a point sampling technique can be used rather than continuous monitoring (Kenward 2001). Each individual equipped with a radio transmitter is tracked and located at specified intervals, often depending on the number of tagged individuals, the length of time needed to locate each individual, and the distance between tagged animals in the study.

Behavioural Studies

Behavioural observations can also be made once the subject is located through radio-tracking. Studies of animal behaviour are of significant value to the science and practice of conservation biology. However, the emphasis on higher levels of ecological organization in conservation biology has meant that the value of behavioural studies to conservation has been largely overlooked (Clemmons and Buchholz 1997). Behavioural studies are particularly useful in single-species conservation (Beissinger 1997). One useful method for studying the behaviour of radio-tracked animals is through focal animal sampling, where one individual is observed for a specified amount of time (Martin and Bateson 1993). To ensure that recorded observations are representative of behaviour throughout the day, behavioural observations should occur at different times of day, preferably with each part of the day being equally represented in the sample (Martin and Bateson 1993). The behaviours of radio-tagged hatchlings at the instant they are located can then be recorded by instantaneous sampling (Martin and Bateson 1993). With instantaneous sampling, a measure of the frequency of each behaviour can be obtained as a proportion of the total sample points for which behaviour was recorded (Martin and Bateson 1993). Behavioural observations can also be related to various environmental conditions such as time of day, temperature, or habitat type to determine behavioural patterns in response to changes in the environment.

Habitat Characterization

Habitat analyses of each radio-tracking location can be performed to determine the types of environments used by individuals in the study. At each location, various habitat characteristics of interest, such as slope, vegetation cover, or distance to important habitat features, can be measured in the field. It may be possible to identify habitat features that are important for survival, or those that serve as cues for selecting appropriate habitats, by summarizing and analyzing habitat data to determine what habitat characteristics may be common to a majority of the habitats used by the individuals in the study.

Movement Patterns

Movement patterns of individuals in a radio-tracking study can also be studied in a variety of methods. Distances and direction of travel can be measured in the field, or using geographic information systems (GIS) software. Point locations of individuals at each location can be entered into GIS software and converted into a map layer. Distances and directions can then be measured using tools within the GIS software.

Various statistical analyses are available to describe movement patterns. Simple descriptive statistics can determine total distances travelled by each individual or average distances travelled over a given time interval. Circular statistics can also be employed to determine the directionality of individual or group movements, that is, if individuals or groups tended to travel in a particular direction (Zar 1999). There are also various methods that can provide a measure of the degree of tortuosity of individual paths, such as a straight-line index (SLI), which can be obtained by dividing the straight-line distance travelled by the total path length of the individual (McNeil et al. 2000)

Risk Analysis

Overview of the Field

Risk analysis is an emerging field of study that has been applied to a wide variety of activities, ranging from scientific to economic and social fields. One of the earliest applications of risk analysis was in the calculation of life tables for the life insurance industry (Covello and Mumpower 1985). Risk analysis has also since been applied in the areas of finance and investment, credit, and business operations (Hertz and Thomas 1983; Archer 2002; McGee 2005).

In the field of public health and safety, risk analysis has been applied to the study of the rate and methods of disease transmission, the potential causes of certain diseases (Hattis and Kennedy 1986; Ames et al. 1987), the toxicity of drugs and other chemicals (Graham 1995; Rechard 1999), the safety of medical treatments, and the quality of the foods we eat (Rodricks and Taylor 1983). Risk analysis is also used in the management of environmental quality, for example, in water and air quality testing, sewage treatment, waste disposal, and pollution mitigation (Rechard 1999; Byrd and Cothern 2000). The impacts of other environmental problems such as habitat loss, landscape disturbance and other anthropogenic stressors on wildlife (Munns 2006), invasive species (Stohlgren and Schnase 2006), and biodiversity loss (Burgman et al. 1993; Reyers et al. 1998) can also be studied and mitigated through the use of risk analysis. Risk analysis has also become an important tool in assessing the safety of industrial processes and engineered systems as well as the health and safety of workers and the people in surrounding communities (Rechard 1999).

Besides the more scientific and economic applications listed above, the concepts of risk analysis have been used in social science fields such as: psychology, sociology and social work, in the analysis of the risk of certain behaviours or behavioural patterns to society in general; common law, in the concepts of nuisance, negligence, and liability (Covello and Mumpower 1985); and even national security, in the face of continued threats of terrorism (Deisler 2002). The use of risk analysis as a decision making tool is now embedded in the policies of many national governments including the US (Kraft 1982; Graham 1995), Canada (Treasury Board of Canada Secretariat 2001), and the UK

(Strategy Unit 2002), particularly in relation to policy analysis and regulatory instruments.

The Nature of Risk and the Risk Analysis Process

An understanding of the concept of risk is essential when undertaking any risk analysis. However, risk is subjective (Kaplan and Garrick 1981; Fischhoff et al. 1984) and can be defined in a variety of ways depending on the context and the nature of the problem. Most general definitions refer to risk as the chance or probability of an unwanted or unpleasant outcome (Rechard 1999; Byrd and Cothern 2000). This definition emphasizes the two components central to the concept of risk: the exposure or potential consequence, and uncertainty over the outcome (Hertz and Thomas 1983; Dooley 1990; Covello and Merkhofer 1993; Holton 2004). Fundamentally, any risk analysis must answer the questions of what can happen (the identification and characterization of risk), how likely it is (estimating probability of occurrence), and what the consequences are (Kaplan and Garrick 1981).

Risk analysis can be defined as simply as the "estimation and evaluation of risk" (Dooley 1990), and for some applications, a risk assessment, which consists of the identification and characterization of risks and consequences and estimates of its probabilities, is the primary focus of a formal risk analysis. However, a risk analysis is typically conducted for a specific purpose, mainly, to manage risks and aid in decision making. In this way, risk analysis becomes more than just a scientific activity (Cumming 1981), or the study of risks, consequences and probabilities. Instead, it functions as a bridge between science and policy, a "hybrid discipline" (Rechard 1999) where the results of the risk assessment, however uncertain and incomplete, are used to make management and policy decisions (Cumming 1981; Rechard 1999). For this reason, risk management (NRC 1983; Food Safety Risk Analysis Unit 2006) is often integrated within risk analysis frameworks to facilitate the use of risk assessment results in decision making. However, despite the importance of a healthy interaction between risk assessment and risk management, many risk analysis frameworks consider risk assessment and risk management as separate activities, with the results of the risk assessment serving as inputs to the risk management stage (NRC 1983; EPA 1992). This separation, intended to maintain the scientific objectivity of the assessment process and to ensure public confidence in the results (Ruckelshaus 1983; Lackey 1997), is necessary because risk management involves subjective judgements and is heavily dependent on ethics, societal values, and public perception of risk (Lowrance 1980; Slovic et al. 1980; Slovic 1997; Byrd and Cothern 2000; Gregory 2004). In essence, risk management integrates the results of the risk assessment with various economic, political, legal, regulatory, and social considerations (EPA 1998) to evaluate what is "acceptable risk" (Derby and Keeney 1981) and to decide among various options.

Frameworks in Risk Analysis

The underlying frameworks for risk analysis are similar across disciplines. Some of the best defined frameworks were developed for the analysis of health, environmental, and technological risks. The report on Risk Assessment in the Federal Government: Managing the Process (NRC 1983) laid out a risk analysis framework that has since served as the basis for other frameworks used in the fields of health and environmental risk analysis (Omenn 1995). Based on this report, the US Environmental Protection Agency (EPA) has developed a set of guidelines for ecological risk assessment (EPA 1992) that is now widely used within the discipline. This framework considers ecological risk assessments as a three step process: 1) problem formulation, which consists of a preliminary examination of the characteristics of exposure to various threats or stressors and effects as well as the type and quality of available and required data; 2) analysis, which is composed of a) exposure characterization, or the measurement or estimation of the level of exposure to the hazard, and b) ecological effects characterization, or the identification and quantification of the adverse effects; and 3) risk characterization, which estimates the consequences under different exposure scenarios. While the guidelines focus only on the ecological risk assessment and not on risk management, the framework does incorporate risk management both at the beginning of the process, in the planning stage, and at the end when assessment results are communicated and used in decision making process. Other frameworks that are available for the analysis of risk in various disciplines may use different terminology and include additional steps, but all address the three questions posed by Kaplan and Garrick (1981) for any risk analysis: what can happen, how likely it is, and what the consequences are.

Policy Analysis

Goals and Objectives of Policy Analysis

The field of policy analysis was developed as a way of understanding the relationship between governments and citizens by focusing the analysis on what governments do (Howlett and Ramesh 2003). It is therefore usually, although not necessarily, associated with the study of public policy, which is generally considered to be the result of decisions made by governments usually in response to a particular problem or situation, or to achieve a specific goal (Howlett and Ramesh 2003). Policy analysis is typically conducted by government officials and analysts (Howlett and Ramesh 2003) and is focused on the development of knowledge relevant to policy formulation and implementation (Torgerson 1986), and more specifically on determining which of various alternative policies will best achieve a given set of goals (Nagel 1990).

Approaches to Policy Analysis

Because public policy is a complex phenomenon consisting of numerous decisions, shaped by earlier policies, and linked to other decisions, various approaches to policy analysis attempt to reduce this complexity by focusing the analysis on specific aspects of public policy (Howlett and Ramesh 2003), such as the decision processes involved in the design, implementation and evaluation of public policy, specific subjects or topics in which governments are interested, and the tools that governments use to achieve their goals (Hood 1983). Another common approach is to subdivide the policy process into a series of steps referred to as the policy cycle (Howlett and Ramesh 2003), which can be used as a framework for analysis. There are a variety of different models available, although many of these are based on the stages of applied problem solving: 1) problem recognition/agenda setting, 2) proposal of solutions/policy formulation, 3) choice of solutions/decision making, 4) implementation of solutions/policy implementation, and 5) monitoring results/policy evaluation (Howlett and Ramesh 2003;

Hessing et al. 2005). Of these stages, an explicit statement of the problem and the desired objectives is crucial in choosing and implementing policies that adequately address the issue (Dunn 1988).

More recent developments in the field of policy analysis have focused the analysis on policy sectors or specific issues such as health care or the environment. They have also emphasized the significant role played by policy actors in the development and implementation of public policy. These actors, who may be from the state, the international system, or society, may be further categorized as belonging to the policy universe, policy subsystem, policy community, or policy network depending on the degree of their involvement in the policy process (Howlett and Ramesh 2003). The interaction among policy actors and their values and perceptions can determine how a given problem is defined and what options will be implemented to solve it (Bressers and O'Toole 1998; Howlett and Ramesh 2003). Knowledge of the various policy actors and the roles they play at different stages of the policy cycle is therefore important and provides a more complete understanding of the policy process.

Instrument Choice Approach

The availability of policy instruments that address specific problems is also important in determining the choice and implementation of public policy. Policy instruments can be defined as the set of tools or techniques available that governments can use to attempt to influence the economy and society, and implement their policy objectives (Linder and Peters 1989; Howlett 1991; Vedung 1998). The importance of instrument choice in shaping public policy and its success has led to an increased focus in describing and understanding the variety of tools available for achieving policy goals and objectives.

The study of policy instruments provides a useful way of understanding linkages between the policy formulation, decision-making, and the policy implementation stages of the policy cycle (Howlett 1991). The instrument choice approach can also be used as a means of organizing and simplifying the complexity of public policy when performing a policy analysis (Hood 1983), and may be useful in comparative policy analysis, particularly in understanding the differences in "policy styles" among governments

(Howlett 1991). Perhaps more importantly, however, this approach can help evaluate the effectiveness of various policy instruments in achieving specific goals or objectives, and lead to an improvement in existing methods and tools for achieving policy objectives (Hood 1983).

Numerous attempts at classifying policy instruments have yielded a number of different instrument typologies based on two different approaches: the resource approach, which places policy instruments into several categories based on the nature of resources they employ, and the continuum approach, in which instruments are organized along a continuum based on a particular variable or factor in the policy implementation (Howlett 1991). However, despite the variety of classification schemes, policy instruments can be reduced into three fundamental types, based on the degree of control or coercion exerted: regulatory, economic, and information instruments (Vedung 1998). In this typology, regulatory instruments are those that attempt to influence human behaviour through the use of regulations, or formulated rules and directives that citizens are expected to obey (Vedung 1998). Economic instruments, in contrast, use material incentives or disincentives such as taxes, fines, grants, or subsidies to promote or discourage certain activities, leaving individuals free to choose whether to engage in the activity or not without legal consequences (Vedung 1998). Exerting the least amount of coercion, information instruments rely on the transfer of knowledge, communication of arguments, and persuasion, to influence people's behaviour, and can include printed materials, education programs, or other ways of communicating information to the public (Vedung 1998).

Despite attempts to classify policy instruments into distinct types, it is important to realize that policy objectives are rarely achieved through the use of only one type of policy instrument. Governments often employ a combination of instruments that work together and complement each other to achieve a given policy objective. Policy analysis using the instrument choice approach therefore requires an understanding of the different policy instruments used and how they interact to achieve the desired goal.

Organization of the Thesis

This thesis takes a holistic approach to the study of the conservation biology of hatchling Blanding's turtles in Nova Scotia by addressing the scientific, management, and policy aspects of the issue. The scientific perspective is explored in Chapter 2, which includes the detailed description and the results of the radio-tracking study on post-emergent hatchling behaviour, movement, and habitat use. Chapter 3 focuses on applying a risk analysis framework to aid in identifying and managing risks to hatchling Blanding's turtles. Various policy alternatives for protecting Blanding's turtles are then discussed in Chapter 4, which uses the instrument choice approach to policy analysis to determine what options are available for protecting biodiversity in Canada and which ones are currently used to protect Blanding's turtles in Nova Scotia. Finally, a summary of the findings from individual chapters and their overall significance is briefly discussed in the concluding chapter of this thesis.

CHAPTER 2. Studying the Behaviour and Habitat Use of Hatchling Blanding's Turtles in Nova Scotia

Introduction

The significant role of biodiversity in providing, regulating and supporting ecosystem services, its numerous aesthetic, spiritual, scientific, educational, recreational and other cultural values, and our role in its decline all provide a strong case for the importance of preserving biodiversity. Of the many different approaches to conservation, landscape, ecosystem, and multi-species approaches are believed to be more effective than single species approaches in preserving a greater diversity of species given limited time, resources, and scientific knowledge (Franklin 1993). However, single species approaches still play a significant role in conservation, particularly in the management of threatened and endangered species, where time is limited and direct intervention is necessary, or in the case of indicator, umbrella, flagship, or keystone species (Simberloff 1998).

Conservation of Blanding's turtle (*Emydoidea blandingii*) in Nova Scotia represents one example of the single species approach. The Nova Scotia population of Blanding's turtle is the most isolated in the entire range of the species, and is restricted to the southwest part of the province, within the Mersey and Medway watersheds (Herman et al. 1995). The population has been designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007a) due to the limited range, uneven age structure, and low recruitment rate of the population (Blanding's Turtle Recovery Team 2002), and is currently protected under the *Species at Risk Act* (S.C. 2002, c. 29) and the Nova Scotia *Endangered Species Act* (S.N.S. 1998, c. 11). There are currently three known genetically distinguishable sub-populations of Blanding's turtles, centered at Kejimkujik National Park and National Historic Site (KNPNHS), McGowan Lake, and Pleasant River (Mockford et al. 2005). Intensive research on the biology and ecology of Blanding's turtles in Nova Scotia, such as range, demography, age structure, genetic structure, and seasonal patterns of habitat use and movements, has been ongoing since the mid 1980s (Blanding's Turtle Recovery Team 2002). Results of these studies have greatly increased our understanding of the needs of this population, and have been used to design and implement more effective management and conservation activities.

Population viability analyses (PVAs) on Blanding's turtle sub-populations at KNPNHS and McGowan Lake reveal that increasing the survival of younger life stages through nest screening or headstarting greatly reduces the extinction risk for the sub-populations and increases the sensitivity of younger life stages (Blanding's Turtle Recovery Team 2006a). These results highlight the importance of younger age classes to the conservation and recovery of Blanding's turtle populations in Nova Scotia. Despite intensive research, however, not much is known about the younger life stages of Blanding's turtles, particularly the hatchling stage. Small hatchling sizes and cryptic behaviours make it difficult to locate and study hatchling turtles in the wild. It is also likely that hatchling Blanding's turtles experience high mortality rates, thus reducing the likelihood of observing hatchlings in the wild.

Previous research on hatchling Blanding's turtles used fluorescent powder to track hatchlings for several days following their emergence from the nest and study their movement patterns and habitat use (Butler and Graham 1995; Standing et al. 1997; McNeil et al. 2000; Smith 2004). Results from these studies suggest that hatchlings in Nova Scotia do not immediately orient or move towards open water after emerging from the nest (Standing et al. 1997; McNeil et al. 2000; Smith 2004), although hatchlings have been observed to enter vegetated wetlands in Massachusetts (Butler and Graham 1995). These studies also raise the possibility of terrestrial overwintering in hatchling Blanding's turtles, a phenomenon that has been documented in hatchlings of other species in northern regions (see, for example: Costanzo et al. 1995; Parren and Rice 2004). Laboratory studies reveal that hatchling Blanding's turtles, like hatchlings of other species, exhibit a degree of freeze tolerance and are capable of supercooling to resist freezing (Packard et al. 1999; Dinkelacker et al. 2004; Dinkelacker et al. 2005). The occurrence of terrestrial overwintering in hatchling Blanding's turtles was recently confirmed by a radio-tracking study of three hatchling Blanding's turtles in Minnesota, which followed hatchlings to overwintering sites in moist to wet soils within terrestrial habitats (Refsnider 2005). However, survival of hatchlings over the winter in these terrestrial overwintering sites is still unknown, and requires further study.

In this study, hatchling Blanding's turtles from the three sub-populations of Blanding's turtles in Nova Scotia were radio-tracked to determine post-emergence behaviour, habitat use, and movement, and, in particular, to locate hatchling overwintering sites for this population. As a preliminary study, this research aims to contribute knowledge about the hatchling life stage in this population that can be incorporated in management and conservation decisions, and to generate hypotheses that may direct future research. This study is part of an ongoing research project on the behaviour, movements and habitat use of post-emergent hatchling Blanding's turtles in Nova Scotia, and the results described are preliminary only.

Materials and Methods

Study Site

The study took place between September 15 and December 16 2006 in southwest Nova Scotia, at Blanding's turtle nest sites in Kejimkujik National Park and National Historic Site (KNPNHS) and around McGowan Lake (ML) and Pleasant River (PR) (Table 1). Nesting sites sampled in KNPNHS included three beach sites of primarily cobble/rock substrate, bordered by woodlands on one side and a lakeshore wetland on the other. At two of the beach sites, a wet meadow exists inland beyond the woodlands. Two inland nesting sites of primarily gravel substrate, located along roadsides, were also sampled in KNPNHS. At ML, two of the three nesting sites were inland, one on an open gravel pit several meters from a gravel road and another on a rock outcrop adjacent to a wetland. The third nest sampled at ML occurred beside a gravel road on a peninsula, with several small ponds separating the road and McGowan Lake 10-20 m away. In PR, only one nest was sampled late in the season to increase the overall sample size for the study; this occurred at the edge of an abandoned railroad bed, currently used by local residents as a recreational trail. A deep, man-made trench surrounded by alder trees and other vegetation occurs on both sides of the rail bed.

Table 1. Location of nests and number of hatchlings radio-tracked.

Population	Nest Location	Nest ID	Date Laid	Number of Hatchlings
KNPNHS	J-Line Road	KP-2006-04	17-Jun-06	3
	Heber beach	KP-2006-11	22-Jun-06	1
	Eel Weir Road	KP-2006-06	13-Jun-06	4
	Glode Island beach	KP-2006-14	21-Jun-06	3
		KP-2006-27	01-Jul-06	3
	Atkins beach	KP-2006-13	02-Jul-06	2
		KP-2006-16	05-Jul-06	2
ML	Woods Road outcrop	ML-2006-03	14-Jun-06	1
		ML-2006-08	23-Jun-06	2
	Peninsula Road	ML-2006-07	22-Jun-06	3
	Mt. Merritt Road gravel pit	ML-2006-05	18-Jun-06	2
PR	abandoned railroad bed	PR-2006-02	14-Jun-06	3

Nesting and Emergence

Nesting of Blanding's turtles in Nova Scotia typically occurs during June and early in July. As part of an ongoing nest monitoring program, known nesting areas were monitored every night for nesting females. In some cases, adult females equipped with radio-transmitters were tracked to suitable nesting locations and observed. Nest data, consisting of the identification of the nesting female, date, time, nest location, clutch size, air and water temperatures, and weather conditions, were recorded once females began to lay eggs. Completed nests were assigned a number and covered with a wood-framed screen cage to protect against nest predators.

Beginning in early September, protected nests were checked regularly for emerging hatchlings. Newly emerged hatchlings were given a nest-specific notch code (unless radio-tracked; see below) for identification, weighed, and measured for carapace length, carapace width, plastron length, and plastron width, according to the established nest emergence protocol (Blanding's Turtle Recovery Team 2007). The nest number, emergence date, temperature and weather conditions were also recorded at the time of emergence. Hatchlings were then released near the nest whenever possible, or released a few meters away if nests were immediately adjacent to roads.

Radio-tracking

To minimize the transmitter weight relative to hatchling biomass, and therefore reduce the potential negative impacts of transmitters on hatchling mobility and energy expenditure, hatchlings approximately 7.0 g or larger were used for this study and were given individual notch codes rather than nest-specific codes. We used BD-2N radio-transmitters from Holohil Systems Ltd. (Carp, Ontario), with frequencies in the 149.999 – 151.999 MHz range. Two transmitter sizes ~0.42/0.44 g and ~0.55/0.59 g with minimum battery lives of 12 days and 21 days respectively, were used for the study. Radio-transmitters were attached to the rear of the hatchling carapace (Figure 1), with the transmitter antenna trailing, using small pieces of Velcro glued to the hatchling carapace and the transmitter with Home Hardware Home-Bond 5 Minute Epoxy Gel (see Appendix A for a detailed description of the transmitter attachment protocol). This attachment method had no apparent negative effect on hatchling movement and behaviour when tested on hatchling Blanding's turtles at Oaklawn Farm Zoo (Aylesford, Nova Scotia), although conditions at the zoo were controlled, with less complex habitats and no predators. Observations of radio-tracked hatchlings during the study, however, also suggested that transmitters had only a minimal effect on hatchling mobility in the wild. Using this attachment method, we were able to replace transmitters quickly and with minimal handling of hatchlings. In addition, the 5 Minute Epoxy Gel is non-permanent – transmitters on hatchlings that are lost will fall off after a few months – and can be peeled off cleanly at the end of the study, thus further minimizing potential negative effects on hatchlings. Altogether, the transmitter-Velcro-epoxy package weighed approximately 0.6 – 0.8 g depending on the transmitter weight and was a maximum of 11.5% of the hatchling body weight.

Figure 1. Hatchling Blanding's turtle with radio-transmitter attached.

Hatchlings were initially tracked on a daily basis starting on the day after the release, and less frequently once hatchlings had stopped moving long distances. Hatchlings were tracked using a combination of three types of handheld antennas – a 3-element Yagi antenna, an RA-1A VHF directional "paddle" or loop antenna (Telonics Inc., Mesa, Arizona), and a small, low gain, highly directional antenna for pinpointing signals at close range (Green 2007, personal communication) – in conjunction with an HR2600 Osprey VHF receiver (HABIT Research, Victoria, British Columbia). As frequently as possible, radio-transmitters were replaced before battery life expired; this was done by carefully removing the transmitter with the attached piece of Velcro, taking care not to peel off the Velcro attached to the hatchling carapace, and replacing it with a new radio also with a piece of Velcro attached (see Appendix A). Care was taken to ensure that disturbance to hatchlings was minimized by limiting handling times and returning hatchlings to the same form and in the same orientation as when found. Hatchlings in this study were tracked until they died, were lost, or until the onset of winter.

Data Collection

After locating each hatchling, NAD 83 UTM coordinates of the location were recorded using a Garmin GPS 72 (Garmin International Inc., Olathe, Kansas) handheld receiver and a flag was placed on the ground as close as possible to the hatchling. The identification of the hatchling, its radio frequency, UTM coordinates, activity, position, and orientation were recorded on an observation card, along with the date and time, information about environmental conditions such as temperature, precipitation, cloud cover and wind speed and direction, and some details about the microhabitat where the hatchling was found (see Appendix B). More detailed habitat characterization of the site was performed one to several days afterwards, once the hatchling had moved from the area. At this time, characteristics of the microhabitat within a 1 m radius of the hatchling location, including water depth and velocity, shoreline type, terrestrial microrelief, identity of abundant plant species, vegetation structure and the height and percentage of vegetation cover, were measured and recorded on the observation card (see Appendix B). Each microhabitat area was estimated using four one-metre sticks laid around the flag marking the hatchling location, oriented toward the four cardinal directions (Figure 2). For reference purposes, standardized photos of the site were also taken using a Pentax Optio W10 digital camera. Photos of the site facing North, East, South, and West were taken from an approximate height of 1 m. Ground photos were also taken from a height of 1m with the camera pointing straight down, while photos of the canopy were taken from an approximate height of 9 cm with the camera facing up. For both ground and canopy photos, the top of the photo was oriented towards North.

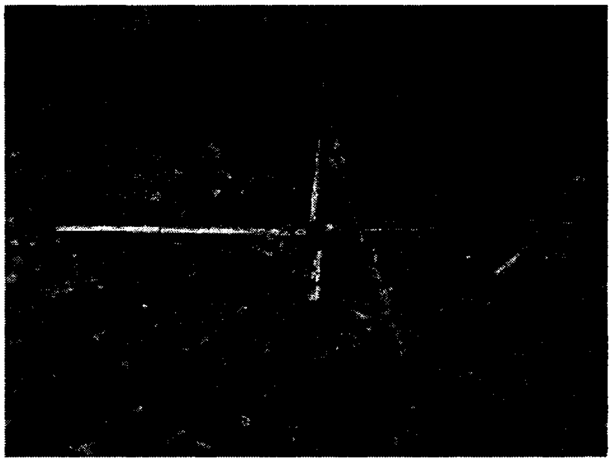

Figure 2. Sample field photo facing North, with the four metre sticks indicating North, East, South, and West.

Analysis

Hatchling Behaviour and Habitat Use

Categorical data on hatchling behaviour and position, substrate type, habitat type and microhabitat type were summarized in frequency tables. The types of data collected and the lack of testable hypotheses for this study limited the types of statistical analyses that could be performed. Therefore, an exploratory approach was taken to examine the results of behavioural observations and generate testable hypotheses for future studies. Contingency table analyses were performed to determine the existence of any correlation between hatchling behaviour and hatchling position, air temperature, precipitation, cloud cover, time of day, substrate, habitat type, or microhabitat type. The likelihood ratio χ^2 test was used at a significance level of $\alpha = 0.05$ to test for statistical significance.

A similar procedure was performed to test for correlations between hatchling position and precipitation, temperature, cloud cover, and time of day, as well as between microhabitat type and the same four variables. All contingency table analyses and likelihood ratio χ^2 tests were performed using SAS 9.1 (SAS Institute Inc., Cary, North Carolina).

Microhabitat Characteristics

Data on microhabitat characteristics were also summarized in frequency tables. These data included surface and below ground moisture content of the perch or substrate, water velocity, shoreline type, terrestrial microrelief, and identity of abundant plant species.

Movement Patterns

The UTM coordinates of Blanding's turtle nests as well as each observation of hatchling location were mapped as point features onto existing digital maps of wetlands, rivers, and lakes of the study area using ArcMap (Environmental Systems Research Institute Inc, Redlands, California). Maps of rivers and lakes were taken from the Nova Scotia Topographic Database, available through Service Nova Scotia's Geographic Information Services website, while the wetlands map was obtained from Frances

MacKinnon at the Department of Natural Resources in Kentville. All map layers used are in 1:10000 scales, and were obtained as ArcGIS vector shapefiles.

Point feature layers of nests and hatchling locations were converted into polyline features using ET Geo Wizards for ArcGIS (ET Spatial Techniques, Faerie Glen, Pretoria, South Africa). The total path length and the straight-line distance from the nest to the final location for each hatchling were then calculated using ArcMap. The distance and direction of hatchling travel from one location to the next were also determined in ArcMap.

As an estimate of tortuosity or crookedness of the path, the straight-line index of individual hatchling movement paths was calculated by dividing the straight-line distance from the nest to the hatchling's final location by the total path length of the hatchling (McNeil et al. 2000). The straight-line indexes at three different general locations – near the nest, while traveling, and at the presumed overwintering site – were also calculated for each hatchling. Straight-line indexes for the three general locations were compared with a Kruskal-Wallis test using the PROC NPAR1WAY procedure in SAS 9.1. The non-parametric Dunn's multiple comparison test (Zar 1999) was performed to determine which pairs of locations were significantly different.

Circular statistics were performed to determine the directionality of hatchling turtle paths. The Rayleigh test (Zar 1999) was used to test whether hatchlings moved uniformly in all directions (uniform distribution) or travelled consistently in one direction (unimodal distribution). The directions (angles, a) of hatchling movements were used to calculate the mean direction (mean angle, $\bar{a}$) and a measure of concentration in the data (r, where $r = 0.0$ when there is a high dispersion and no mean angle, and $r = 1.0$ when all observations are in the same direction). The null hypothesis of circular uniformity was tested by calculating Rayleigh's z, where $z = nr^2$ and n is the number of observations, and comparing it to critical values of z. For this study, the Rayleigh test was performed for each individual hatchling using all of the calculated values of direction. To determine if directionality of hatchling paths differed according to location, separate Rayleigh tests were performed for movement directions near the nest, while travelling, and at the overwintering site. The tests were performed only when $n > 5$.

To determine the relationship between observed hatchling orientation and subsequent travel direction the following day, a non-parametric paired-sample test of angles was conducted. Two sets of data were combined into one sample by calculating the paired differences. The Moore test (Zar 1999) was then performed by using the rectangular coordinates (X_j and Y_j) of each paired difference (j) to calculate $r_j = \sqrt{(X_j^2 + Y_j^2)}$. Values of r_j were assigned ranks (i) from 1 to n, with 1 as the smallest r_j value and n as the largest, which were used to calculate the test statistic, $R' = \sqrt{((X^2 + Y^2)/n)}$, where $X = (\Sigma\, i \cos \bar{a}_i)/n$ and $Y = (\Sigma\, i \sin \bar{a}_i)/n$. The test statistic R' was then compared to critical values to test the null hypothesis that the difference between the hatchling orientation and the direction of travel is equal to zero. While hatchlings may orient in the same direction as their immediate travel path, hatchling orientation at the time of observation may not necessarily be indicative of the net direction of travel over the course of the day, particularly if hatchling paths are tortuous and hatchling behaviour and position continually change throughout the day. A correspondence between hatchling orientation and subsequent travel direction over the following day (*i.e.*, lack of significant difference between hatchling orientation and travel direction) may therefore be indicative of the presence of a specific cue used by individual hatchlings to locate and travel toward their eventual destination.

Results

Hatchling emergence began on Sep 15 and lasted until Oct 22 2006, when nests on lake shores were excavated in anticipation of rising water levels in the late fall season. Sample size was higher for KNPNHS than for ML as more nests were protected in KNPNHS. In addition, due to low emergence success and small hatchlings in 2006, sampling of hatchlings from nests and nest areas was opportunistic, and the first hatchlings that emerged and met the minimum size requirements were used for the study. One nest from PR was sampled late in the season to increase the overall sample size for the study; the original study design did not include sampling hatchlings from the PR sub-population. In total, 29 hatchlings from 12 nests were used for this study (Table 2). Of these, nine hatchlings were lost; in many cases, the radio-transmitters fell off due to

Velcro or epoxy failures, although some hatchlings were also lost due to transmitter failure. Radio-tracking ended on Dec 16; hatchlings were tracked from the day after they emerged from the nests to the end of the study period, or until hatchlings were lost or confirmed dead.

Table 2. Summary of radio-tracking

Nest Location	Nest ID	Hatchling ID	Emergence Date	Fate	Date
J-Line Road	KP04	8,10-10,11	16-Sep	Lost	12-Oct
	KP04	8,10-9,11	16-Sep	Lost	22-Sep
	KP04	8,10-9,10	17-Sep	Road Mortality	29-Sep
Heber Beach	KP11	8,10-8,11	01-Oct	Dead	23-Nov
Eel Weir Road	KP06	8,10-1,4	19-Sep	Lost	20-Sep
	KP06	8,10-1,8	20-Sep	Predated	10-Oct
	KP06	8,10-2,3	23-Sep	Predated	04-Oct
	KP06	8,10-2,4	07-Oct	Predated	09-Oct
Glode Island Beach	KP14	8,10-1,9	20-Sep	Lost	22-Sep
	KP14	8,10-1,10	20-Sep	Lost	21-Sep
	KP14	8,10-1,11	20-Sep	Lost	21-Sep
	KP27	8,10-2,10	22-Oct	Predated	23-Oct
	KP27	8,10-2,11	22-Oct	Predated	23-Oct
	KP27	8,10-3,4	22-Oct	Predated	23-Oct
Atkins Beach	KP13	8,10-2,8	11-Oct	Alive	14-Dec
	KP13	8,10-2,9	13-Oct	Dead	14-Dec
	KP16	8,10-3,8	22-Oct	Predated	14-Dec
	KP16	8,10-3,9	22-Oct	Dead	13-Nov
Woods Road Outcrop	ML03	8,10-0	20-Sep	Lost	25-Sep
	ML08	8,10-8	27-Oct	Alive	15-Dec
	ML08	8,10-1,3	27-Oct	Lost	21-Nov
Peninsula Road	ML07	8,10-1	12-Oct	Alive	16-Dec
	ML07	8,10-2	18-Oct	Predated	24-Oct
	ML07	8,10-4	23-Oct	Predated	13-Nov
Mt. Merritt Road Gravel Pit	ML05	8,10-3	21-Oct	Dead	16-Dec
	ML05	8,10-1,2	21-Oct	Dead	18-Nov
Abandoned Railroad Bed	PR02	8,10-3,12	26-Oct	Lost	30-Oct
	PR02	8,10-3,10	26-Oct	Predated	30-Nov
	PR02	8,10-3,11	26-Oct	Alive	13-Dec

Of the 20 hatchlings that were not lost, only four were still alive by the end of the study period, yielding a mortality rate of 80%. Predation was the primary source of mortality in this study (Figure 3), with eight hatchlings likely predated by small mammals – one by a shrew, another three by a chipmunk, and the remaining four likely predated by either squirrels or chipmunks – and another two by an unknown aquatic predator. Road mortality also resulted in the death of one hatchling from a roadside nest. Another five hatchlings were found dead from unknown causes, although exposure to cold and/or high water levels is suspected as hatchlings were found dead after bouts of cold or freezing temperatures in sites where there was little shelter from the cold (Gravel Pit), or where water levels had risen significantly (Atkins and Heber).

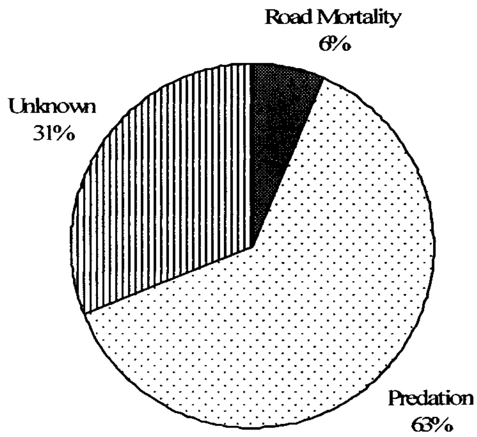

Figure 3. Sources of hatchling mortality observed during the radio-tracking study. Percentages are out of a total of 20 hatchlings radio-tracked and not lost.

Hatchling Behaviour and Habitat Use

Field observations of hatchling behaviour suggested that hatchlings were primarily stationary or inactive particularly on cold days, and basking or active on warm days. On at least four separate occasions, hatchlings were also observed to be very active on warm, rainy days. Hatchlings were often found buried in ground substrate, which consisted mostly of leaf litter, *Sphagnum* sp., and graminoid/forb species. When in water, hatchlings were typically found at the edges of the aquatic habitat, resting on the bottom along the shoreline a few centimetres deep, or clinging to submerged or emergent aquatic vegetation. On a few occasions, hatchlings were observed basking on shore before returning to the water in the late afternoon.

Many of the hatchlings in this study spent several days (1 – 6 days, with a few exceptions) in habitats near the nest before they travelled, usually over a relatively short time (1 – 3 days for most hatchlings), to their overwintering site. The types of overwintering sites used by hatchlings varied, but tended to be permanent or seasonally flooded wetlands, including wet meadows, swamps, treed bogs, ponds, and man-made trenches. In late fall, two hatchlings were also observed for several days in existing burrows within dry woodland habitats. One of the hatchlings eventually left the burrow and moved in the direction of a wet meadow before being predated, while the second hatchling was lost in a complex of holes in an outcrop rock 2 m away from a shrub bog; it is uncertain whether this hatchling used the burrow as overwintering habitat.

Once at the overwintering site, some of the hatchlings in the study buried themselves deep in the substrate, usually *Sphagnum* sp. and leaf litter, or used existing holes in the ground. In seasonally flooded habitats, these hatchlings were often flooded out of their forms in late fall and were seen near the surface of the water. Other hatchlings remained active throughout the fall, basking or moving on warm days and inactive during cooler days. In early winter, radio-tracked hatchlings in aquatic habitat were often seen just beneath the ice cover, and hatchlings in terrestrial habitat were often under snow cover for several days. In this study, hatchlings in aquatic habitat typically survived short periods of ice cover, while hatchling mortality was greater under snow cover in terrestrial habitat.

Hatchlings tracked for ten days or longer spent a majority of time (79 – 100% of observations) stationary (inactive or not moving) (Table 3). Significantly less time was spent active; the behaviour was recorded only 0 – 40% of the time. Basking behaviour comprised only 0 – 10% of individual hatchling observations, although it is possible that these values underestimate the actual amount of time spent basking, since only obvious basking behaviours were recorded. Basking behaviours that take place under indirect sunlight or on cloudy days will likely have been recorded as stationary by the observers.

Hatchlings were observed fully covered in terrestrial habitat approximately 32% of the time, and fully submerged in aquatic habitats in 28% of observations (Table 4). Hatchlings were found in water with heads exposed in 22% of observations, and with carapace exposed in only 3% of observations. The remainder of the time, hatchlings were on land fully exposed in 12% of the observations, and partially covered for 4%.

Table 3. Percentage of observations of different behaviours for twenty hatchlings

Turtle ID	Number of Observations	Behaviour		
		Stationary	Active	Basking
8,10-10,11	26	100.00	0.00	0.00
8,10-9,11	5	60.00	40.00	0.00
8,10-9,10	12	91.67	8.33	0.00
8,10-1,8	19	94.74	5.26	0.00
8,10-2,3	10	80.00	10.00	10.00
8,10-2,4	1	100.00	0.00	0.00
8,10-8,11	47	100.00	0.00	0.00
8,10-2,8	41	97.56	2.44	0.00
8,10-2,9	40	82.50	17.50	0.00
8,10-3,9	15	100.00	0.00	0.00
8,10-3,8	31	83.87	9.68	6.45
8,10-1	62	88.71	6.45	4.84
8,10-2	5	80.00	20.00	0.00
8,10-4	14	78.57	14.29	7.14
8,10-3	53	86.79	7.55	5.66
8,10-1,2	28	89.29	7.14	3.57
8,10-1,3	25	92.00	8.00	0.00
8,10-8	48	100.00	0.00	0.00
8,10-3,10	27	96.30	0.00	3.70
8,10-3,11	35	91.43	2.86	5.71

Table 4. Frequency and percentage of observation of hatchlings in various positions

	Position	Frequency	Percent
On Land	All Exposed	65	11.59
	Partially Covered	125	22.28
	Covered	178	31.73
In Water	Carapace Exposed	21	3.74
	Head Exposed	16	2.85
	Submerged	156	27.81

Forest leaf litter was the most common substrate used by hatchlings (34% of observations), followed, in descending order, by grass/leaf litter (15%), grass (11%), and *Sphagnum* (8%). Hatchlings were also observed 8% of the time in water, and another 7% of the time in *Sphagnum*/leaf litter substrate. Substrates used less frequently included cobble/rock, gravel/pebble, soil/mud, shrubs, logs/sticks, and emergent vegetation (Table 5). When grouped according to general substrate types, ground vegetation, consisting of the categories leaf litter, grass, *Sphagnum*, and beneath organic, was used by hatchlings in 82% of observations. Water was the second most frequent substrate type used, followed by bare ground, which was recorded in 4% of the observations and consisted of cobble/rock, gravel/pebble, outcrop, and soil/mud substrates. Other substrate groups used included woody vegetation (shrubs and logs/sticks), aquatic bottom, emergent vegetation, and other substrates (Table 6).

Table 5. Frequency and percentage of observation of each substrate/perch type used by hatchlings

Substrate/Perch	Frequency	Percent
Forest Litter	192	34.1
Grass/Litter	83	14.74
Grass	61	10.83
Sphagnum	47	8.35
Water	46	8.17
Sphagnum/Litter	40	7.1
Cobble/rock	12	2.13
Log/sticks	11	1.95
Sphagnum/Grass/Litter	11	1.95
Beneath Organic	10	1.78
Shrubs	10	1.78
Beach Litter	9	1.6
Bottom	8	1.42
Gravel/pebble	7	1.24
Other	6	1.07
Emergent Vegetation	4	0.71
Sphagnum/Grass	3	0.53
Soil/mud	2	0.36
Outcrop	1	0.18

Table 6. Frequency and percentage of observation of substrate/perch used, with similar types grouped in the same general category

Grouped Substrate/Perch	Frequency	Percent
Ground Vegetation	456	82.46
Water	46	8.32
Bare Ground	22	3.98
Woody Vegetation	11	1.99
Bottom	8	1.45
Other	6	1.08
Emergent Vegetation	4	0.72

Habitats used by hatchlings appeared to vary widely and depended on the types of habitat available near the nest site (Table 7). However, when grouped into two general categories, wetland and dry terrestrial habitat, hatchlings were significantly more likely to be found in wetland habitats than in drier habitats ($X^2 = 22.68$, d.f. = 1, $p < 0.0001$) (Table 8). Within these habitat types, hatchlings were found more often on dry terrestrial microhabitat than wet/flooded microhabitats or normally aquatic microhabitats such as in ponds, trenches, or lakes ($X^2 = 256.4$, d.f. = 2, $p < 0.0001$) (Table 9).

Table 7. Frequency and percentage of habitat use by hatchlings

Habitat	Frequency	Percent
Swamp	100	17.76
Shrubland	89	15.81
Pond	83	14.74
Trench/Ditch	68	12.08
Wet Meadow	63	11.19
Woodland	57	10.12
Roadside	37	6.57
Beach	30	5.33
Treed Bog	13	2.31
Lake	11	1.95
Forest Edge	9	1.6
Gravel Pit	3	0.53

Table 8. Frequency and percentage of habitats used, grouped into major types

Grouped Habitat Type	Frequency	Percent
Terrestrial	225	39.96
Wetland	338	60.04

Table 9. Frequency and percentage of observations that hatchlings are found in different microhabitats

Microhabitat	Frequency	Percent
Terrestrial	366	65.01
Flooded	113	20.07
Normally Aquatic	84	14.92

Results of the contingency table analyses suggest that hatchling behaviour (stationary, active or basking) varied with temperature, precipitation, and amount of cloud cover (Table 10). A closer examination of the contingency table (Appendix Table C.1) revealed that hatchlings basked less than expected in cold temperatures (< 10°C), and more frequently than expected at warm air temperatures (10 – 20°C). Hatchlings were also observed active more frequently than expected at warm air temperatures.

Hatchlings also appeared to be more active than expected during moderate to heavy rain and during days of no precipitation (Appendix Table C.2). This was confirmed through a partitioning of the contingency table; when the active category was ignored in the analysis, the results were no longer significant (Likelihood ratio X^2 = 8.4390, d.f. = 5, p = 0.1336). In addition, during cloudy days (60 – 100 % cloud cover), basking was observed less frequently than expected, while the reverse was true on days with light cloud cover (0 – 30%) or on partially cloudy days (30 – 60%) (Appendix Table C.3). Hatchlings were also more active during partially cloudy days (Appendix Table C.3).

Table 10. Results of the likelihood ratio tests for independence of variables.

Variable 1	Variable 2	Degrees of Freedom	Likelihood Ratio X^2	Probability
Behaviour	Temperature	6	17.0741	0.009
	Precipitation	10	35.3129	0.0001
	Cloud Cover	6	27.0493	0.0001
	Time	4	4.3201	0.3644
	Grouped Substrate	12	11.1677	0.5146
	Microhabitat	4	0.9324	0.9199
	Habitat Type	2	4.6654	0.097
Position	Activity	10	82.8754	<0.0001
	Temperature	15	61.6088	<0.0001
	Precipitation	25	23.3572	0.5567
	Cloud Cover	15	15.0652	0.4467
	Time	10	15.6947	0.1087
Microhabitat	Temperature	6	31.9899	<0.0001
	Precipitation	10	21.4517	0.0182
	Cloud Cover	6	5.7642	0.4501
	Time	4	17.1004	0.0018

Hatchling behaviour also did not appear to be independent of hatchling position (Table 10). Hatchlings were observed more frequently as fully exposed on land and with the head or carapace exposed in water while active and basking. Hatchlings were also observed partially covered on land more frequently than expected when active. In contrast, hatchlings were seen less often than expected as submerged in water while active and basking; they were also observed less often than expected as partially covered on land while basking (see Appendix Table C.5). Hatchling position also varied significantly with temperature (Table 10). Hatchlings were observed fully exposed on land more often than expected during warm days but less often on cool days, and partially covered less often in freezing weather (< 0°C). In water, hatchlings were submerged less often than would be expected during hot weather (> 20°C) (Appendix Table C.9).

The types of microhabitats where hatchlings were observed varied depending on the temperature (Table 10); hatchlings were seen more often than would be expected in flooded microhabitats in cold and freezing weather, and less often in hot days. Hatchlings were also observed more often in terrestrial microhabitats during hot days, and slightly less often than expected at freezing temperatures (Appendix Table C.13). Precipitation also had an effect on the microhabitat use of hatchlings (Table 10), particularly during periods of light rain. Hatchlings were less likely than expected to be observed in flooded habitats and more likely to be in normally aquatic habitats during light rain. There was also a higher than expected frequency of use of normally aquatic habitats during flurries, and of terrestrial habitats during moderate to heavy rain (Appendix Table C.14). Finally, hatchling microhabitat use varied significantly with the time of day (Table 10). Hatchlings were found more often than expected in normally aquatic habitats during the mornings and afternoons, and less often than expected in the middle of the day (Appendix Table C.16).

Microhabitat Characteristics

While the types of microhabitats used by hatchlings were highly variable depending on the location of the nest site and the types of habitats surrounding the nest, there were some characteristics common to a majority of the microhabitats characterized in the study. Surface moisture of the hatchling substrate or perch, for instance, was primarily moist or saturated/flooded ($X^2 = 43.2473$, d.f. = 3, $p < 0.0001$) (Table 11); similarly, below ground moisture content was also predominantly moist or saturated/flooded ($X^2 = 183.6487$, d.f. = 3, $p < 0.0001$) (Table 12). Aquatic habitats within the 1 m radius were also predominantly lentic, that is, with little or no flow (Table 13). Shorelines were either convoluted or hummocky, and these two shoreline types were observed with equal frequency ($X^2 = 2.1333$, d.f. = 1, $p = 0.1441$) (Table 14). For dry terrestrial habitats, the microrelief was primarily a constant slope, with uneven/irregular and hummocky terrain observed in lesser frequencies ($X^2 = 355.1874$, d.f. = 3, $p < 0.0001$) (Table 15).

Table 11. Frequency and percentage of observations for each category of surface moisture content of substrates

Moisture Content	Frequency	Percent
Dry	105	18.82
Moist	172	30.82
Saturated/Flooded	184	32.97
Wet	97	17.38

Table 12. Frequency and percentage of observations for each category of ground moisture content of substrates

Moisture Content	Frequency	Percent
Dry	30	5.38
Moist	220	39.43
Saturated/Flooded	212	37.99
Wet	96	17.2

Table 13. Frequency and percentage of observations of different flow velocities of flooded or aquatic habitats within 1m radius of the hatchling location

Velocity	Frequency	Percent
No Flow	270	98.9
Slow	3	1.1
Fast	0	0

Table 14. Frequency and percentage of each shoreline type within a 1m radius of the hatchling location

Shoreline	Frequency	Percent
Convoluted	147	54.44
Hummocky	123	45.56

Table 15. Frequency and percentage of each category of microrelief within a 1m radius of the hatchling position

Microrelief	Frequency	Percent
Constant Slope	311	59.46
Flat	26	4.97
Hummocky	85	16.25
Uneven/irregular	101	19.31

Several vegetation types were also commonly observed in the microhabitats used by hatchlings (Table 16). Aquatic portions of the microhabitat were typically open water with very little vegetation present. Submerged vegetation that were present in aquatic habitat included *Sphagnum* sp., leaf litter, and rush (*Juncus* sp.); emergent vegetation included rush, sweet gale (*Myrica gale*), and sedge (*Carex sp.*). Bank overhang was also typically open, with rush, alder (*Alnus* sp.), sedge, and sweet gale occurring less abundantly. At ground level, terrestrial habitats were typically covered with leaf litter or were open (with no vegetation), although *Sphagnum* sp., grass, moss, and sedge were also observed. Finally, the overstory of terrestrial habitats was primarily open, with rush, grass, huckleberry (*Gaylussacia* sp.), sedge and alder also observed in less abundance.

Table 16. Most abundant plant types present in hatchling microhabitats. Only the most frequently observed plants of the top two abundance categories (Rank 1 and Rank 2) are included in the list. Percentages listed below show the percent that each type or species was observed out of the total observations for each vegetation category

	Rank 1[†]			Rank 2[†]		
Category	Species	Frequency	Percent	Species	Frequency	Percent
Aquatic Submerged	Open Water[*]	176	64.23	Leaf Litter	157	57.30
	Sphagnum sp.	62	22.63	*Juncus* sp.	26	9.49
				Sphagnum sp.	22	8.03
Aquatic Emergent	Open Water[*]	215	78.75	*Juncus* sp.	59	21.69
				Myrica gale	37	13.60
				Carex sp.	36	13.24
Bank Overhang	Open[*]	233	97.08	*Juncus* sp.	78	32.77
				Alnus sp.	51	21.43
				Carex sp.	43	18.07
				Myrica gale	37	15.55
Terrestrial Ground Level	Leaf Litter	223	42.88	Leaf Litter	186	36.05
	Open[*]	125	24.04	Moss	53	10.27
	Sphagnum sp.	66	12.69	*Sphagnum* sp.	53	10.27
	Grass	61	11.73	Grass	51	9.88
				Carex sp.	47	9.11
Terrestrial Overstory	Open[*]	426	82.40	*Juncus* sp.	76	14.79
				Grass	67	13.04
				Gaylussacia sp.	55	10.70
				Carex sp.	50	9.73
				Alnus sp.	46	8.95

[†]Ranks indicate the relative abundance of each plant type or species. Plants in Rank 1 are the most abundant in the given category, while plants in Rank 2 are the second most abundant type in the category.
[*]'Open Water' or 'Open' represents no vegetation.

Movement Patterns

Accuracies of UTM coordinates of nest sites and hatchling locations ranged from 2 – 15 m, with typical values between 4 – 8 m. While obvious outliers were excluded from the analysis based on a visual inspection of the maps in ArcGIS, measurements of distances likely overestimate the actual distances travelled by hatchlings, despite straight-line distances between point locations being measured rather than actual path lengths, which are likely to be more tortuous. Resulting measurements of directions based on path lengths are therefore only rough estimates of the actual direction.

Total path lengths and straight-line distances travelled by individual hatchlings varied greatly depending on the total number of days that hatchlings were tracked and the location of the nest relative to the last known location of the hatchling. Total path lengths, from the nest to the last known location, ranged from about 47 m (21 days) to 344 m (62 days), while straight-line distances varied from around 8 m (25 days) to 96 m (26 days) (Table 17). Average daily distances travelled also varied among individuals, and ranged from less than 1 m/day to 14 m/day (Table 17).

Table 17. Total, straight-line, and average daily distances travelled by individual hatchlings. Only hatchlings with five or more observations are presented in the table. The observation period indicates the number of days from emergence to the last time the individual was observed.

Turtle ID	Total Path Length (m)	Straight-Line Distance (m)	Average Daily Distance (m/day)	Observation Period (days)
8,10-1	184.62	8.54	2.84	65
8,10-1,2	119.36	23.02	4.26	28
8,10-1,3	117.41	7.62	4.70	25
8,10-1,8	161.16	54.12	8.06	20
8,10-10,11	197.86	96.05	7.61	26
8,10-2	47.66	11.70	7.94	6
8,10-2,3	140.75	43.57	14.07	10
8,10-2,8	161.31	53.15	2.52	64
8,10-2,9	342.88	35.47	5.53	62
8,10-3	152.65	25.02	2.73	56
8,10-3,10	83.38	13.42	2.32	36
8,10-3,11	113.20	14.14	2.31	49
8,10-3,8	194.25	54.45	3.67	53
8,10-3,9	11.71	9.00	0.62	19
8,10-4	47.24	12.53	2.25	21
8,10-8	106.80	37.12	2.18	49
8,10-8,11	96.49	35.74	1.82	53
8,10-9,10	133.27	57.49	11.11	12

Total path lengths do not necessarily correspond with straight-line distances. The ratio of straight-line distance to the total path length provides a measure of the tortuosity of the path, with low values indicative of high path tortuosity. Hatchlings in this study exhibited high path tortuosity, with SLI values ranging from 0.05 to 0.49, with one individual having an unusually high value of 0.77 (Table 18). Low and variable GPS accuracies, however, may have contributed to the low SLI values observed in this study.

Table 18. Straight-line index (SLI) values for individual hatchling paths, calculated using the total path and the path lengths at each location. SLI was calculated only when there are two or more path segments available.

	Location†			
Turtle ID	Nest	Travel	Overwintering Site	Total Path
8,10-1			0.0261	0.0463
8,10-1,2	0.1544		0.1256	0.1929
8,10-1,3	0.6551		0.0991	0.0649
8,10-1,8		0.5726	0.0856	0.3358
8,10-10-11	0.2653	0.7386	0.2671	0.4854
8,10-2			0.1236	0.2456
8,10-2,3	0.0345	0.8453	0.7720	0.3095
8,10-2,8	0.6972	0.6592	0.1492	0.3295
8,10-2,9		0.5259	0.1943	0.1034
8,10-3		0.9802	0.0431	0.1639
8,10-3,10			0.0676	0.1609
8,10-3,11			0.0951	0.1249
8,10-3,8	0.0794	0.7946		0.2803
8,10-3,9	0.7688			0.7688
8,10-4			0.2430	0.2652
8,10-8	0.3925		0.1171	0.3476
8,10-8,11	0.2394	0.9585	0.0845	0.3704
8,10-9,10	0.2201			0.4314

†'Locations' indicate concentrations of hatchling activity. 'Nest' include path segments near the nest site, 'Travel' include hatchlings paths while travelling to overwintering sites, and 'Overwintering Site' include path segments at the presumed overwintering site. Hatchling paths before 'travel' are considered as 'nest' while those occurring after are classified under 'overwintering site'.

Many of the hatchlings in this study remained near the nest area for several days before spending 1 – 7 days in relatively long-distance travel, often ending up in habitats that differed from those at the nest site, usually wetlands or woodlands, where they spent the remainder of the time. Calculating separate SLI values for each of the three different areas – near the nest, while travelling, and at the overwintering site – revealed that hatchling paths tended to be consistently less tortuous (higher SLI values) while travelling than while around the nest or at the overwintering site (Table 18). Results of the Kruskal-Wallis test confirmed that SLI values differed significantly between the three locations (Kruskal-Wallis $X^2 = 15.7710$, d.f. = 2, $p = 0.0004$). Dunn's multiple comparison test revealed that SLI values during hatchling travel were significantly higher than values while at the overwintering site ($Q = 3.9705$, $k = 3$, $p < 0.05$). SLI values during travel were also higher than at the nest site, although this was not significant ($Q = 2.3274$, $k = 3$, $0.05 < p < 0.10$). Nest and overwintering site SLI values did not differ significantly ($Q = 1.5537$, $k = 3$, $0.2 < p < 0.5$).

The relatively high path tortuosity exhibited by individual hatchlings in this study was also reflected in the analysis of directionality of hatchling paths. Results of the Rayleigh tests for circular uniformity indicated that only one of the hatchlings (8,10-2,9) exhibited significant unimodality in movement direction (Table 19); the null hypothesis of no mean direction could not be rejected for any of the other hatchlings. While the results of the test do not rule out the possibility of bi-modality in movement direction, a brief examination of the circular scatter diagrams of direction for each individual did not reveal any observable bi-modality in direction (Appendix D). Analysis of movement directionality at each location did not reveal any significant unimodality, again with the exception of one hatchling (8,10-2,9) while at the overwintering site (Table 20).

Table 19. Results of the Rayleigh test for total hatchling paths, where n is the number of observations, r is the measure of concentration in the data, and Rayleigh's z is the test statistic compared to a table of critical values. The test was performed only for hatchlings with greater than five observations.

Turtle ID	n	R	Rayleigh's z	Probability
8,10-1	38	0.0995	0.3762	$p > 0.5$
8,10-1,2	13	0.1635	0.3477	$p > 0.5$
8,10-1,3	17	0.1609	0.4403	$p > 0.5$
8,10-1,8	10	0.2448	0.5995	$p > 0.5$
8,10-10,11	16	0.3147	1.5849	$0.2 < p < 0.5$
8,10-2	6	0.1149	0.0792	$p > 0.5$
8,10-2,3	9	0.4896	2.1575	$0.1 < p < 0.2$
8,10-2,8	12	0.1382	0.2293	$p > 0.5$
8,10-2,9	32	0.3775	4.5613	$0.005 < p < 0.01$
8,10-3	23	0.1894	0.8250	$0.2 < p < 0.5$
8,10-3,10	14	0.1595	0.3561	$p > 0.5$
8,10-3,11	14	0.1443	0.2913	$p > 0.5$
8,10-3,8	16	0.1361	0.2966	$p > 0.5$
8,10-4	12	0.2409	0.6964	$p > 0.5$
8,10-8	15	0.1935	0.5616	$p > 0.5$
8,10-8,11	15	0.1756	0.4628	$p > 0.5$
8,10-9,10	11	0.1948	0.4173	$p > 0.5$

Table 20. Results of the Rayleigh test by individual hatchling location, where n is the number of observations, r is the measure of concentration in the data, and Rayleigh's z is the test statistic compared to a table of critical values. Location categories represent areas of hatchling activity. The test was performed only for location categories containing more than five observations.

Turtle ID	Location	N	r	Rayleigh's z	Probability
8,10-1	overwintering site	37	0.0785	0.2281	$p > 0.5$
8,10-1,2	overwintering site	9	0.2091	0.3935	$p > 0.5$
8,10-1,3	overwintering site	11	0.2713	0.8095	$0.2 < p < 0.5$
8,10-10,11	travel	7	0.4903	1.6827	$0.1 < p < 0.2$
8,10-2,8	overwintering site	7	0.2928	0.6000	$p > 0.5$
8,10-2,9	travel	13	0.3419	1.5195	$0.2 < p < 0.5$
8,10-2,9	overwintering site	19	0.4025	3.0787	$0.02 < p < 0.05$
8,10-3	overwintering site	20	0.1904	0.7254	$0.2 < p < 0.5$
8,10-3,10	overwintering site	13	0.1320	0.2266	$p > 0.5$
8,10-3,11	overwintering site	13	0.0797	0.0827	$p > 0.5$
8,10-3,8	nest	14	0.0959	0.1288	$p > 0.5$
8,10-4	overwintering site	11	0.2142	0.5049	$p > 0.5$
8,10-8	nest	6	0.1388	0.1157	$p > 0.5$
8,10-8	overwintering site	8	0.3540	1.0028	$0.2 < p < 0.5$
8,10-8,11	overwintering site	9	0.2828	0.7199	$0.2 < p < 0.5$
8,10-9,10	nest	10	0.2033	0.4133	$p > 0.5$

Table 21. Results of the Moore test for paired difference between orientation and direction. N represents the number of observations, while R' is the test statistic that is compared to a table of critical values.

Turtle ID	N	R'	Probability
8,10-10,11	14	0.7243	> 0.1
8,10-9,10	10	3.1458	< 0.001
8,10-1,8	4	2.0838	< 0.001
8,10-2,3	7	6.6656	< 0.001
8,10-8,11	8	0.6373	> 0.1
8,10-2,8	9	1.9455	< 0.001
8,10-2,9	20	16.3121	< 0.001
8,10-3,8	11	4.9246	< 0.001
8,10-1	19	11.2683	< 0.001
8,10-2	2	1.8345	< 0.001
8,10-3	22	10.0570	< 0.001
8,10-1,2	12	2.2141	< 0.001
8,10-4	7	4.5276	< 0.001
8,10-1,3	5	3.1605	< 0.001
8,10-8	8	0.8980	> 0.1
8,10-3,10	5	1.5656	< 0.001
8,10-3,11	11	4.8572	< 0.001

The observed orientation of hatchlings and their subsequent movement directions differed significantly for most hatchlings (Table 21). Only three hatchlings in the study (8, 10-10,11, 8,10-8,11, and 8,10-8) displayed a correspondence between orientation and movement direction (Table 21).

Discussion

The nature of conservation biology often necessitates taking action before all the information becomes available. However, an understanding of the species and ecosystem remains important in ensuring that conservation measures are effective and achieve the desired goal, and that they do not have negative impacts on the species. Scientific research therefore continues to be a significant part of biodiversity conservation, and research findings should be incorporated into conservation and management activities when they become available.

This study provided additional evidence to support findings from previous research on hatchling Blanding's turtles (Butler and Graham 1995; Standing et al. 1997; McNeil et al. 2000; Smith 2004; Refsnider 2005). It also revealed new information about hatchling behaviour, habitat use, and movement patterns that can be incorporated in conservation and management decisions.

Mortality

It is generally assumed that hatchling and juvenile mortality in many species of turtles is high, based primarily on low recapture rates of these age classes and the low recruitment of young adults. In this study, hatchling mortality was high, in contrast to a previous study of hatchlings in this population which reported low hatchling mortality rates (Smith 2004). The discrepancy in observed mortality rates between the two studies may be due to differences in 1) total sample size, 2) tracking methodology, or 3) length of the study period. The smaller sample size in this study may have resulted in a biased estimate of hatchling mortality, particularly if sources of mortality such as predation are site specific; if predation only occurs on a few of the sites and therefore affects only a few of the hatchlings, then increasing the sample size by sampling from a wide variety of nests and nest locations may not necessarily yield a higher frequency of mortality. It is also likely that hatchlings in Smith's (2004) powder tracking study whose trails were lost were predated, but lack of conclusive evidence for predation precludes their inclusion in the estimate of mortality rate, thus resulting in an underestimate of true hatchling mortality. In addition, the use of radio-transmitters in this study may have adversely affected hatchling survival, leading to higher mortality rates, although hatchling mobility did not appear compromised by the attachment of the radio-transmitter. Finally, because of the longer study period, mortality occurring later in the season is more likely to be observed in a radio-tracking study, resulting in higher estimates of hatchling mortality.

Studies of other species of freshwater turtles suggest that predation and desiccation may be the primary causes of mortality during the migration from nest to overwintering sites, with evolutionary consequences for the morphology and behaviour of hatchling turtles (Britson and Gutzke 1993; Janzen 1993; Tucker 2000; Kolbe and Janzen 2001, Kolbe and Janzen 2002). It is also reasonable to assume that freezing is a likely source of mortality during winter, particularly for hatchlings that overwinter in terrestrial habitats. Predation was the primary source of mortality in this study, and it tended to be site-specific, with 2 or 3 locations experiencing higher predation rates than others. Site-specific predation was also observed in a previous study of this population, with half of the predation recorded at one nest site (Smith 2004).

Road mortality was also site-specific, as would be expected, and occurred only at the J-Line Road location (Smith 2004; this study). While the absolute frequency of road mortality was low in both this study and the one by Smith (2004), it was, in fact, relatively high given the number of hatchlings sampled and the total number of hatchlings that emerged from nests at that location. In this study, only three hatchlings from the J-Line Road were radio-tracked, from a total of 11 hatchlings that emerged from the nest. Hatchlings not radio-tracked were released in a nearby wetland rather than by the nest to prevent road mortality; it is likely that road mortality would have been higher if these hatchlings were released beside the nest, immediately adjacent to the road.

A third apparent source of mortality observed in this study was exposure to cold and high water levels. Although conclusive evidence is lacking, hatchling deaths attributed to this source of mortality coincided with periods of low temperatures and flooding. Two hatchlings from Mt. Merritt Road gravel pit were found dead after periods of freezing or near freezing temperatures; hatchlings did not appear to be otherwise disturbed, rather, they simply stopped moving. In both cases, hatchlings were found in fairly open areas, with short, sparse shrubs and grassy vegetation, hard soil/pebble substrate and sparse leaf litter layer, all of which provided little shelter for the hatchlings. A similar situation was observed for one hatchling at Atkins beach. In this case, the hatchling spent several days on the cobble beach at the edge of the lake, beside low lying forbs; its death was not noticed until water levels in the lake began to rise and flooded the hatchling location. In this case, the hatchling had not moved for some time and was likely dead before the water level rose. Two additional hatchlings, one from Heber beach and another from Atkins beach, likely died due to cold temperatures and flooding; both were in wetlands that were initially dry, but later were flooded to depths up to 70 cm. Mortality occurred later in the season, when water temperatures were colder and subject to occasional surface freezing, and after hatchlings had spent a considerable time suspended in the water column.

Hatchling Behaviour and Habitat Use

Post-emergent hatchlings behaved essentially as expected, spending most of their time stationary, fully covered on land or submerged in water, and on leaf litter/grass/ *Sphagnum* substrate. Basking occurred more frequently in moderately warm temperatures (10 – 20°C), light to moderate cloud cover (< 60%), and while fully or with their head/carapace exposed, and less often in cold and freezing weather, cloudy days, and while submerged in water or covered on land. Hatchlings were also more active in moderately warm temperatures, moderate to heavy rain and days with no precipitation, partial cloud cover (30-60%), and less often while submerged in water.

Hatchlings were not observed basking at high temperatures (> 20°C) or clear days (0% cloud cover). They were also observed to be more active at cool or warm temperatures (0 – 20°C) and moderate to heavy rain, and only rarely at high temperatures. These behaviours were also observed in hatchling Blanding's turtles in Massachusetts (Butler and Graham 1995), and likely allow hatchlings to minimize moisture loss on hot, sunny days. Several studies on hatchlings in other turtle species indicate that nest to water migration strategies are highly influenced by the risk of water loss and predation;

hatchlings can increase their chances of survival either by migrating faster to reduce the exposure to predation, or by waiting for optimal conditions that minimize water loss and the risk of desiccation (Kolbe and Janzen 2002). Hatchlings that migrated faster lost more mass due to higher rates of water loss (Tucker 2000; Kolbe and Janzen 2002); hatchlings were also more likely to be recaptured and lost less mass during precipitation events and intermediate air temperatures (Kolbe and Janzen 2002).

Hatchlings were observed more often on dry terrestrial microhabitat at high temperatures, while they were observed more often in flooded or normally aquatic habitats in cold or freezing temperatures. This result is more likely due to the seasonal changes in temperature and water levels than to particular behavioural strategies of hatchling Blanding's turtles. The early fall season is characterized by higher temperatures and less precipitation, and hatchlings are also more likely to be closer to the nest than the overwintering site; dry, terrestrial microhabitats are therefore more likely to be observed during this time. In contrast, temperatures are much lower during the late fall season. Precipitation also increases in the late fall, resulting in high water levels and flooding. These factors, combined with the fact that hatchlings are more likely to be in wetland overwintering sites at this time, increase the frequency of use of flooded and normally aquatic habitats by hatchlings. Increased frequency of terrestrial microhabitat use during moderate to heavy rain could be an indirect effect of increased hatchling activity during this time, as discussed above. Finally, higher frequencies of aquatic microhabitat use during mornings and afternoons, and lower frequencies during midday, likely correspond to hatchlings being active or basking at warmer temperatures, and retreating to the water for protection from cold or freezing temperatures.

Habitat use by hatchling Blanding's turtles varied widely and was dependent on the types of habitat available within a reasonable distance from the nest. The characteristics of nests sites varied according to location, and ranged from cobble beaches surrounded by woodland and lakeshore wetland, to inland nests with surrounding trees and shrubs, and to relatively open roadside nests. The presumed overwintering sites of hatchlings also varied according to location, with hatchlings generally heading towards wetland habitats closest to the nest. These included wet meadows with tall shrubs and *Sphagnum*/leaf litter dominated ground cover, swamp habitats in closed canopy forests, treed bogs, and ponds or trenches beside roads. The variability in habitats used makes it difficult to identify common characteristics and determine what habitat features hatchlings may be using in selecting habitats. It is also possible that hatchlings simply used habitats as available; hatchling habitat use relative to availability should be further investigated to determine which habitats or habitat features may be important for hatchling survival and which ones were used in proportion to their availability. While such a determination was not possible during the course of this study, information on the distance and pattern of hatchling movements from this study may help determine the appropriate scale at which to randomly sample habitats and measure the availability of different habitat types and habitat features in future studies.

Microhabitat Characteristics

Some features were common to a majority of microhabitats used by hatchlings. Among these is soil moisture content, which was predominantly moist or saturated/flooded for both surface and below ground moisture. Selection of moist and saturated/flooded substrates would help minimize moisture loss and protect hatchlings from freezing temperatures in the winter. The observed low frequency of wet habitats in the study is probably a result of a bias in data collection; wet substrates were more likely to be recorded during precipitation events, whereas moist and saturated/flooded substrates were recorded regardless of precipitation level.

Vegetation communities within microhabitats also appeared to consist of a few distinct plant species or types. Microhabitats in the study were primarily open habitats, with leaf litter, rush, *Sphagnum*, grasses and sedge occurring in less abundance. Shrubs such as sweet gale, alder, and huckleberry were also observed in some habitats. As with habitat use, future studies of hatchling microhabitat use relative to availability would be beneficial in determining the importance of specific microhabitat features to hatchling survival.

Movement Patterns

As mentioned previously, hatchlings in this study appeared to use wetlands as overwintering sites. This finding is consistent with previous research on hatchling Blanding's turtles both in this population and elsewhere (Butler and Graham 1995;

Standing et al. 1997; McNeil et al. 2000; Smith 2004; Refsnider 2005). Several hatchlings in the Massachusetts population were tracked to flooded wetlands or vernal pools (Butler and Graham 1995). In contrast, findings from several studies of hatchlings in the Nova Scotia populations (Standing et al. 1997; McNeil et al. 2000; Smith 2004) reveal that hatchlings do not appear to move directly towards water following emergence. However, studies of the Nova Scotia population tested hatchling movements towards open water, which does not necessarily indicate avoidance of vegetated wetland habitats. In this study, hatchlings from beach nests either moved directly away from the lake, or spent a few days near the edge of the lake before heading inland and into wetland habitats. As suggested by McNeil et al. (2000), it is likely that open lake habitats are not ideal hatchling habitats due to high water levels and wave action, and that vegetated wetlands similar to juvenile habitats are preferred. In Minnesota, overwintering habitats used by three radio-tracked hatchling Blanding's turtles consisted of 1) a mesic grassland patch within a woodland habitat, 2) the edge of a permanent wetland, and 3) an existing complex of mammal tunnels (Refsnider 2005). Similar habitats were also used as overwintering sites by hatchlings in the current study.

Laboratory studies have demonstrated that hatchling Blanding's turtles have some degree of freeze tolerance and supercooling ability (Packard et al. 1999; Dinkelacker et al. 2004; Dinkelacker et al. 2005), and could therefore potentially survive overwintering in terrestrial habitats. In this study, hatchlings on beach nests avoided the open lake and headed towards terrestrial habitats, where they burrowed into *Sphagnum* and leaf litter substrates or existing mammal holes in the woodland. However, terrestrial overwintering could not be confirmed as rising water levels led to flooding in these habitats, while the hatchling in the woodland was predated before the end of the study period. In inland nests, hatchlings used either permanently flooded wetlands such as bogs, ponds, or trenches, or moist terrestrial habitats with *Sphagnum* and leaf litter substrates. As moist terrestrial habitats tend to be vernal pools or seasonally flooded wetlands, these habitats were also flooded later in the season, and therefore terrestrial overwintering could not be confirmed. On three occasions, hatchlings were last tracked to relatively dry terrestrial habitats; however, two of the hatchlings died in the open while in an area with only sparse low shrubs and short forbs and grasses for cover, and it is unlikely that this habitat would have been used for overwintering by these hatchlings. The third hatchling was lost in the woodland approximately 2 m away from a wetland, and it is unknown whether the hatchling remained in the woodland over winter or eventually found its way to the wetland. It is likely that both aquatic and terrestrial overwintering strategies are used by hatchlings in this species, depending on the types of habitats that are available near the nest site. Such a mixed strategy can increase the chances of survival for hatchlings, particularly for late-emerging hatchlings that do not have as much time to find suitable overwintering habitats (Refsnider 2005). This becomes particularly important in the Nova Scotia population due to the cool climate and later emergence of hatchlings (Standing et al. 1999). Future studies on the characteristics of overwintering sites during the winter and the overwintering survival of hatchling Blanding's turtles may help determine optimal overwintering conditions that promote hatchling survival.

Migration of hatchlings from the nest to the overwintering site usually took several days, with hatchlings spending some time near the nest before travelling towards overwintering sites. This pattern of movement was also observed in hatchlings in Minnesota (Refsnider 2005). The distance travelled by hatchlings is partially determined by the distance between the nest and the overwintering site, although path tortuosity of hatchlings also has a significant effect on the total length of hatchling paths. Hatchling paths in this study were highly tortuous and randomly directed, as evidenced by the low SLI values and uniform circular distribution of movement direction, particularly near the nest and at the overwintering site. It is possible that inaccuracies in the UTM coordinates contributed to low SLI values and the absence of unimodality; however, other studies also report high path tortuosities (McNeil et al. 2000; Smith 2004) and random orientation of travel (Refsnider 2005) for some hatchling Blanding's turtles. Tortuous paths may indicate searching behaviour, or may simply be a response to various habitat features (McNeil et al. 2000; Smith 2004). In this study, path tortuosity reflected the tendency of some hatchlings to remain near the nest for several days, occasionally changing forms, and to remain active during the winter, moving within a relatively small area. In contrast, hatchling paths during travel from nest to overwintering sites were characterized by high SLI values, indicating a relatively straight path towards overwintering sites.

Relatively straight travel paths from nests to overwintering sites suggest that hatchlings may be responding to cues that alert them to the presence of appropriate overwintering habitats, although at this time, the types of cues hatchlings use to find overwintering sites are still unknown. In contrast, hatchling orientation did not appear to be related to the subsequent direction of travel. It is possible that this lack of correspondence may be due to inaccuracies in UTM coordinates, although it is more likely due to the fact that radio-tracking simply does not capture fine scale movements of hatchling Blanding's turtles. It is also likely that hatchlings shift their positions within forms to either maximize or minimize exposure to the sun and to minimize exposure to cold temperatures.

Implications for Conservation

The high hatchling mortality rates observed in this study have negative consequences for the long term stability of the population, particularly given the uneven age structure in this population. The sources of mortality were primarily natural – predation and exposure to cold and flooding – and therefore difficult to control in the field. It may be possible to mitigate road mortality through intensive monitoring, releasing hatchlings away from roads, or redirection of traffic flow; however, rates of road mortality may be too low to justify such efforts. High mortality rates in the field emphasize the importance of hatchling headstarting in increasing hatchling and juvenile survival and recruitment in this population. Headstarting, or captive rearing, can increase the survival and recruitment of younger age classes by removing hatchlings from the wild and away from the primary sources of mortality, raising them in captivity under optimal conditions, and releasing them back into the wild when they are less vulnerable to various threats. However, research into the effectiveness of headstarting as a conservation tool and appropriate captive rearing techniques, as well as consideration of the ethical issues surrounding invasive management techniques, should be performed before beginning a headstarting program.

Hatchling behaviour and habitat use were, to some extent, typical of other age classes and species, but also include strategies that minimize risks, such as predation and desiccation, that are unique to hatchlings. These strategies frequently involve modification of activity or microhabitat use in response to various environmental conditions. Protection of habitat integrity is therefore important in reducing hatchling mortality, and future studies should attempt to identify the specific microhabitat features that are important for hatchling survival.

The locations of overwintering sites relative to the nest, and the movement patterns of hatchlings in this study indicate the importance of protecting habitats around the nest. Since hatchlings can potentially overwinter in both terrestrial and aquatic habitats, a relatively large area surrounding the location of the nest site may have to be included in designations of critical habitats under the *Species at Risk Act* (S.C. 2002, c. 29), or core habitats under the Nova Scotia *Endangered Species Act* (S.N.S. 1998, c. 11), and actual sizes and locations of habitats to be protected should be based on what is currently known about movement distances of post-emergent hatchlings and the types of habitats they use. Future studies to determine overwintering site characteristics will be useful in predicting potential overwintering sites and in better defining critical or core habitats. Studies focusing on identifying cues used by hatchlings to locate suitable overwintering habitats will also help determine what habitat features hatchling Blanding's turtles respond to, and therefore what habitat features should be protected.

Findings from this study highlight the vulnerability of hatchlings to both natural and anthropogenic sources of mortality. Protection of this age class is vitally important in the conservation of Blanding's turtle in Nova Scotia, particularly considering the high juvenile recruitment typically required to maintain a stable population in long-lived organisms (Congdon et al. 1993). Future studies should therefore focus on increasing current knowledge of the hatchling and juvenile life stages in order to improve the effectiveness of conservation activities.

CHAPTER 3. Identifying Potential Threats to the Survival of Hatchling Blanding's Turtles: A Risk Analysis Approach

Risk Analysis in Conservation Biology

Conservation biology, as a "crisis discipline" (Soulé 1985), deals primarily with the prevention of an adverse outcome – biodiversity loss. Risk analysis, therefore, is not a foreign concept to conservation biology. The most common application of risk analysis in conservation biology is through the analysis of extinction risks and population viability analysis (PVA). In general, PVAs use models and simulations to estimate either the time to extinction, or the probability of extinction or persistence of a species or population over a specified time period (Boyce 1992; Burgman et al. 1993). Traditionally, most PVAs rely on stochasticity, demography and genetic variation to estimate extinction or persistence parameters, while giving less consideration to other ecological factors such as predation and competition, disease, habitat loss and degradation, harvesting, and invasive species (Boyce 1992); however, this is beginning to change as more PVAs incorporate ecological and management factors into the analysis (Reed et al. 2002).

Risk analysis has also been increasingly applied to wildlife research and management, with implications for conservation. Wildlife risk analyses dealing with habitat loss and disturbance have focused on the impacts of landscape change and/or fragmentation on dispersal capabilities and metapopulation structures (Akçakaya 2001), as well as on the effect of specific disturbances on wildlife populations (*e.g.*, Efroymson et al. 2001; Efroymson and Suter 2001). Risk analysis has also been used to address risks related to invasive species, their dispersal, establishment, and the effect on native wildlife populations as well as on human populations (Landis 2003; Andersen et al. 2004; Stohlgren and Schnase 2006).

Many of these risk analyses used the ecological risk assessment framework developed by the US Environmental Protection Agency (EPA) (1992; 1998) as a starting point for developing alternative frameworks that are more suitable for wildlife risk analysis. As the name suggests, this framework focuses on risk assessment, which it divides into three steps: 1) problem formulation, 2) analysis, and 3) risk characterization. While primarily developed and used to assess ecological risks from chemical contaminants, the ecological risk assessment framework itself is, in theory, applicable to a wide range of physical, chemical or biological stressors (EPA 1992). One alternative framework suggests a modular approach for the analysis of multiple activities or stressors, wherein a separate problem formulation, analysis, and risk characterization is performed for each activity or stressor (Suter 1999). In addition to its own suggestions for dealing with multiple stressors, the Wildlife Research Strategy developed by the EPA also proposes a tiered approach, consisting of several assessment levels, from screening to definitive, that optimizes the analysis effort based on the objectives, costs, and the quality and quantity of data required or available (EPA 2005).

With the development and use of alternative frameworks, the use of risk analysis has the potential to extend into other areas of wildlife management and conservation biology. One area where formal risk analysis could have a significant contribution is in the initial identification of risks, both natural and anthropogenic, to wildlife populations. This is especially important for threatened and endangered species or populations, where knowledge of the threats to survival is important for the success of any conservation effort. Information on the risks to species or populations is also necessary for PVA and the estimation of extinction risks. The identification and assessment of various risks to threatened and endangered species has traditionally been performed informally by wildlife and conservation biologists, using field observations and knowledge of the ecology of species and populations and the sources of mortality. With the development of more suitable risk analysis frameworks, there is a greater opportunity for formal risk analysis to play a larger role in conservation biology, particularly in the systematic identification, characterization, and management of risks and their consequences. In this chapter, I examine this potential by applying a modified ecological risk assessment framework to the analysis of risks to endangered Blanding's turtle hatchlings in Nova Scotia.

Application of Risk Analysis to Hatchling Blanding's Turtles

In most ecological risk assessments, a specific event, activity, or stressor is the main focus of the investigation. In these cases, the stressor is known to some extent, and information about the stressor and its characteristics are used to determine the ecological effects and assessment endpoints. In contrast, risk assessments for particular species, populations or life stages are typically value-initiated, that is, the main reason for performing a risk assessment is to achieve or protect specific goals for the species or population (EPA 1998). The relevant assessment endpoints, which in many cases include mortality, reduced reproductive output, or population decline, are usually established based on the goals (EPA 1998) and provide the basis for identifying potential stressors with ecological effects that influence the endpoints. The risk analysis therefore takes a slightly different form, with greater emphasis on the identification of risks and their characterization rather than on the effects and the endpoints. Because the risk analysis does not focus on any one particular activity or set of activities, I have chosen to apply the modular approach only to the analysis stage of the risk assessment framework, rather than using a complete modular approach to the risk analysis as suggested by Suter (1999). For this risk analysis, therefore, there is a single problem formulation stage, followed by a modular analysis stage where each identified stressor is assessed individually. The analyses are then integrated into a single risk characterization stage followed by a discussion of risk management options.

Problem Formulation

1. *Discussion between the risk assessor and risk manager.*

In the ecological risk assessment framework, the problem formulation stage is primarily a planning step to establish the goals, scope and focus of the assessment through a preliminary exploration of the risks and the ecological effects (EPA 1992). The process begins with a discussion between the risk assessor and the risk manager to ensure that both management and scientific perspectives are considered in the risk assessment and that the assessment will provide scientifically valid data relevant to management and decision making. In this specific example, both scientific and management needs were considered in the development of the recovery strategy for the Blanding's turtles. I therefore referred to the Blanding's turtle recovery plan (Blanding's Turtle Recovery Team 2002) and the management and recovery goals outlined therein to determine the goals and focus of this risk analysis.

Blanding's turtles (*Emydoidea blandingii*) are freshwater turtles found in North America, with a main range centred on the Great Lakes region and isolated and disjunct populations located at the periphery of the range (Blanding's Turtle Recovery Team 2002). The most isolated of these occurs in Nova Scotia, where Blanding's turtles occur in three genetically distinguishable sub-populations in the southwest part of the province (Mockford et al. 2005). Blanding's turtles in Nova Scotia were initially designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) primarily due to their limited range, uneven age structure, and low recruitment rate into the breeding population (Blanding's Turtle Recovery Team 2002); their status was subsequently changed to Endangered in 2005 (COSEWIC 2007a). The Blanding's turtles are also listed as Endangered under the Nova Scotia *Endangered Species Act* (S.N.S. 1998, c.11) (*Species at Risk List Regulations* N.S. Reg. 109/2000). Intensive research on the biology and ecology of this population has been ongoing since the 1980s (Blanding's Turtle Recovery Team 2002), with more recent activities focused on identifying and delineating critical habitats, conducting population viability analyses, and establishing volunteer and stewardship initiatives for the protection and recovery of this population.

One objective in the Blanding's turtle recovery plan is to "remove or reduce threats to Blanding's turtles and their habitats" (Blanding's Turtle Recovery Team 2002). Risk analysis can support this objective through systematic identification and characterization of the threats as well as the formulation of management options. This is especially important with hatchling Blanding's turtles because little known about their behaviour and ecology. Protection of hatchlings from various threats can also contribute to maintaining and restoring population sizes, another objective in the Blanding's turtle recovery plan (Blanding's Turtle Recovery Team 2002).

Data used in the risk analysis consisted primarily of field observations of behaviour, mortality, and habitat use of hatchlings made during a radio-tracking study in Fall 2006, as well as data collected from previous studies of hatchling Blanding's turtles. Due to its exploratory nature and the absence of data on some of the stressors, this risk analysis represents a qualitative screening level analysis only, according to the tiered approach proposed in the Wildlife Research Strategy (EPA 2005). Nevertheless, results of this exercise can be used to develop risk management options, and can serve as a starting point for future quantitative risk analyses.

2. *Stressor characteristics, ecosystem at risk, and ecological effects*

In order to identify risks to hatchling Blanding's turtles, it is important to understand how hatchlings behave and interact with their environment. Previous studies revealed that hatchlings emerge from their nests between early September and mid-October (Standing et al. 1997). After emergence, hatchlings appear to show no directed movement towards open water (Standing et al. 1997; McNeil et al. 2000; Smith 2004), although hatchlings also do not appear to move randomly (Smith 2004). Hatchlings also display cover-seeking behaviour (McNeil et al. 2000) and behave differently when in areas with vegetation cover (Standing et al. 1997; Smith 2004). Forms, or resting places, preferred by hatchlings include dense grass and leaf litter; spaces between rocks, cobble/gravel, *Sphagnum*, dense shrubs and beach litter are also used (Smith 2004; but see also Standing et al. 1997). Sources of hatchling mortality observed in previous studies include predation by ants, small mammals such as shrews, or birds, and road mortality (Standing et al. 1999; Smith 2004).

A radio-tracking study of hatchling Blanding's turtles conducted during Fall 2006 allowed hatchlings to be followed for a longer period than previously possible. Results from this study confirmed some of the earlier findings and revealed some new information about hatchling behaviour and habitat use. Following emergence from nests, which are located along cobble beaches or inland near roadsides or gravel pits, hatchlings typically spent a few days in areas around the nest before they headed towards permanently or seasonally flooded wetland habitats such as bogs, wet meadows, swamps, or ponds and trenches. Hatchlings from beach nests did not spend a significant amount of time in open water; those that moved towards the lake spent several days close to the shore before they moved further inland. Once in wetland habitats, most hatchlings remained within a very small area and often spent several days to weeks in the same form. Preferred terrestrial forms included leaf litter, grass and *Sphagnum*, or a combination of the three, although some hatchlings also spent time in water and were observed resting on the bottom of the shallow area near the shoreline or on submerged vegetation. Hatchlings often remained buried under leaf litter or *Sphagnum* unless basking or moving; in some cases, hatchlings remained buried until flooding occurred later in the fall. Hatchlings that were in ponds or trenches remained active throughout the season; they frequently moved up to the shore on warm days to bask and remained in the water on cooler days. By the onset of winter, most of the remaining hatchlings were in habitats flooded with water at least 3 – 5 cm deep, and under ice or snow cover for a portion of the time. During this study, high rates of predation by small mammals such as squirrels and chipmunks were observed, although most instances of predation were localized to certain habitats. Road mortality and exposure to cold temperatures and high water levels were the other main sources of hatchling mortality.

From the data on sources of hatchling mortality and current knowledge of hatchling behaviour and habitat use, some of the main threats to hatchlings appear to include: 1) predation, primarily by small mammals, 2) low temperatures and sudden temperature changes, 3) high water levels and flooding, 4) road traffic, 5) habitat loss or disturbance, and 6) climate change. These threats have the potential to affect hatchling survival either by direct mortality, as in the case of predation or road mortality, or indirectly through the effects on hatchling energy allocation, habitat selection, or thermoregulation.

3. Endpoint selection

Following the preliminary characterization of the stressors, ecosystems, and ecological effects, the framework recommends the establishment of assessment and measurement endpoints. The assessment endpoint is defined in the framework as the expression of the environmental value that is to be protected, while the measurement endpoint is the measurable response to a stressor that is related to the assessment endpoint and serves as an indicator for the assessment endpoint (EPA 1992). Based on the goals stated in the recovery plan, population sizes of Blanding's turtles are the environmental value that is to be protected. However, since the scope of this assessment is limited to the hatchling stage, I chose survival of hatchling Blanding's turtles as the assessment endpoint for this study. As a measurable response to stressors that can be directly related to the chosen assessment endpoint, hatchling mortality was chosen as the measurement endpoint for this analysis.

4. Conceptual model

The conceptual model consists of a number of hypotheses describing how the identified threats or stressors may affect the chosen endpoints (EPA 1992). These hypotheses can be developed using observations about hatchling behaviour and habitat use, and current knowledge of the nature of potential risks. For some stressors, the effect on hatchling survival is clear. For instance, predation from small mammals, birds, or fishes can directly result in the mortality of the hatchling. The same can be said for exposure of hatchlings to road traffic. Other stressors, however, can have both direct and indirect effects on hatchling survival. Freezing temperatures can directly result in hatchling mortality, while cold temperatures may cause mortality only indirectly through their effect on thermoregulation and energy budgets. Because hatchlings appear to behave differently and use different habitats on warm days than they do on cold days, temperature fluctuations, and particularly sudden drops in temperature, may have a negative effect on survival if hatchlings are unable to respond quickly to the temperature change, for example, by moving to a different microhabitat. High water levels in the fall also pose a direct threat to hatchlings through drowning, and an indirect threat by changing the type and quantity of available habitat; hatchlings may select a habitat that is suitable earlier in the fall, but later becomes flooded to a depth of 50 – 100 cm, resulting in hatchlings spending energy to relocate. Similarly, habitat loss or degradation due to human activities can negatively impact hatchling survival by reducing the quality or the amount of available habitat. Finally, climate change can have multiple indirect effects on hatchling survival through its influence on temperature, precipitation and habitat type.

Analysis

The analysis stage of the ecological risk assessment involves 2 steps: the characterization of exposure, which measures or estimates the distribution of the stressor in space and time as well as its co-occurrence with the ecological component of concern; and the characterization of ecological effects, which determines and evaluates the ecological effects of the stressor (EPA 1992). Both of these steps are further subdivided into multiple steps to simplify analysis; however, due to the qualitative and exploratory nature of this analysis, and in order to minimize redundancies in the information presented, the components of each analysis step is integrated into a single discussion. In addition, to incorporate a modular component, this analysis is structured according to the type of stressor identified in the problem formulation stage.

Predation

1. Characterization of exposure

Hatchlings are vulnerable to predation due to their small size and soft carapace. Previous studies have observed predation of hatchlings by ants, shrews, and a small bird or other mammals (Standing et al. 1999; Smith 2004), although the locations and patterns of predation were not described. High predation rates were observed in the radio-tracking study, with about 63% of total hatchling mortality attributed to predation. Small mammals, squirrels and chipmunks in particular, were the primary predators, although predation by small aquatic predators, possibly fish, was also observed. Predation by small mammals was concentrated at specific nest areas and usually occurred in woodland habitats. Most instances of predation observed during the study occurred after hatchlings were seen exposed, either active or basking. Predation, therefore, typically occurred shortly after emergence, when hatchlings were moving away from the nest but before they found suitable cover, or on warm days when hatchlings tended to be more active. The actual risk of predation, however, depends on the frequency of occurrence of the predator, which varies depending on the number of predators present in any particular area, as well as the occurrence of conditions favouring predation. Studies that determine the abundance of predators at hatchling habitats and factors contributing to the likelihood of predation occurring would be beneficial to future risk analysis efforts.

2. Characterization of ecological effects

For predation risk, the characterization of ecological effects is relatively straightforward. Only one type of ecological effects data, hatchling mortality, was considered, which is directly related to the assessment and measurement endpoints as discussed in the problem formulation stage. The magnitude of the response to the stressor is always the same, in this case, death of the hatchling, and there is a direct causal relationship between the stressor and response.

Temperature

1. *Characterization of exposure*

Located in the northern temperate zone, Nova Scotia experiences seasonal variations in temperature. Climate data over the past 10 years for Kejimkujik National Park and National Historic Site, in southwest Nova Scotia, indicate that freezing temperatures occur as early as October, with average minimum temperatures ranging from -7.6 to 3.1°C during November and December (Environment Canada 2007b). The province also experiences significant temperature fluctuations during the winter when low-pressure systems move north and briefly replace the cold Arctic air (Davis and Browne 1996; Environment Canada 2007a); in 2006, daily temperature ranges of up to 18°C occurred well into December (Environment Canada 2007b). On a yearly basis, therefore, hatchlings are exposed to cold and freezing temperatures, and wide fluctuations in temperature.

2. *Characterization of ecological effects*

Although the effects data as well as the relationship between the assessment and measurement endpoints are the same in temperature as in predation risk, the characterization of the ecological effects of temperature is not as straightforward as it was for predation. While extreme cold or freezing temperatures can result in hatchling mortality, a set of conditions must likely be in place for this to occur. Laboratory studies on hatchling Blanding's turtles have found that hatchlings have the ability to supercool and are freeze tolerant to a certain extent (Dinkelacker et al. 2004). However, these two abilities are dependent on hatchlings being in suitable microhabitats; hatchlings occupying these habitats are less susceptible to mortality due to low temperatures. Hatchling mortality due to low temperatures, therefore, is more likely to occur when hatchlings are in exposed microhabitats that are not conducive to supercooling or freeze tolerance.

The dependence of hatchlings on suitable habitats for survival during cold or freezing bouts highlights the potential negative effects of extreme temperature changes on hatchling survival. Sudden temperature drops may leave hatchlings, quite literally, out in the cold – that is, with insufficient time to move to suitable microhabitats that provide protection from the cold and promote freeze tolerance and supercooling. It therefore follows that extreme fluctuation in temperature – large decreases in temperature over a short time – increases the probability of hatchling mortality. However, further research into the influence of temperature fluctuations on mortality should be conducted to determine the strength of the cause-and-effect relationship. Estimates of the observed frequency or the probability of occurrence of extreme temperature fluctuations would also be useful in future risk analyses.

Water

1. Characterization of exposure

Average monthly precipitation at Kejimkujik National Park and National Historic Site increases steadily throughout the fall (Environment Canada 2004). This increase is reflected in the hydrometric data by a corresponding increase in mean water discharges in the Mersey and the Medway rivers (Environment Canada 2006b), as well as an increase in the mean water level at Kejimkujik Lake (Environment Canada 2006b). These data correspond to the observed increase of water levels in permanently flooded wetlands, and the flooding of wet meadows and vernal pools that have dried up over the summer. Water level rise in the fall is a normal occurrence, and hatchlings that use wetlands and vernal pools or habitats adjacent to rivers and lakes are exposed to risks that may be posed by rising water levels.

2. Characterization of ecological effects

The effects of high water levels in late fall on hatchling Blanding's turtles can be variable, depending on the timing of exposure relative to hatchling behaviour, the habitat the hatchling is in at the time of exposure, the amount of water level increase, air and water temperature, and the duration of exposure. In 2006, hatchling behaviour following emergence from the nest varied; some hatchlings remained active throughout the season, while others buried themselves beneath *Sphagnum* or leaf litter upon reaching wetlands and became inactive for several days or weeks. This variation may be related to the habitats that hatchlings are in; hatchlings in ponds and trenches remained active and moved regularly between the terrestrial and aquatic habitats, while hatchlings in wet meadows and vernal pools often buried themselves in the substrate. It is likely that active hatchlings may be better able to deal with the change in the water level than inactive ones. In fact, behavioural observations of active hatchlings show no apparent change in behaviour in response to rising water levels. In contrast, hatchlings that were inactive and buried in substrate prior to flooding became active and occasionally moved up to the water surface. This behavioural change may have potential negative effects on hatchling survival through its effect on hatchling energy budgets. In addition, the amount of flooding, the temperature, and the duration of exposure may all have compounding effects on the survival of hatchlings. Field observations suggest that higher water levels, colder temperatures, and longer exposures increase the likelihood of hatchling mortality. Higher water levels may require that hatchlings expend more energy to remain afloat, to resist the current, or to search for terrestrial habitats, while cold temperatures may leave hatchlings with less energy to do so. Longer exposure to these conditions may also intensify the negative effects on hatchling survival. All these factors are likely to contribute to increased likelihood of hatchling mortality from cold or drowning.

Road Traffic

1. Characterization of exposure

In all three sub-populations of Blanding's turtles in Nova Scotia, some adult females regularly nest inland along road sides or other areas accessible by motorized vehicles. Hatchlings that emerge from these nests are therefore at risk of vehicle related mortality. Of the three sub-populations, those in Kejimkujik National Park and National Historic Site (KNPNHS) and Pleasant River (PR) are more vulnerable to road mortality because of their location in areas that experience higher traffic volumes. Situated within a national park, the KNPNHS sub-population is exposed to traffic from visitors to the park, particularly in summer and early fall. The PR sub-population, in contrast, is located within a working landscape that is primarily privately owned. Road traffic within this area is composed of local traffic and ATVs. In the third sub-population at McGowan Lake (ML), inland nesters use areas along less frequented roads, and are therefore less vulnerable to road mortality.

A report on visitor traffic to KNPNHS indicated that about 6 600 parties visited KNPNHS for at least 30 minutes or longer in 2000 (Corporate Research Associates 2002). However, this number represents out of province visitors only, and is therefore an underestimate of the total visitor traffic. In 2002, Jeremy's Bay Campground was occupied for 25 991 site nights (number of sites occupied x number of nights) (Morrison et al. 2004), which indicates the number of overnight visitors to the Park but does not include visitors on day trips. Neither estimate includes multiple re-entries or travel within the park, and therefore both only roughly indicate the volume of traffic in the park. Although most visits occur during July and August, before the hatchlings emerge, the Park also receives many visitors in early fall, when hatchlings are beginning to emerge from roadside nests and are more vulnerable.

Future risk analyses will benefit greatly from a more accurate estimate of traffic within KNPNHS as well as in ML and PR. In particular, traffic estimates should focus on roads or road sections that are known Blanding's turtle nesting areas. A quantitative analysis of the probability of mortality due to road traffic would also be useful; for this, previous studies by Hels and Buchwald (2001) and by Gibbs and Shriver (2002) on road mortality might inform the analysis.

2. *Characterization of ecological effects*

Just as it was for predation risk, the ecological effect of road traffic is clear: hatchling mortality. The co-occurrence of the stressor, road traffic, with the ecological component, hatchling Blanding's turtles, results in mortality of the hatchling. The causal relationship in this case is direct. The magnitude of the effect is constant regardless of the number or size of vehicles; what is uncertain is the probability of co-occurrence of the stressor and the ecological component and, therefore, the extent of the actual risk.

<u>Habitat Loss and Disturbance</u>

1. *Characterization of exposure*

Habitat loss is one of the main causes of biodiversity loss today (Baillie et al. 2004; Millennium Ecosystem Assessment 2005). As the human population continues to grow, greater demand for space and resources increases the pressure to convert wilderness areas into working landscapes. Located within a national park, the KNPNHS sub-population enjoys the greatest protection from this threat, although disturbances caused by visitors as well as park activities such as road or trail development still pose a risk for hatchling Blanding's turtles. At McGowan Lake, Bowater designated a significant portion of Blanding's turtle habitat as a conservation area under its Unique Areas Program (Bowater 2007); this land has recently been acquired by the provincial government and is slated for conservation (MacDonald 2007). However, although this recent development provides greater protection against habitat loss, McGowan Lake contains a hydroelectric dam and therefore remains subject to periodical disturbances. In addition, some nest areas are located on private lands, and hatchlings from these nests are more vulnerable to the effects of habitat loss and disturbance. In Pleasant River, Blanding's turtle habitats are located entirely within private lands, and are therefore most vulnerable to habitat loss and disturbance. Close consultations with landowners about current land use and proposed developments will help determine the magnitude of the risk and ensure that adequate protection for Blanding's turtles continues.

2. Characterization of ecological effects

According to Wildlife Habitat Canada (2007), "Without habitat, there is no wildlife…it's that simple!" And it is certainly true that wildlife cannot exist without the habitat to provide food, shelter, and other resources required for survival. Habitat loss and degradation can result in hatchling mortality; however, the causal relationship is not as simple and direct. For hatchlings, loss or degradation of habitats could reduce the availability of shelter from the cold and from predation as well as the availability of suitable microhabitats to survive the winter; both would make hatchlings more vulnerable to predation or cold temperatures. Habitat loss, therefore, increases the probability of other risks rather than causing direct mortality in hatchlings. In addition, nest site fidelity as well as restricted travel by hatchlings during the first few months after emergence increase the sensitivity of hatchlings to loss of habitat in and around the nest area. In general, the effect of habitat loss on hatchling Blanding's turtles will depend on the size, quality and location of the remaining habitats; the magnitude of effect on hatchling survival likely increases as the size and quality of remaining habitats decrease and the distance from the nest increases.

Climate Change

1. *Characterization of exposure*

Over the years, the topic of climate change has increasingly taken center stage in discussions about energy and the environment, and numerous studies have been conducted to predict patterns of change and determine how the effects of climate change can be mitigated. In the recent report by the Intergovernmental Panel on Climate Change, regional climate projections for eastern North America indicate a warming of surface air temperatures by 2 – 3°C as well as a general increase in precipitation particularly during the winter and spring (Christensen et al. 2007). Diurnal temperature ranges are predicted to increase along with the frequency and magnitude of extreme temperature events, and a widespread increase in extreme precipitation events is also expected to occur (Christensen et al. 2007). Given these predictions, it is highly likely that hatchling Blanding's turtles will be exposed to risks associated with future climate change.

2. *Characterization of ecological effects*

Climate change has an indirect but potentially devastating effect on hatchling Blanding's turtles. Increases in diurnal temperature ranges as a result of climate change increases the risk of hatchling mortality due to high temperature variability, as discussed previously. Likewise, an increase in precipitation has the potential to result in hatchling mortality via its effect on water levels. Changes in temperature and precipitation may also bring about a shift in vegetation patterns and corresponding changes in habitats, potentially resulting in a decrease in the availability of suitable hatchling habitats. In addition, changes in ecological communities are likely to occur in response to the temperature changes or to the vegetation shift; in either case, changes in the ranges and distributions of different species could alter predator-prey relationships and potentially result in increased predation pressure on hatchling Blanding's turtles. While climate change may also have positive effects on Blanding's turtle populations, the combined effects of multiple stressors on hatchling survival could mean that climate change may be the greatest risk facing hatchling Blanding's turtles in the future.

Risk Characterization

Risk characterization, in the ecological risk assessment framework, is an evaluation step intended to integrate the exposure profile and the effects profile to determine the likelihood of the adverse effect occurring as a result of exposure (EPA 1992). Like earlier stages in the risk assessment, the risk characterization stage is further subdivided into multiple steps. The first step in risk characterization is risk estimation, which compares the exposure and the effects profile and identifies uncertainties in the analysis. Results from the risk estimation are then summarized in the risk description along with a discussion of the significance of the results. Finally, results are communicated to risk managers through a discussion between the risk assessor and the risk manager.

1. Risk estimation

For some of the stressors identified in this analysis, the adverse effect in response to the stressor is guaranteed in the event of a co-occurrence of the stressor and hatchling Blanding's turtles. This is true for road mortality, where the presence of a moving vehicle in the same time and place as a hatchling will result in hatchling mortality. To a certain extent, this may also be said for predation; the presence of a predator at the same time and place as the hatchling is likely to result in the mortality of the hatchling, although other factors such as visibility or accessibility of the hatchling to the predator may influence the actual outcome of the encounter. For other stressors – temperature, water level, habitat loss, and climate change – the likelihood of hatchling mortality may be influenced by the behaviour and physiology of the hatchling. The degree to which hatchlings can tolerate low temperatures in different habitats, changes in their energy budgets and unsuitable habitats, and the rate at which they can adapt their behaviour in response to changes in environmental conditions can affect their ability to survive after being exposed to the stressors. Current lack of knowledge about these aspects of hatchling biology makes it difficult to assess the likelihood of hatchling mortality due to exposure to the identified stressors. However, due to their small size and dependence on specific habitats close to the nest area, it is likely that the presence of suitable habitats is important to the survival of hatchlings, and that in the absence of these habitats, there is a high likelihood of hatchling mortality in response to exposure to stressors.

Due to its qualitative and exploratory nature, there were considerable uncertainties in this risk analysis, particularly with respect to the data used for the assessment. For a more detailed and accurate risk assessment, it would be useful to obtain habitat specific data on number of predators, frequency of predation, traffic volume, and degree of habitat disturbance. Studies on the physiological and behavioural tolerance of hatchlings will also help risk assessors better understand the effects of various stressors on hatchlings. In addition, a number of assumptions were made about the relationships between the stressors and the hatchling responses, particularly about the significance of suitable habitats on hatchling survival at low temperatures and the effect of climate change on vegetation patterns and associated changes in the dynamics of ecological communities. These assumptions add another layer of uncertainty to the analysis. Finally, the stochasticity inherent in temperature, precipitation, and climate change patterns provides another source of uncertainty in the analysis of risks to hatchling Blanding's turtles.

2. *Risk description*

The risk analysis has revealed that hatchlings face a number of different stressors – predation, low temperatures, high water levels, road mortality, habitat loss, and climate change – and that these stressors pose varying levels of risk to hatchlings. The likelihood of the adverse effect – hatchling mortality – also varies and is influenced to some extent by hatchling behaviour and physiology. While there are great uncertainties in the analysis due to the assumptions made, the lack of data, and environmental stochasticity, some reasonable conclusions can still be drawn. Predation, temperature, and road traffic appear to have the most direct causal relationship with hatchling mortality, while water level, habitat loss and climate change have primarily indirect effects. And while predation, road mortality and exposure to cold appear to be the main sources of hatchling mortality, the risk analysis also reveals that through the influence on other stressors, habitat loss and climate change may pose a greater threat over the longer term to hatchling Blanding's turtles.

Risk Management

The EPA framework considers risk management as a separate activity from the risk assessment and therefore provides very little guidance for this component of the risk analysis. In general, however, the risk management process consists of the development, evaluation, selection, and implementation of options that can be used to manage risks. There are various frameworks available to help incorporate social, economic, political and legal considerations along with the results of the risk assessment into the risk management process (Dooley 1990; Byrd and Cothern 2000). The exploration and application of risk management frameworks is beyond the scope of this study; however, it is possible to derive a preliminary list of potential risk management options based on the results of the risk assessment.

The risk assessment revealed that hatchling mortality can result from both natural and anthropogenic stressors. Natural stressors include predation, low temperatures and high water levels, and can be difficult to manage. Nevertheless, some efforts can be made to address these threats or reduce their impact on hatchling Blanding's turtles. It may be possible to reduce the risk of predation through the removal or reduction of the number of predators in the area, perhaps through translocation (live-trapping and removal of predators to a different area) or by culling. If predators are subsidized, their populations can potentially be reduced by eliminating food subsidies, perhaps by prohibiting the intentional feeding of wildlife, or by securing waste containers to limit wildlife access to them; these measures, however, are not likely to result in an immediate decrease in predator populations, and should therefore be considered as part of a long term management plan. In addition, it would seem unlikely that observed predators of hatchlings were, in fact, subsidized predators, particularly given that instances of hatchling predation occurred in locations not frequented by human traffic and predators were therefore not likely to have had much access to human food. An alternative option is a captive rearing or headstarting program, where hatchlings are removed from the wild after emergence, raised in captivity, and returned to the wild upon reaching a certain size; this can help reduce not only the risk of predation but also the risks from other natural stressors, such as low or variable temperatures and high water levels, by moving hatchlings away from these risks and raising them in a more controlled environment.

However, a number of factors must also be considered before proceeding with a headstarting program, including the impact on the normal growth, development, and behaviour of individual hatchlings, the potential population-level consequences of releasing headstarted hatchlings back to the wild (*e.g.* increased competition for resources and mating opportunities), the resources required to raise hatchlings in captivity, and ethical concerns with the removal of hatchlings from their habitats and interfering with the dynamics of the ecological system. Careful consideration of the costs and benefits of captive rearing is important before selecting and implementing this management option.

Anthropogenic stressors include road traffic, habitat loss and climate change and, it may be argued, should be managed as much as possible to minimize their effects. These risks can be addressed through a variety of different management options. Road mortality, for instance, can be minimized by lowering speed limits or by reducing or redirecting traffic during critical times. These initiatives may be complemented by the use of road signs or other means of increasing public awareness of the issue. Future habitat loss or disturbance may also be minimized by conducting environmental impact assessments of new development projects and proposed changes to current land use practices; assessing the potential impacts of these activities can help identify alternatives with less impact or develop plans to mitigate the effects. An even more effective option is habitat protection, through either stewardship or legislation, that prohibits activities that can result in the loss or disturbance of hatchling habitats. Other, less direct, options that are available include climate change mitigation, to minimize the effects of future climate change, and support for various conservation initiatives for protecting wildlife and habitats.

Implementation of the management options outlined above can vary in complexity and effectiveness. Strategies such as reducing speed limits, redirecting traffic, or erecting road signs can be relatively simple to implement and effective in directly minimizing a specific risk over the short term. Other options such as risk mitigation through environmental impact assessments and land use planning, or habitat protection through stewardship or legislation, are more difficult to implement and require the support of governments, communities, and land owners. However, these options can be more effective in addressing multiple risks over the long term. A headstarting program for hatchling Blanding's turtles can also be very effective in reducing the risks to hatchlings, although implementation can be complicated by biological, ethical, legal, or political considerations. More uncertain is the effectiveness of indirect measures such as climate change mitigation and other conservation initiatives; although they can be valuable tools in addressing risks to wildlife and habitats in general, benefits to hatchlings and especially hatchling survival are only incidental. An evaluation of these options through the use of a formal risk management framework would be useful and highly recommended when selecting appropriate measures to implement.

Evaluation of the Risk Analysis Approach

Despite the absence of quantitative data on stressors and the lack of strong evidence to support the assumptions made, the risk analysis approach has been useful in identifying potential risks to hatchling Blanding's turtles. This preliminary, or screening level, risk analysis provided a systematic way of assessing the nature of potential stressors and evaluating the relative magnitude of the risks. Through this process, management options that address the risks can also be developed and evaluated to determine the most effective methods of managing the risks to hatchling Blanding's turtles. There is no doubt, however, that more detailed risk analyses, using spatially and temporally specific quantitative data on identified stressors, would help provide a better characterization of threats and increase the accuracy of estimates of the likelihood of exposure and the severity of the risk, and thus have greater utility for conservation biology. Nevertheless, qualitative, screening level risk analyses can play a role in the preliminary identification of threats, primarily for instances where data on threats or stressors are limited, and in the design and planning of future research and risk analyses.

The application of a formal risk analysis to conservation biology, and in particular to the process of identifying threats to wildlife populations, can have positive implications for the field. It provides researchers and managers with a framework for understanding the nature of the threats facing wildlife populations and developing effective strategies to manage those threats. In addition, risk analysis forces researchers to explicitly state and describe the nature of the problem, the goals of management and conservation programs, and the relationships between the perceived threat and its potential effects; often, this can reveal issues or solutions that would otherwise have remained unnoticed. Finally, risk analysis allows wildlife conservation issues to be considered from a different perspective, which often leads to a clearer understanding of the problem and the development of more effective solutions. Given the advantages of this approach, risk analysis has the potential to make significant contributions to the field of conservation biology. Further research on improving risk analysis frameworks and adapting them more specifically for applications in wildlife conservation and management will be instrumental in the realization of this potential.

CHAPTER 4. Protecting Biodiversity and Habitats in Nova Scotia: A Review of Policy Instruments

The Issue

There is little doubt within the scientific community and, to some extent, the general public that the world is currently experiencing a rapid loss in biological diversity, resulting in a mass extinction similar in rate and magnitude to the five largest mass extinction events that have occurred in the past. The cause of this sixth mass extinction event (Leakey and Lewin 1995) is not a major catastrophic event, such as an asteroid impact or widespread volcanism. Nor is it due to slow and inevitable global change, such as geological and/or climatic change. Instead, the current mass extinction event is directly attributable to the steady increase in the dominance and impact of one of Earth's species: humans. In fact, species extinction rates are estimated to be 100 to 1000 times higher than pre-human levels, and are predicted to increase along with the continued increase in human population (Pimm et al. 1995). There is also little doubt that the leading cause of this biodiversity loss is habitat loss in the form of habitat change (Millennium Ecosystem Assessment 2005) and land conversion from high to low diversity uses (OECD 1996). According to Baillie et al. (2004), habitat loss, primarily in the form of deforestation and conversion to agriculture, has affected up to 86% of threatened birds, 88% of threatened amphibians, and 86% of threatened mammals. Habitat protection is therefore an important component of biodiversity conservation and the prevention of future biodiversity loss.

The issue of biodiversity loss and protection became more prominent on the international agenda through the *Convention on Biological Diversity*, an international agreement that seeks to reduce the rate of biodiversity loss worldwide. The Convention places the responsibility on each signatory country to protect biodiversity within its national boundaries through the development of national strategies and programs that reflect the measures set out in the Convention (*Convention on Biological Diversity*, Article 6), which include the establishment of a system of protected areas for conservation as well as the protection and restoration of ecosystems to promote the recovery and maintenance of viable populations of species in their natural surroundings

(*Convention on Biological Diversity*, Article 8). Signed during the 1992 Rio Earth Summit (SCBD 2001-2005) and reaffirmed at the 2002 Johannesburg World Summit (UN/DESA 2002) by a number of countries, including Canada, Parties to the Convention agreed to:

> "achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth." (UNEP/CBD 2002)

However, over a decade later and with only four years remaining to achieve this goal, a significant reduction to the rate of biodiversity loss at any level remains to be seen. Data from the International Union for Conservation of Nature and Natural Resources (IUCN) show that during the period from 1996/98 to 2004, the total number of listed critically endangered, endangered, and vulnerable species has actually increased from 10,533 to 15,587 species (Baillie et al. 2004). Similarly, the number of assessed species that have become extinct or extinct in the wild has increased from 729 species in 1996/98 to 844 species in 2004 (Baillie et al. 2004). These statistics clearly show that greater effort must be made worldwide in order to achieve the 2010 target and "effectively halt the loss of biodiversity" (UNEP/CBD 2002).

The Problem of Biodiversity: Complexity, Measurement, and Valuation

Cited among the various obstacles to the implementation of the Convention is the "lack of political will and support" (UNEP/CBD 2002). Part of the reason for this may be the inherent difficulty in defining the concept of biodiversity and in understanding its complex role within ecosystems, which creates difficulties in the assessment of biodiversity and in the appreciation of its importance to the maintenance of ecosystem functioning and continued human survival. The consequent uncertainty surrounding biodiversity estimates and the poor understanding of its significance to human life make it difficult for biodiversity conservation and habitat protection to become a significant part of the policy agenda, even in developed countries such as Canada that have considerably more resources to invest.

Biological diversity, or biodiversity, can be defined in a number of different ways. The most commonly accepted definition, and the one used by the *Convention on Biological Diversity*, is:

> "...the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems."
> (*Convention on Biological Diversity* 1992, Article 2)

This definition emphasizes the hierarchical nature of biodiversity: variation at the gene, species and ecosystem levels. This greatly complicates the assessment of overall biodiversity, and scientists often evaluate biodiversity based on a simplified measure of species diversity or species richness (OECD 1996; Tilman 1997). Even with this simplification, however, estimates of biodiversity often remain controversial. For example, differences in the way species are defined (whether two similar groups are considered as subspecies/sub-populations of a single species or as two different species) can lead to different estimates of biodiversity. In addition, other concepts such as species endemism (whether a species is restricted to a specific region or locality) and taxonomic diversity (diversity at higher taxonomic levels such as the genus or family level) can further complicate the assessment of biodiversity within a given area (OECD 1996). These issues lead to uncertainty and lack of confidence in biodiversity estimates that make it more difficult for the issue to become part of the policy agenda.

The complexity of the role of biodiversity in ecosystems also results in difficulties in its measurement. The long time scales involved, particularly for species with long life spans, mean that the effects of any conservation or management activities will not immediately be reflected in measurements of population abundance and distribution. The interrelationships among different species and the environmental conditions within an ecosystem also make it difficult to determine not only the importance of biodiversity in ecosystem productivity and resilience (Tilman 1997; Thébault and Loreau 2005), but also the relative impact of conservation and management activities in comparison with other environmental factors that may be present. Furthermore, because of this inherent complexity, a large amount of data on various biological and environmental factors must be collected in order to provide an adequate and relevant assessment of biodiversity and its change over time, all of which require a considerable amount of resource investment. All of these factors combined – the long time scales, ecosystem complexity, and the large amount of resources required in data collection – make it difficult to formulate and evaluate the success of various policy options that address biodiversity protection.

The lack of appreciation for the value and importance of biodiversity in sustaining life on Earth also presents a major challenge to the incorporation of the issue into the current policy agenda. Biodiversity plays an important role in providing ecosystem services such as: provisioning of food, fuel, raw materials and medicines; regulation of climate and various biogeochemical cycles (*e.g.* water, carbon, and nitrogen cycles); and support for life on earth through soil enrichment and protection, pollination of crops and other vegetation, seed dispersal, primary production, pest control, waste decomposition and nutrient cycling (OECD 1996; Daily 1997; Millennium Ecosystem Assessment 2005). Biodiversity also provides significant aesthetic, spiritual, scientific, educational, recreational and other cultural values (OECD 1996; Millennium Ecosystem Assessment 2005). Biodiversity, in a sense, has infinite value in that life cannot exist without it (Daily 1997). However, these values are often hidden, overlooked, and unappreciated because the services provided by biodiversity are free and typically have no market value attached to them. The absence of a market value for biodiversity and its services often means that the importance of biodiversity is given little weight in policy decisions (Costanza et al. 1997).

More recently, ecologists and economists alike have attempted to put an economic or a monetary value on biodiversity using methods provided by the emerging discipline of ecological economics (Edwards and Abivardi 1998). These methods attempt to classify the values of services provided by biodiversity into various categories: direct use (resource extraction or recreational values), indirect use (provision of ecosystem services and support for species with direct use values), and non-use values such as existence values (value from the sheer contemplation of the existence of biodiversity) and option values (potential use value in the future) (Goulder and Kennedy 1997; Edwards and Abivardi 1998; Bräuer 2003). Values are often assigned using cost-benefit analyses (cost of conservation vs. value of the benefits provided by biodiversity), replacement/restoration costs (cost of replacing lost biodiversity service), direct commercial values (in the cases of extracted resources with a market value), travel-cost methods (as a measure of people's willingness to pay for recreational opportunities), and contingent valuation (stated preferences or demand for biodiversity services based on a hypothetical market) (Goulder and Kennedy 1997; Bräuer 2003; Chee 2004; Cullen et al. 2005).

However, just as there are many scientists and economists that advocate economic valuation of biodiversity services, there are equally as many that criticize existing approaches used in valuation studies (*e.g.* Nunes and van den Bergh 2001; Dore and Webb 2003; Turner et al. 2003; Chee 2004; Cullen et al. 2005; Zhang and Li 2005), the relevance and usefulness of valuation in conservation (*e.g.* Bulte and van Kooten 2000; Stanley 2005), or the ethical basis of valuation (*e.g.* Goulder and Kennedy 1997; Bräuer 2003). But despite the controversy surrounding the economic valuation of biodiversity, it can be an important tool that allows biodiversity concerns to be considered alongside economic and social issues in the policy decision-making process.

Biodiversity Conservation Policy in Nova Scotia

As previously stated, habitat loss is one of the major driving forces of biodiversity loss. Any initiative that seeks to protect biodiversity must necessarily address the issue of habitat loss and protection. In Canada, a mix of policy instruments is used to encourage biodiversity conservation and habitat protection. In this section, I will describe the different regulatory, economic, information, and voluntary instruments that are currently being implemented as well as discuss potential ways of measuring the progress and evaluating the success of the various policy instruments in preserving biodiversity. While the different policy instruments will be discussed separately, the different types do not necessarily work in isolation and independently of each other; in fact, important links exist between the different types of policy instruments, and policy packages typically consist of more than one type of instrument.

Policy Community and Policy Network

In order to formulate effective policies, one must be aware of the stakeholders and their roles in the policy cycle. As with any policy initiative, biodiversity and habitat protection affects a number of interested actors that make up the policy community. This may consist of state actors such as elected government officials responsible for passing legislation as well as appointed officials who draft legislation, enforce regulations and implement policy. The policy community may also include landowners (individuals, corporations or governments), land users other than owners (*e.g.* recreational users), and land planners and developers, all of whom may be affected by or have an interest in any restrictions on the use of the land for the purposes of habitat protection. Other policy community members include scientists who study biodiversity and endangered species and their habitats, environmental non-governmental organizations (NGOs) that educate the public about biodiversity and organize support for greater habitat protection, and other concerned citizens who are aware of and care about the issue of biodiversity and habitat protection.

The policy network is the subset of the policy community that may be directly involved in the policy decision-making (Hessing et al. 2005). In this case, the policy network includes appointed officials who are primarily responsible for the creation and implementation of government policies dealing with habitat protection. It also includes biologists and ecologists who have information on where habitats are located, how they can be protected, and how the impact of various policy instruments on the protection of biodiversity can be evaluated. Environmental NGOs also play a role in lobbying governments to adopt or change specific policies and in encouraging the public to engage in voluntary habitat protection. Finally, landowners are an important part of the policy network because they are directly responsible for habitats on their land and the implementation of the policy at ground level.

Policy Instruments and Implementation

<u>Regulatory Instruments</u>

Regulatory instruments for wildlife and habitat protection consist of various legislations that protect wildlife, and particularly threatened and endangered species, and allow the creation of protected habitat areas, where activities that may disturb and endanger wildlife or their habitats are prohibited. Among these are the *Migratory Birds Convention Act* (S.C. 1994, c. 22), which protects migratory birds and enables the establishment of Migratory Bird Sanctuaries (s. 12(1)(i)), the *Canada Wildlife Act* (R.S.C. 1985 c. W-9), which contains provisions for the protection of endangered wildlife (s. 8) and allows for the creation of National Wildlife Areas (*Wildlife Area Regulations* C.R.C., c. 1609) and Marine Wildlife Areas (*Canada Wildlife Act* R.S.C. 1985, c. W-9, s. 4.1(1)), the *Canada National Marine Conservation Areas Act* (S.C. 2002, c. 18) and the *Oceans Act* (S.C. 1996, c. 31), which provide for the creation of Marine Conservation Areas (s. 9(3)) and Marine Protected Areas (s. 35), respectively, and the *Species at Risk Act* (S.C. 2002, c. 29), which prohibits the intentional harming or disturbance of any listed species (s. 32) as well as protects the residence (s. 33) and critical habitats (s. 58) of Canada's threatened and endangered species. In addition, the *Canada National Parks Act* (S.C. 2000, c. 32) also provides for the maintenance of ecological integrity and the protection of natural resources (s. 8(2)) as well as allows for the creation of Wilderness Areas within national parks (s. 14(1)). The *Canadian Environmental Protection Act* (S.C. 1999, c. 33) also provides some protection of the environment and biodiversity from toxic substances and the impact of biotechnologies (s. 2(1)).

The above legislations, however, apply primarily to federal public lands or to wildlife species under federal jurisdiction; wildlife and habitat protection in non-federal Crown land fall under various provincial jurisdictions. In Nova Scotia, the provincial *Wildlife Act* (R.S.N.S. 1989, c. 504) regulates activities related to wildlife and conservation (s. 6), and allows for the creation of wildlife sanctuaries, management areas, and parks (ss. 14 – 16). The Nova Scotia *Endangered Species Act* (S.N.S. 1998, c. 11) also provides protection for listed threatened and endangered species, their dwelling places, and core habitats within the province (s. 13(1)). In addition, a number of other provincial legislation also provide varying degrees of protection for wildlife, biodiversity, and habitats, including the *Environment Act* (S.N.S. 1994-95, c. 1), which includes the preservation and prevention of loss of biodiversity as part of its purpose (s. 2(b)(i)), specifies the requirements for the environmental assessment process (ss. 31-41), and prohibits the alteration and release of substances into water courses and wetlands (s. 105(3)(a)), the *Environmental Goals and Sustainable Prosperity Act* (S.N.S. 2007, c. 7), which commits the provincial government to protecting 12% of provincial land mass by 2015 (s. 4(2)), and the *Provincial Parks Act* (R.S.N.S. 1989, c. 367) and *Wilderness Areas Protection Act* (S.N.S. 1998, c. 27), which protect wildlife and habitats through the creation and management of parks and wilderness areas. The *Forests Act* (R.S.N.S. 1989, c. 179) also ensures that wildlife conservation requirements and ecological impacts of forestry practices are considered (s. 8(1)(b)) and that wildlife and wildlife habitats and forest ecosystem diversity are managed (s. 10), while the *Beaches Act* (R.S.N.S. 1989, c. 32) provides for the preservation and management of beaches and the preservation and protection of flora and fauna on beaches (s. 13).

Despite the existence of federal and provincial legislation for wildlife and habitat protection, the language of the legislation, particularly with respect to habitat protection, is often enabling and not mandatory; government departments responsible for implementing the legislation "may" establish protected areas, but are not required to do so. Because of this, regulatory instruments are sometimes seen primarily as "safety nets" that may only minimally contribute to the policy objective. In fact, the *Species at Risk Act* (S.C. 2002, c. 29) itself emphasizes the importance of stewardship in conservation and recovery (ss. 10.1 – 13). The responsibility therefore falls to scientists, environmental NGOs and the concerned public to put pressure on governments to create more protected areas. There is also a greater reliance on other policy instruments to provide protection for wildlife and their habitats.

Economic Instruments

In addition to various federal and provincial legislations that protect wildlife and their habitats, there are also provisions under the *Income Tax Act* (R.S.C. 1985, c. 1 (5th Supp.)) that provide economic incentives for biodiversity conservation. In Canada, there are tax incentives for donating to registered charities, which can include various environmental or conservation groups working to protect wildlife and habitats, or to municipal, provincial or federal governments through various conservation funds (*Income Tax Act* R.S.C. 1985, c. 1 (5th Supp.), s. 118.1). These donations can help provide those involved in research and conservation with the resources needed to continue their work. Tax incentives under the federal Ecological Gifts Program are also available for landowners that enter into contractual agreements, such as conservation easements, covenants or servitudes, with other parties for the purpose of protecting habitats on their land (*Income Tax Act* R.S.C. 1985, c. 1 (5^{th} Supp.), s. 118.1). Another economic instrument enabled by legislation is the monetary compensation for economic losses resulting from conservation initiatives. Landowners who suffer financial losses from any mandatory habitat protection measures on their lands can be deterred from destroying the habitats by the possibility of monetary compensation for those losses. In such cases, compensation is enabled by the federal *Species at Risk Act* (S.C. 2002, c. 29, s. 64) and the Nova Scotia *Endangered Species Act* (S.N.S. 1998, c. 11, s. 16(7)). Various disincentives also exist under the *Canada Wildlife Act* (R.S.C. 1985, c. W-9), the *Species at Risk Act* (S.C. 2002, c. 29), the Nova Scotia *Endangered Species Act* (S.N.S. 1998, c.11), and the Nova Scotia *Wildlife Act* (R.S.N.S. 1989, c. 504). These disincentives primarily take the form of large fines for harming or disturbing wildlife and their habitats (*Canada Wildlife Act* R.S.C. 1985, c. W-9, s. 13; *Wildlife Act* R.S.N.S. 1989, c. 504, s. 111), and listed endangered species in particular (*Endangered Species Act* S.N.S. 1998, c. 11, s. 22; *Species at Risk Act* S.C. 2002, c. 29, s. 97), against the law. License and permit fees for hunting, trapping or fishing (*Wildlife Act* R.S.N.S. 1989, c. 504, s. 24) may also be considered as disincentives to protect wildlife populations.

Other economic instruments that are used to encourage biodiversity and habitat protection include grants and subsidies, fee simple acquisition of lands, and market benefits. Various grants and subsidies are available from governments, such as the federal Habitat Stewardship Program (Canadian Wildlife Service 2006), Nova Scotia Habitat Conservation Fund (Department of Natural Resources 2006a), and Nova Scotia Species at Risk Conservation Fund (Department of Natural Resources 2006b), and from various environmental or conservation groups such as WWF-Canada (WWF-Canada 2007a) or Wildlife Habitat Canada (Wildlife Habitat Canada/Habitat Faunique Canada 1999-2007a) that provide financial help for individuals or organizations wishing to protect habitats on their lands or engage in other conservation activities. Landowners who do not wish to protect habitats on their land can also potentially benefit through fee simple land acquisitions, by selling their land to others, such as governments or environmental NGOs, who wish to protect habitats and who may be willing to pay the market price or more for the land.

There are additional market benefits, especially for corporations, to protect species and their habitats. Companies that protect endangered species or their habitats or those that pass specific certification programs may be seen as more environmentally and socially responsible by consumers, who then become more willing to purchase products and/or services from those companies. There is also a potential to receive greater investment money through ethical funds (Heinkel et al. 2001; Michelson et al. 2004), although currently most funds consider general environmental performance, rather than biodiversity and/or habitat protection specifically, as part of their criteria.

Other economic incentives, presently in use in the United States but that could potentially be implemented in Canada, include tradable development rights and conservation or mitigation banking (Parkhurst and Shogren 2005). Given a limit on the amount of development allowed in a given area, tradable development or land-use rights allow landowners that protect habitats on their land to sell their surplus development rights to other landowners or use them to offset developments elsewhere (Weber and Adamowicz 2002; Parkhurst and Shogren 2005). Similarly, conservation or mitigation banking allows development credits to be earned through protection of wildlife and improvements in habitat quality; these credits can then be sold to developers to fulfill mitigation requirements of development projects (Parkhurst and Shogren 2005).

Information Instruments

Effective implementation of any policy initiative often relies on information instruments to educate the stakeholders and the general public about the importance of the issue, encourage them to take action, and inform them about available policy options. In the case of biodiversity and habitat protection, information is typically disseminated by environmental NGOs or by governments. Environmental NGOs, such as WWF-Canada (WWF-Canada 2007b), Sierra Club (Sierra Club of/du Canada 2007) or the Canadian Parks and Wilderness Society (CPAWS 2007), provide information through advocacy campaigns that organize public support for increased wildlife and habitat protection.

These campaigns usually consist of public information sessions, information booths, posters or brochures, media advertising, press releases and other news coverage, petitions, demonstrations, or other events that attempt to raise awareness about endangered species and habitat issues as well as encourage the public to become actively involved in conservation activities. These information instruments have generally been very effective in that they actively engage the public and bring the issue to them.

In contrast, government initiated information instruments consist primarily of more passive ways of providing information, such as government websites or publications about the status of plant and wildlife species in Canada or about systems of protected areas (*e.g.*, COSEWIC 2007b; Environment Canada 2006a; Government of Canada 2007). These may be less effective in making information accessible to the public because they require that people have prior knowledge or awareness of the issue to know what type of information to look for and where. Another information instrument typically initiated by government agencies are public/stakeholder information sessions and opportunities for public input on government projects or environmental impact assessments. While these instruments are more interactive, they also typically occur only during a short window of time, are not widely publicized, and often involve primary stakeholders only. Such information sessions are often made more effective by environmental NGOs that actively publicize the events and encourage greater public participation.

School programs provide another, often overlooked, means of providing information. While these may not result in an immediate increase in protection, incorporating biodiversity and the importance of its preservation into school curricula may contribute to long term solutions that address the underlying causes of biodiversity and habitat loss such as overconsumption, overpopulation and unsustainable practices (OECD 1996). In addition, educating younger generations about the importance of biodiversity may also increase their receptiveness to conservation initiatives, which can then lead directly to greater biodiversity and habitat protection in the future.

Voluntary Instruments

Successful information and economic instruments can often encourage people to participate in voluntary initiatives to protect wildlife and habitats. Voluntary instruments for biodiversity and habitat protection primarily take the form of stewardship. Wildlife stewardship can be as simple as donations to help fund research and conservation activities, reporting sightings of endangered species, participating in research and monitoring activities, or volunteering for various conservation organizations. These voluntary activities can have a positive impact on the conservation of biodiversity and habitats by contributing additional resources for conservation activities, and by helping to improve knowledge about endangered species and their distribution and habitat use.

Protection of habitats on private land can also occur through habitat stewardship. Habitat stewardship is generally regarded as the careful and responsible management of lands where wildlife habitats occur, and may be performed by individual landowners, corporations, or a variety of different groups. Individual landowners, for instance, may voluntarily choose to protect habitats that occur on their lands for various reasons, such as for aesthetic, spiritual or moral reasons, or for their own personal enjoyment. Some corporations also voluntarily set aside part of their lands to be protected as wildlife habitat, and studies have shown that there are various non-monetary benefits to doing so, including improved employee morale and improved relationships with environmental organizations, communities, and regulators (Cardskadden and Lober 1998), in addition to the economic incentives discussed previously.

A range of organizations also engage in habitat stewardship activities. These include environmental NGOs, such as the Nature Conservancy of Canada (Nature Conservancy of Canada 2006) or the Nova Scotia Nature Trust (NSNT 2007), that protect lands that have been purchased by the organization or have been donated to them. Community groups also become involved in habitat stewardship initiatives, in which community members and volunteers organize to protect local wilderness areas and wildlife habitats, often occurring on public lands, and to put pressure on governments to set aside these areas for protection. Local examples of community groups engaged in habitat stewardship can be found in the Nova Scotia Public Lands Coalition (2006) website. More recently, multi-stakeholder groups have formed for the purpose of habitat protection. These groups typically consist of government agencies or departments, environmental NGOs, individual landowners or corporations, scientists and community members that work together in protecting habitats. Multi-stakeholder groups can often be successful in accomplishing this because they have access to more financial resources and scientific/technical expertise. Because environmental NGOs and community groups are often involved, there is also greater public support for habitat protection initiatives by multi-stakeholder groups. Some organizations, such as Wildlife Habitat Canada (Wildlife Habitat Canada 1999-2007b), have also been created to help facilitate the formation of multi-stakeholder groups that engage in habitat protection.

Policy Evaluation

Evaluation of the success or failure of various policy instruments depends on the establishment of clear and measurable goals during the initial policy formulation. However, difficulties in assessing biodiversity and the impact of management activities leave us with inadequate data and an incomplete understanding of the way ecosystems work. This often means that setting relevant and meaningful quantitative goals may not be possible or practical. Because of this, we are left with the alternative of measuring progress towards overall objectives rather than evaluating the success of policy instruments in achieving specific goals. To this end, there are various ways to measure the effectiveness of the different policy instruments in protecting biodiversity and habitats. However, since similar measures may be used to evaluate different policy instruments, I will discuss the evaluation of the different policy instruments together rather than separately.

The simplest measure of effectiveness in encouraging habitat protection is the size and number of habitats that are protected through the various instruments. These can be expressed either as total size or number, *e.g.*, the amount of area protected through corporate stewardship or the number of different protected areas created by various levels of government, or as a percentage of the total area that is protected through habitat stewardship. We can also compare the effectiveness of the different policy instruments by looking at the total area of protected habitats and calculating the percentage that can be attributed to individual policy instruments (*e.g.*, tax incentives vs. grants and subsidies).

A more difficult, but potentially more useful, way of evaluating policy instruments is to determine the extent to which the various instruments have modified the behaviour of actors to achieve the desired objectives. This can be done qualitatively through surveys and interviews with stakeholders and other affected individuals. This is particularly important in evaluating information instruments that often do not directly lead to biodiversity conservation. Interviewing those at the receiving end of information instruments may help determine how the information has affected their decision making, whether it has encouraged them to become involved, and which methods are more effective in relaying the information. Surveys and interviews can also help evaluate the effectiveness of regulatory instruments in deterring people from harming or disturbing threatened and endangered species and from engaging in prohibited activities within protected areas. Finally, these qualitative methods can provide insight into people's motivations; this can be particularly useful in distinguishing the impact of voluntary instruments from that of economic instruments, and thus allow policy makers to evaluate the relative effectiveness of the two instrument types in encouraging the preservation of biodiversity.

The most important measure of success, however, is the ultimate effect of conservation policies on preserving biodiversity and increasing species populations. This is considerably more difficult to measure and requires greater resources. The knowledge and technical expertise of scientists is required to evaluate the impact of various conservation activities and increased habitat protection on population abundances and distributions. In many cases, this is hindered by the lack of baseline data for comparison. Changes in population size may also involve time lags, particularly for species with long life spans. The effect of various policy instruments, therefore, may not be immediately apparent. However, given enough time, it is possible to monitor changes in population sizes and demographic parameters such as birth rates, recruitment, or mortality rates in response to the implementation of various policy instruments. In the meantime, we must rely on other measures to evaluate the success of policy instruments and make necessary improvements.

Policy Instruments for Blanding's Turtle Conservation

Blanding's turtle (*Emydoidea blandingii*) is a freshwater turtle species with the main geographic range centered on the Great Lakes (Herman et al. 1995, and references therein); peripheral populations extend to the East and include a highly disjunct population complex in southwest Nova Scotia, comprising three genetically distinguishable sub-populations (Mockford et al. 2005). Due to their limited range, uneven age structure and low recruitment of juveniles, the Nova Scotia population of Blanding's turtles was designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Blanding's Turtle Recovery Team 2002). As a result of this designation, a number of policy instruments have been implemented to protect this population and to aid in its recovery. Selection of this set of policy instruments has been primarily influenced by policy actors directly involved in Blanding's turtle conservation. This policy network currently consists of the relevant federal and provincial agencies, a team of Blanding's turtle researchers based primarily at Acadia University and Kejimkujik National Park and National Historic Site (KNPNHS), private and corporate landowners directly affected by conservation activities, and other organizations that contribute resources and expertise to the conservation and recovery of Blanding's turtles. Representatives of these groups and organizations, which include the Acadia University Biology Department, the Nova Scotia Department of Natural Resources Wildlife Division, KNPNHS, Friends of Keji, Mersey Tobeatic Research Institute, Nova Scotia Museum of Natural History, Bowater Inc., and Nova Scotia Power Inc., form part of the Blanding's Turtle Recovery Team, which directs research and conservation of Blanding's turtles in Nova Scotia and provides advice to governments and other decision-makers and planners on matters related to Blanding's turtles in Nova Scotia (Blanding's Turtle Recovery Team 2006b). Other interested actors that may not be directly involved in policy decision-making but form part of the larger policy community include Mi'kmaq communities in the surrounding area, other federal and provincial agencies involved in general wildlife and endangered species conservation, residents and landowners in various communities where the three sub-population of Blanding's turtles are concentrated, and conservation biologists, environmental NGOs, visitors to KNPNHS and other members of the public interested in endangered species and conservation issues.

Due to its endangered status, the Nova Scotia population of Blanding's turtles is currently protected under the *Species at Risk Act* (S.C. 2002, c. 29, Schedule 1) and the Nova Scotia *Endangered Species Act* (S.N.S. 1998, c. 11) (*Species at Risk List Regulations* N.S. Reg. 109/2000). These regulatory instruments prohibit the harming or disturbance of listed species and their habitats. The *Species at Risk Act* (S.C. 2002, c. 29, s. 37) and the Nova Scotia *Endangered Species Act* (S.N.S. 1998, c. 11, s. 15) also require the preparation of a recovery plan to guide research and conservation activities. This task has been undertaken by the Blanding's Turtle Recovery Team, along with the identification of critical habitats (*Species at Risk Act* S.C. 2002, c. 29, s. 41(1)(c)) and core habitats (*Endangered Species Act* S.N.S. 1998, c. 11, s. 15(4)(h)) also required by federal and provincial legislation.

In addition to the protective measures afforded by regulatory instruments, economic instruments such as fee simple acquisition and market benefits have also been used by corporate landowners and the provincial government to protect portions of Blanding's turtle habitats. In 2003, Bowater designated a significant portion of Blanding's turtle habitat near McGowan Lake as a conservation area under its Unique Areas Program (Bowater 2007); this land has recently been purchased by the provincial government and is slated for conservation (MacDonald 2007). Grants and subsidies from the federal and provincial governments as well as various NGOs have also played important roles in providing funds for Blanding's turtle research and conservation through the years.

Various information instruments have also been used to promote Blanding's turtle conservation. These range from posters requesting people to report sightings of Blanding's turtles and a Blanding's turtle website with information about the species biology, research and conservation activities (Blanding's Turtle Recovery Team 2006b), to interpretive programs at KNPNHS, and to community outreach programs that include school talks, public displays, presentations and community meetings, field trips and other special events, newsletters and other types of media coverage, and various spontaneous public encounters (Caverhill 2006).

These information instruments have been highly effective in educating people about Blanding's turtles and the importance of their conservation, as well as in promoting voluntary stewardship opportunities. In addition to habitat stewardship, there are currently several opportunities to participate in Blanding's turtle research and conservation activities within KNPNHS and the surrounding area. These include the nest monitoring program, which occurs every year in early June – early July and in mid September – mid October, and various volunteer programs to help radio-track Blanding's turtles and conduct visual and trapping surveys from late spring to early fall of each year (Smith and Caverhill 2006). The success of these volunteer programs can be attributed to information instruments that effectively engage citizens and encourage them to help protect Blanding's turtles and their habitats.

Many of the policy instruments currently used to protect Blanding's turtles can also be applied specifically to protect hatchling Blanding's turtles, as in the legal designation of critical or core hatchling habitats, the protection of hatchling habitats through various economic incentives, or the use of grants to fund research on hatchlings. Specific information about hatchling road mortality and vulnerability to habitat change can also be included in public outreach materials to increase awareness of these issues and suggest ways that people can minimize their impact. Information instruments can also encourage the public to participate in volunteer programs to help protect hatchling Blanding's turtles, such as the nest monitoring or nest emergence programs.

Policy instruments for protecting hatchling Blanding's turtles can be made more effective by incorporating scientific knowledge and management considerations into the formulation and implementation of conservation policies, and by specifically addressing the threats to hatchlings. It may be possible, for instance, to lower the risk of predation by implementing regulatory instruments that limit food subsidies or control predator populations at nest sites and hatchling overwintering sites. In addition to the use of information instruments such as road signage or public outreach to increase awareness, road mortality may also be reduced through consideration of the potential impacts on wildlife in road design, traffic management, or land use policies. Research on captive rearing of Blanding's turtles or other species can also help determine its potential role in the conservation of Blanding's turtles, as well as in the development of policies and regulations for captive rearing of Blanding's turtles and other threatened and endangered species. Finally, data on hatchling movements and habitat use should be considered in the identification and designation of critical and core habitats, particularly with respect to the size, type, and location of areas requiring legal protection.

Further research to identify additional policy instruments and their potential application in addressing specific threats to hatchling Blanding's turtles would be beneficial and greatly contribute to the success of Blanding's turtle conservation. It is also important to consider the various social and ethical issues in the design and implementation of policy instruments, particularly those that involve more invasive management such as predator population control or captive rearing of individuals, or those that affect communities or individual landowners such as critical or core habitat designation or land-use planning. Public and stakeholder consultations and careful consideration of the costs and benefits of each policy option may help highlight and resolve some of these issues. Risk assessment and risk management tools may also be useful in deciding which policy options should be implemented to address particular threats to Blanding's turtle and their hatchlings.

This brief review of the policy instruments implemented in Blanding's turtle conservation reveals patterns that reflect general trends in Canadian biodiversity and habitat protection policies. In this study, baseline protection for Blanding's turtles and their habitats are provided by regulatory instruments such as the *Species at Risk Act* (S.C. 2002, c. 29) and the Nova Scotia *Endangered Species Act* (S.N.S. 1998, c.11). Beyond this, other policy instruments play a larger role in the conservation and recovery of Blanding's turtles in Nova Scotia. In this case, economic incentives such as grants and subsidies and fee simple acquisitions have played important roles in the large-scale conservation of Blanding's turtles in Nova Scotia, although, to date, instruments such as conservation easements, covenants and servitudes have not played a significant role in promoting habitat stewardship at smaller scales on private lands. Efforts to increase the use of easements, covenants and servitudes to protect habitats would contribute greatly to Blanding's turtle conservation given the relatively large proportion of privately owned land in Nova Scotia. Information instruments can help encourage the use of easements, covenants and servitudes by highlighting their economic benefits and by promoting them as a potential alternative to critical or core habitat designation on private land. Information instruments have already been highly successful in encouraging people to engage in voluntary habitat stewardship and participate in research and conservation programs. Various sighting reports and volunteer surveys have expanded current knowledge of Blanding's turtle distribution within Nova Scotia. The nest monitoring program has also resulted in the protection of numerous nests from predation and the successful emergence and release of hundreds of hatchlings over the years. Data on the changes in population sizes can help evaluate the effectiveness of these initiatives in the conservation and recovery of Blanding's turtles in Nova Scotia. Surveys of public outreach program participants and volunteers may also help assess the effectiveness of information and voluntary instruments in encouraging the public to help protect Blanding's turtles and turtle habitats.

Summary and Conclusions

Biodiversity and the services it provides are invaluable and must be protected. However, due to its complexity and the absence of economic valuation, the issue of biodiversity continues to be largely ignored in policy decisions. Biodiversity loss continues to occur, primarily through continued habitat loss. Policies to prevent further biodiversity loss must therefore address the issue of habitat loss. In Canada, protection of biodiversity and habitats is achieved through a mixture of regulatory, economic, information, and voluntary instruments that are closely linked. This interaction between policy instruments can be observed in the conservation and recovery of Blanding's turtles in Nova Scotia. In this example, regulatory instruments that protect Blanding's turtles and their habitats are complemented by various economic and information instruments that in turn promote voluntary stewardship activities.

Due to the lack of adequate information, it is not often possible to set quantitative goals against which the success of different policy instruments can be measured. The evaluation of policy instruments is therefore limited to measuring progress towards the overall objective of increased wildlife populations and habitat protection. To this end, qualitative research methods such as surveys and interviews may be more useful in evaluating the relative effectiveness of the various policy instruments, particularly as they provide insight into the motivation behind individual and group behaviours and provide guidance on how policy instruments can be improved to provide greater protection. Ultimately, however, the success of any wildlife and habitat protection policy initiative will be determined by increases in species populations and overall biodiversity.

CHAPTER 5. Conclusions

In this thesis, I explored the science, management, and policy aspects of protecting hatchling Blanding's turtles in Nova Scotia. Hatchling Blanding's turtles were radio-tracked to study post-emergent hatchling behaviour, movements, and habitat use. The radio-tracking study revealed that hatchlings suffered from high mortality following the emergence from the nest, with the primary sources being predation, exposure to cold, and road mortality. Hatchlings that survived spent most of their time stationary and fully covered on land or submerged in water. They were observed most frequently on ground cover substrate such as leaf litter, graminoid and forb species, and *Sphagnum*. Hatchling behaviours were influenced by temperature, precipitation and cloud cover, with basking and active behaviours observed more often on moderately warm days with partial cloud cover, although active behaviour was also observed during moderate to heavy rain. Habitats used by hatchlings varied considerably depending on the types of habitats near the nest; in the study, hatchlings were observed in roadsides, gravel pits, cobble beaches, outcrops, woodland, and different types of wetland habitats. Within these habitats, hatchlings were often found in relatively open microhabitats with moist or saturated/flooded soils and leaf litter, rush, *Sphagnum*, grasses and sedge present. Following emergence, most of the hatchlings spent several days near the nest, moving in highly tortuous paths that appear to be directed uniformly in all directions, before travelling in a relatively straight path towards overwintering sites. These sites generally consisted of wetland habitats near the nest sites, but also included dry woodland habitats.

A risk analysis approach, based on the ecological risk assessment framework developed by the United States Environmental Protection Agency (EPA 1992; 1998), was applied to identify and describe potential threats to hatchling Blanding's turtles, using results and observations from the radio-tracking study as well as previous studies on hatchling Blanding's turtles. Potential stressors include predation, freezing temperatures and high temperature variability, high water levels, road traffic, habitat loss and degradation, and climate change. The likelihood of occurrence of predation, cold and fluctuating temperatures, high water levels, and road mortality is high for any given year, although the level and frequency of exposure varies depending on the type of habitats that hatchlings occupy. Exposure to these stressors can result in direct mortality of the hatchling or leave hatchlings more susceptible to other sources of mortality. In contrast, the likelihood of habitat loss and disturbance as well as climate change is more uncertain, with exposure resulting in decreased hatchling survival due to one or several other sources of mortality. Because of the potential for multiple additive effects on hatchling survival, habitat loss/disturbance and climate change appear to pose a greater risk to hatchling Blanding's turtles than the more direct sources of mortality. These risks can be mitigated by minimizing the impacts of land use on habitats, by protecting habitats, either through stewardship activities or legislation, from further disturbance or degradation, and by engaging in activities that may help reduce greenhouse gas emissions and mitigate future climate change. Road mortality, which is another anthropogenic source of mortality, can also be reduced by managing traffic flow through the area, reducing speed limits, redirecting traffic, and posting signs that increase public awareness of the issue.

The advantages of a formal risk analysis approach lie in the explicit statement and detailed characterization of the risks. A thorough understanding of the nature of the risks is important in developing and selecting appropriate management alternatives that will effectively mitigate or minimize the risk. While it is common practice for field biologists to identify threats and their consequences for wildlife populations, these are typically done informally and in-depth studies of the nature of the risks are not always conducted. A formal risk analysis approach provides a systematic framework for identifying and studying the risks to wildlife populations, which can be useful when dealing with complex systems and can yield important information that may otherwise be overlooked. A formal risk analysis approach can also incorporate the needs and values of society in the decision-making process; this becomes particularly important in managing situations with potential for conflict between human and wildlife needs.

Decisions made and actions taken to manage risks and protect wildlife become part of the policy to address the problem. In general, policy can be defined as a guideline or a course of action adopted by any individual or organization, although studies of policy focus specifically on the analysis of public policy, or the decisions and activities of governments. Policy analysis provides a method of studying the process of developing, selecting, and implementing policy to address specific issues. It can also provide a useful framework for evaluating and refining current policies.

Policy analysis has previously been applied to studies of environmental policy, and also has potential applications for conservation biology. In this thesis, I performed an analysis of current biodiversity and habitat protection policies in Canada to determine the suite of policy instruments currently in use and available for protecting biodiversity and wildlife habitats. I then focused more specifically on the protection of Blanding's turtles in Nova Scotia to identify which of the available policy instruments have been used, as well as their relative effectiveness. Results of the analysis show that a variety of regulatory, economic, information and voluntary policy instruments, such as legislation, tax incentives, grants and subsidies, public awareness campaigns, and stewardship opportunities, are available and used to protect biodiversity and habitats in Canada. Of these, information instruments such as posters, educational programs and community outreach programs have been successful in encouraging people to participate in various stewardship activities to protect Blanding's turtles. Economic instruments such as grants and subsidies and fee simple acquisitions have also been effective in protecting Blanding's turtles, although other economic incentives such as conservation easements, servitudes, or covenants have not played a significant role in Blanding's turtle conservation thus far. In contrast, regulatory instruments have played a relatively minor role in the protection of Blanding's turtles, providing only a baseline protection in the form of prohibitions on the harm or disturbance of listed species and habitats and guidelines for recovery activities. Future conservation initiatives should therefore encourage the use of other economic instruments to promote Blanding's turtle conservation, as well as increase pressure on governments to create and enforce stronger legislation for protecting wildlife and their habitats.

Ultimately, conservation biology seeks to protect biodiversity by reducing and mitigating human impact on species and ecosystems. To do this effectively requires the translation of scientific knowledge into concrete solutions, ways in which risks can be minimized or mitigated and populations can be recovered. It is therefore important that scientific research be fully integrated into management programs, ensuring that the relevant questions are asked and that the answers are communicated, understood, and utilized by managers. In addition, all conservation efforts, from species reintroductions and translocations to creation of large reserves and protected areas, also require the support of various stakeholders and the larger community, which to some extent can be won with the help of various policy instruments for protecting biodiversity and wildlife habitats. Conservation biology, therefore, relies not just on science to provide information about the species or ecosystem in question, but also on the social sciences to help identify society's needs and values and incorporate them into the decision-making process. Science, management, and policy play equally important roles in conservation, and all three must be given adequate consideration to ensure the successful protection and recovery of biodiversity.

Reference List

Akçakaya, H. R. 2001. Linking population-level risk assessment with landscape and habitat models. Science of the Total Environment **274**:283-291.

Ames, B. N., R. Magaw, and L. S. Gold. 1987. Ranking possible carcinogenic hazards. Science **236**:271-280.

Andersen, M. C., H. Adams, B. Hope, and M. Powell. 2004. Risk assessment for invasive species. Risk Analysis **24**:787-793.

Archer, D. 2002. Creating a risk management framework. CMA Management **76**:16-19.

Baillie, J. E. M., C. Hilton-Taylor, and S. N. Stuart, editors. 2004. 2004 IUCN Red List of Threatened Species. A Global Species Assessment. IUCN, Gland, Switzerland and Cambridge, UK.

Beissinger, S. R. 1997. Integrating behavior into conservation biology: Potentials and limitations. Pages 23-47 in J. R. Clemmons and R. Buchholz, editors. Behavioral Approaches to Conservation in the Wild. Cambridge University Press, Cambridge, UK.

Blanding's Turtle Recovery Team. 2002. National recovery plan for the Blanding's turtle (*Emydoidea blandingii*) Nova Scotia population. Nova Scotia, Canada.

Blanding's Turtle Recovery Team. 2006a. Blanding's turtle PVA and Critical Habitat Workshop, March 6-7, 2006, Acadia University. Unpublished report presented to Blanding's Turtle Recovery Meeting, November 2006, Wolfville, NS.

Blanding's Turtle Recovery Team. 2006b. Nova Scotia's Blanding's Turtles Conservation and Recovery. Blanding's Turtle Recovery Team. Available from http://www.speciesatrisk.ca/blandings/index.html (accessed July 3 2007).

Blanding's Turtle Recovery Team. 2007. Standard research and handling procedures for Nova Scotia Blanding's turtles. Nova Scotia, Canada.

Bowater. 2007. Bowater Incorporated Environmental Highlights. Bowater. Available from http://www.bowater.com/en/highlights.shtml (accessed June 20 2007).

Boyce, M. S. 1992. Population viability analysis. Annual Review of Ecology and Systematics **23**:481-506.

Bräuer, I. 2003. Money as an indicator: To make use of economic evaluation for biodiversity conservation. Agriculture, Ecosystems and Environment **98**:483-491.

Bressers, H. T. A., and L. J. O'Toole, Jr. 1998. The selection of policy instruments: A network-based perspective. Journal of Public Policy **18**:213-239.

Britson, C. A., and W. H. N. Gutzke. 1993. Antipredator mechanisms of hatchling freshwater turtles. Copeia **1993**:435-440.

Bulte, E., and G. C. van Kooten. 2000. Economic science, endangered species, and biodiversity loss. Conservation Biology **14**:113-119.

Burgman, M. A., S. Ferson, and H. R. Akçakaya. 1993. Risk Assessment in Conservation Biology. Chapman & Hall, London, UK.

Butler, B. O., and T. E. Graham. 1993. Tracking hatchling Blanding's turtles with flourescent pigments. Herpetological Review **24**:21-22.

Butler, B. O., and T. E. Graham. 1995. Early post-emergent behavior and habitat selection in hatchling Blanding's turtles, *Emydoidea blandingii*, in Massachusetts. Chelonian Conservation and Biology **1**:187-196.

Byrd, D. M., and C. R. Cothern. 2000. Introduction to Risk Analysis. Government Institutes, Rockville, Maryland, USA.

Canadian Wildlife Service. 2006. Habitat Stewardship Program. Environment Canada. Available from http://www.cws-scf.ec.gc.ca/hsp-pih/default.asp?lang=En&n=59BF488F-1 (accessed July 3 2007).

Cardskadden, H., and D. J. Lober. 1998. Environmental stakeholder management as business strategy: The case of the corporate wildlife habitat enhancement programme. Journal of Environmental Management **52**:183-202.

Caverhill, B. P. 2006. Blanding's Turtle Conservation in Nova Scotia: Linking Science and Stewardship Through Public Education. MSc Thesis. Acadia University, Wolfville, Nova Scotia, Canada.

Chee, Y. E. 2004. An ecological perspective on the valuation of ecosystem services. Biological Conservation **120**:549-565.

Christensen, J. H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R. K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C. G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton. 2007. Regional Climate Projections. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, New York, USA.

Clemmons, J. R., and R. Buchholz. 1997. Linking conservation and behavior. Pages 3-22 in J. R. Clemmons and R. Buchholz, editors. Behavioral Approaches to Conservation in the Wild. Cambridge University Press, Cambridge, UK.

Congdon, J. D., A. E. Dunham, and R. C. Van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): Implications for conservation and management of long-lived organisms. Conservation Biology **7**:826-833.

Corporate Research Associates. 2002. 2000 Nova Scotia visitor traffic flow report. Final report. Nova Scotia Department of Tourism and Culture, Nova Scotia, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2007a. Canadian Species at Risk. Committee on the Status of Endangered Wildlife in Canada. Available from http://www.cosewic.gc.ca/eng/sct0/rpt/dsp_booklet_e.htm (accessed June 14 2007).

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2007b. COSEWIC. Government of Canada. Available from http://www.cosewic.gc.ca/eng/sct5/index_e.cfm (accessed July 3 2007).

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature **387**:253-260.

Costanzo, J. P., J. B. Iverson, M. F. Wright, and R. E. Lee, Jr. 1995. Cold hardiness and overwintering strategies of hatchlings in an assemblage of northern turtles. Ecology **76**:1772-1785.

Covello, V. T., and J. Mumpower. 1985. Risk analysis and risk management: An historical perspective. Risk Analysis **5**:103-120.

Covello, V. T., and M. W. Merkhofer. 1993. Risk Assessment Methods. Approaches for Assessing Health and Environmental Risks. Plenum Press, New York, New York, USA.

CPAWS (Canadian Parks and Wilderness Society). 2007. Canadian Parks and Wilderness Society. Canadian Parks and Wilderness Society. Available from http://www.cpaws.org/ (accessed July 3 2007).

Cullen, R., K. F. D. Hughey, G. Fairburn, and E. Moran. 2005. Economic analyses to aid nature conservation decision making. Oryx **39**:327-334.

Cumming, R. B. 1981. Is risk assessment a science? Risk Analysis **1**:1-3.

Daily, G. C. 1997. Introduction: What are ecosystem services? Pages 1-10 in G. C. Daily, editor. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C. and Covelo, California, USA.

Davis, D. S., and S. Browne, editors. 1996. Natural History of Nova Scotia. Vol 1. Revised edition. Province of Nova Scotia and Nimbus Publishing, Nova Scotia, Canada.

Deisler, P. F., Jr. 2002. A perspective: Risk analysis as a tool for reducing the risks of terrorism. Risk Analysis **22**:405-413.

Department of Natural Resources. 2006a. Nova Scotia Habitat Conservation Fund. Department of Natural Resources, Province of Nova Scotia. Available from http://www.gov.ns.ca/natr/wildlife/habfund/ (accessed July 3 2007).

Department of Natural Resources. 2006b. Nova Scotia Species at Risk Conservation Fund. Department of Natural Resources, Province of Nova Scotia. Available from http://www.gov.ns.ca/natr/wildlife/sarfund/ (accessed July 3 2007).

Derby, S. L., and R. L. Keeney. 1981. Risk analysis: Understanding 'How safe is safe enough?' Risk Analysis **1**:217-224.

Dinkelacker, S. A., J. P. Costanzo, and R. E. Lee, Jr. 2005. Anoxia tolerance and freeze tolerance in hatchling turtles. Journal of Comparative Physiology B **175**:209-217.

Dinkelacker, S. A., J. P. Costanzo, J. B. Iverson, and R. E. Lee, Jr. 2004. Cold-hardiness and dehydration resistance of hatchling Blanding's turtles (*Emydoidea blandingii*): Implications for overwintering in a terrestrial habitat. Canadian Journal of Zoology **82**:594-600.

Dooley, J. E. 1990. Risk Analysis for Health and Environmental Management. Environmental Management Development in Indonesia, Halifax, Nova Scotia, Canada and Jakarta, Indonesia.

Dore, M. H. I., and D. Webb. 2003. Valuing biodiversity: Reality or mirage? Environmental Monitoring and Assessment **86**:91-104.

Dunn, W. N. 1988. Methods of the second type: Coping with the wilderness of conventional policy analysis. Policy Studies Review **7**:720-737.

Edwards, P. J., and C. Abivardi. 1998. The value of biodiversity: Where ecology and economy blend. Biological Conservation **83**:239-246.

Efroymson, R. A., and G. W. Suter II. 2001. Ecological risk assessment framework for low-altitude aircraft overflights: II. Estimating effects on wildlife. Risk Analysis **21**:263-274.

Efroymson, R. A., G. W. Suter II, W. H. Rose, and S. Nemeth. 2001. Ecological risk assessment framework for low-altitude aircraft overflights: I. Planning the analysis and estimating exposure. Risk Analysis **21**:251-262.

Environment Canada. 2004. Canadian Climate Normals 1971-2000. Environment Canada. Available from http://www.climate.weatheroffice.ec.gc.ca/climate_normals/results_e.html?Province=NS%20%20&StationName=&SearchType=&LocateBy=Province&Proximity=25&ProximityFrom=City&StationNumber=&IDType=MSC&CityName=&ParkName=&LatitudeDegrees=&LatitudeMinutes=&LongitudeDegrees=&LongitudeMinutes=&NormalsClass=A&SelNormals=&StnId=6372& (accessed June 18 2007).

Environment Canada. 2005. Species at Risk. Blanding's Turtle Nova Scotia Population. Environment Canada. Available from http://www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=276 (accessed October 23 2005).

Environment Canada. 2006a. Species at Risk – Home. Environment Canada, Government of Canada. Available from http://www.speciesatrisk.gc.ca/default_e.cfm (accessed July 3 2007).

Environment Canada. 2006b. Water Survey of Canada – Archived Hydrometric Data. Environment Canada. Available from http://www.wsc.ec.gc.ca/hydat/H2O/index_e.cfm?cname=main_e.cfm (accessed June 18 2007).

Environment Canada. 2007a. Atlantic Climate Centre – The Climate of Nova Scotia. Environment Canada. Available from http://atlantic-web1.ns.ec.gc.ca/climatecentre/default.asp?lang=En&n=61405176-1 (accessed June 18 2007).

Environment Canada. 2007b. Monthly Data. Environment Canada. Available from http://www.climate.weatheroffice.ec.gc.ca/climateData/monthlydata_e.html (accessed June 18 2007).

EPA (U.S. Environmental Protection Agency). 1992. Framework for ecological risk assessment. EPA/630/R-92/001. Risk Assessment Forum, Washington, D.C., USA.

EPA (U.S. Environmental Protection Agency). 1998. Guidelines for ecological risk assessment. EPA/630/R-95/002F. Risk Assessment Forum, Washington, D.C., USA.

EPA (U.S. Environmental Protection Agency). 2005. Wildlife research strategy. EPA/600/R-04/050. Office of Research and Development, Research Triangle Park, North Carolina, USA.

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

Fischhoff, B., S. R. Watson, and C. Hope. 1984. Defining risk. Policy Sciences **17**:123-139.

Food Safety Risk Analysis Unit. 2006. Risk analysis framework to address animal health, plant health and food safety risks within the Canadian Food Inspection Agency. Canadian Food Inspection Agency. Available from http://www.inspection.gc.ca/english/fssa/ris/fracade.shtml#1note (accessed June 10 2007).

Franklin, J. F. 1993. Preserving biodiversity: Species, ecosystems, or landscapes? Ecological Applications **3**:202-205.

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

Goulder, L. H., and D. Kennedy. 1997. Valuing ecosystem services: philosophical bases and empirical methods. Pages 23-47 in G. C. Daily, editor. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C. and Covelo, California, USA.

Government of Canada. 2007. SARA Public Registry – Homepage. Government of Canada. Available from http://www.sararegistry.gc.ca/default_e.cfm (accessed July 3 2007).

Graham, J. D. 1995. Historical perspective on risk assessment in the federal government. Toxicology **102**:29-52.

Green, N. 2007. Personal communication. Halifax, Nova Scotia, Canada.

Gregory, R. S. 2004. Valuing risk management choices. Pages 213-250 in T. L. McDaniels and M. J. Small, editors. Risk Analysis and Society. An Interdisciplinary Characterization of the Field. Cambridge University Press, Cambridge, UK.

Hattis, D., and D. Kennedy. 1986. Assessing risks from health hazards: An imperfect science. Technology Review **89**:60-71.

Heinkel, R., A. Kraus, and J. Zechner. 2001. The effect of green investment on corporate behavior. Journal of Financial and Quantitative Analysis **36**:431-449.

Hels, T., and E. Buchwald. 2001. The effect of road kills on amphibian populations. Biological Conservation **99**:331-340.

Herman, T. B., T. D. Power, and B. R. Eaton. 1995. Status of Blanding's turtles, *Emydoidea blandingii*, in Nova Scotia, Canada. Canadian Field Naturalist **109**:182-191.

Herman, T., J. S. Bleakney, J. S. Boates, C. Drysdale, J. Gilhen, I. Morrison, T. Power, K. L. Standing, and M. Elderkin. 1999. National Recovery Plan for Blanding's Turtle (*Emydoidea blandingii*) Nova Scotia population. Report No. 18. Recovery of Nationally Endangered Wildlife Committee, Ottawa, Ontario, Canada.

Hertz, D. B., and H. Thomas. 1983. Risk Analysis and its Applications. John Wiley & Sons, Chichester, UK.

Hessing, M., M. Howlett, and T. Summerville. 2005. Canadian Natural Resource and Environmental Policy. 2nd Edition. UBC Press, Vancouver, British Columbia, Canada.

Holohil Systems Ltd. 2006. Holohil Systems Ltd. – Transmitters. Holohil Systems Ltd. Available from http://www.holohil.com/xmtrs.htm (accessed April 13 2006).

Holton, G. A. 2004. Defining risk. Financial Analysts Journal **60**:19-25.

Hood, C. C. 1983. The Tools of Government. McMillan Press Ltd., London and Basingstoke, UK.

Howlett, M. 1991. Policy instruments, policy styles, and policy implementation: National approaches to theories of instrument choice. Policy Studies Journal **19**:1-21.

Howlett, M. and M. Ramesh. 2003. Studying Public Policy: Policy Cycles and Policy Subsystems. 2nd Edition. Oxford University Press, Don Mills, Ontario, Canada.

Janzen, F. J. 1993. An experimental analysis of natural selection on body size of hatchling turtles. Ecology **74**:332-341.

Kaplan, S., and B. J. Garrick. 1981. On the quantitative definition of risk. Risk Analysis **1**:11-27.

Kenward, R. E. 2001. A Manual for Wildlife Radio Tagging. Academic Press, London, UK.

Kolbe, J. J., and F. J. Janzen. 2001. The influence of propagule size and maternal nest-site selection on survival and behaviour of neonate turtles. Functional Ecology **15**:772-781.

Kolbe, J. J., and F. J. Janzen. 2002. Experimental analysis of an early life-history stage: Water loss and migrating hatchling turtles. Copeia **2002**:220-226.

Kraft, M. E. 1982. The use of risk analysis in federal regulatory agencies: An exploration. Policy Studies Review **1**:666-675.

Lackey, R. T. 1997. Ecological risk analysis. Pages 87-97 in V. Molak, editor. Fundamentals of Risk Analysis and Risk Management. CRC Press, Boca Raton, Florida, USA.

Landis, W. G. 2003. Ecological risk assessment conceptual model formulation for nonindigenous species. Risk Analysis **24**:847-858.

Leakey, R. E., and R. Lewin. 1995. The Sixth Extinction: Biodiversity and its Survival. Phoenix, London, UK.l

Linder, S. H., and B. G. Peters. 1989. Instruments of government: Perceptions and contexts. Journal of Public Policy **9**:35-58.

Lowrance, W. W. 1980. The nature of risk. Pages 5-14 in R. C. Schwing and W. A. Albers, Jr., editors. Societal Risk Assessment. How Safe is Safe Enough? Plenum Press, New York, New York, USA.

MacDonald, R. 2007. Premier's Speeches – Bowater Lands Acquisitions. Province of Nova Scotia. Available from http://www.gov.ns.ca/premier/speeches/2007-03-19-Bowater.asp (accessed June 20 2007).

Martin, P., and P. Bateson. 1993. Measuring Behaviour: An Introductory Guide. 2nd Edition. Cambridge University Press, Cambridge, UK.

McGee, M. W. 2005. Measuring the payoffs of strategic risk management. CMA Management **79**:30-35.

McMaster, N. L., and T. B. Herman. 2000. Occurrence, habitat selection and movement patterns of juvenile Blanding's turtles (*Emydoidea blandingii*) in Kejimkujik National Park, Nova Scotia. Chelonian Conservation and Biology **3**:602-610.

McNeil, J. A., T. B. Herman, and K. L. Standing. 2000. Movement of hatchling Blanding's turtles (*Emydoidea blandingii*) in Nova Scotia in response to proximity to open water: A manipulative experiment. Chelonian Conservation and Biology **3**:611-617.

Michelson, G., N. Wailes, S. van der Laan, and G. Frost. 2004. Ethical investment processes and outcomes. Journal of Business Ethics **52**:1-10.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, D.C., USA.

Mockford, S. W., L. McEachern, T. B. Herman, M. Snyder, and J. M. Wright. 2005. Population genetic structure of a disjunct population of Blanding's turtle (*Emydoidea blandingii*) in Nova Scotia, Canada. Biological Conservation **123**:373-380.

Morrison, I. 1996. A study of head started Blanding's turtle (*Emydoidea blandingii*) hatchlings in Kejimkujik National Park. Parks Canada, Atlantic Region, Halifax, Nova Scotia, Canada.

Morrison, I., S. O'Grady, L. Vasseur, and N. Green. 2004. Human use impact assessment and rehabilitation of a campground at Kejimkujik National Park and National Historic Site of Canada. Research and Development Monograph Series, 2001. Canadian Environmental Assessment Agency, Ottawa, Ontario, Canada.

Munns, W. R., Jr. 2006. Assessing risks to wildlife populations from multiple stressors: overview of the problem and research needs. Ecology and Society **11**:23 [online]. Available from http://www.ecologyandsociety.org/vol11/iss1/art23/ (accessed April 16 2007).

Nagel, S. S. 1990. Introduction: Bridging theory and practice in policy/program evaluation. Pages ix-xxiv in S. S. Nagel, editor. Policy Theory and Evaluation: Concepts, Knowledge, Causes, and Norms. Greenwood Press, Westport, Connecticut, USA.

Nature Conservancy of Canada. 2006. The Nature Conservancy of Canada: Protecting Priority Landscapes. Nature Conservancy of Canada. Available from http://www.natureconservancy.ca/site/PageServer?pagename=ncc_main (accessed July 3 2007).

Nova Scotia Public Lands Coalition. 2006. Nova Scotia Public Lands Coalition. Ecology Action Centre. Available from http://www.publicland.ca/home/index.html (accessed July 3 2007).

NRC (National Research Council). 1983. Risk Assessment in the Federal Government: Managing the Process. National Academy Press, Washington, D.C., USA.

NSNT (Nova Scotia Nature Trust). 2007. NSNT – Home. Nova Scotia Nature Trust. Available from http://www.nsnt.ca/ (accessed July 3 2007).

Nunes, P. A. L. D., and J. C. J. M. van den Bergh. 2001. Economic valuation of biodiversity: Sense or nonsense? Ecological Economics **39**:203-222.

OECD (Organisation for Economic Co-operation and Development). 1996. Saving Biological Diversity: Economic Incentives. OECD, Paris, France.

Omenn, G. S. 1995. Assessing the risk assessment paradigm. Toxicology **102**:23-28.

Packard, G. C., M. J. Packard, J. W. Lang, and J. K. Tucker. 1999. Tolerance for freezing in hatchling turtles. Journal of Herpetology **33**:536-543.

Parkhurst, G. M., and J. F. Shogren. 2005. An economic review of incentive mechanisms to protect species on private lands. Pages 65-127 in J. F. Shogren, editor. Species at Risk: Using Economic Incentives to Shelter Endangered Species on Private Lands. University of Texas Press, Austin, Texas, USA.

Parren, S. G., and M. A. Rice. 2004. Terrestrial overwintering of hatchling turtles in Vermont nests. Northeastern Naturalist **11**:229-233.

Pimm, S. L., G. J. Russell, J. L. Gittleman, and T. M. Brooks. 1995. The future of biodiversity. Science **269**: 347-350.

Rechard, R. P. 1999. Historical relationship between performance assessment for radioactive waste disposal and other types of risk assessment. Risk Analysis **19**:763-807.

Reed, J. M., L. S. Mills, J. B. Dunning, Jr., E. S. Menges, K. S. McKelvey, R. Frye, S. R. Beissinger, M.-C. Anstett, and P. Miller. 2002. Emerging issues in population viability analysis. Conservation Biology **16**:7-19.

Refsnider, J. M. 2005. Reproductive Ecology of Blanding's Turtles (*Emydoidea blandingii*) in East-central Minnesota. M.S. Thesis. University of Minnesota, Minnesota, USA.

Reyers, B., A. S. Van Jaarsveld, M. A. McGeoch, and A. N. James. 1998. National biodiversity risk assessment: A composite multivariate and index approach. Biodiversity and Conservation **7**:945-965.

Rodricks, J., and M. R. Taylor. 1983. Application of risk assessment to food safety decision making. Regulatory Toxicology and Pharmacology **3**:275-284, 302-307.

Rowe, J. W., and E. O. Moll. 1991. A radiotelemetric study of activity and movements of the Blanding's turtle *Emydoidea blandingii* in Northeastern Illinois, USA. Journal of Herpetology **25**:178-185.

Ruckelshaus, W. D. 1983. Science, risk, and public policy. Science **221**:1026-1028.

SCBD (Secretariat of the Convention on Biological Diversity). 2001-2005. The Convention on Biological Diversity. UNEP (United Nations Environment Program). Available from http://www.biodiv.org/convention/default.shtml (accessed on March 14 2006).

Sierra Club of/du Canada. 2007. Welcome to the Sierra Club of Canada! Sierra Club of/du Canada. Available from http://www.sierraclub.ca/index.shtml (accessed July 3 2007).

Simberloff, D. 1998. Flagships, umbrellas, and keystones: Is single-species management passé in the landscape era? Biological Conservation **83**:247-257.

Slovic, P. 1997. Risk perception and trust. Pages 233-245 in V. Molak, editor. Fundamentals of Risk Analysis and Risk Management. CRC Press, Boca Raton, Florida, USA.

Slovic, P., B. Fischhoff, and S. Lichtenstein. 1980. Facts and fears: Understanding perceived risk. Pages 181-214 in R. C. Schwing and W. A. Albers, Jr., editors. Societal Risk Assessment. How Safe is Safe Enough? Plenum Press, New York, New York, USA.

Smith, D. A. 2004. Dispersal of Neonate Blanding's Turtles (*Emydoidea blandingi*) in Nova Scotia. M.Sc. Thesis. Acadia University, Wolfville, Nova Scotia, Canada.

Smith, D., and Caverhill, B. 2006. Volunteer News 2006 for the Greater Kejimkujik Ecosystem. Nova Scotia, Canada.

Soulé, M. E. 1985. What is conservation biology? BioScience **35**:727-734.

Standing, K. L., T. B. Herman, and I. P. Morrison. 1999. Nesting ecology of Blanding's turtle (*Emydoidea blandingii*) in Nova Scotia, the northeastern limit of the species' range. Canadian Journal of Zoology **77**:1609-1614.

Standing, K. L., T. B. Herman, D. D. Hurlburt, and I. P. Morrison. 1997. Postemergence behaviour of neonates in a northern peripheral population of Blanding's turtle, *Emydoidea blandingii*, in Nova Scotia. Canadian Journal of Zoology **75**:1387-1395.

Stanley, D. L. 2005. Local perception of public goods: Recent assessments of willingness-to-pay for endangered species. Contemporary Economic Policy **23**:165-179.

Stohlgren, T. J., and J. L. Schnase. 2006. Risk analysis for biological hazards: What we need to know about invasive species. Risk Analysis **26**:163-173.

Strategy Unit. 2002. Risk: Improving government's capability to handle risk and uncertainty. Full report – a source document. Strategy Unit, Cabinet Office, London, UK.

Suter, G. W. II. 1999. A framework for assessment of ecological risks from multiple activities. Human and Ecological Risk Assessment **5**:397-413.

Thébault, E., and M. Loreau. 2005. Trophic interactions and the relationship between species diversity and ecosystem stability. American Naturalist **166**:E95-E114.

Tilman, D. 1997. Biodiversity and ecosystem functioning. Pages 93-112 in G. C. Daily, editor. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C. and Covelo, California, USA.

Torgerson, D. 1986. Between knowledge and politics: three faces of policy analysis. Policy Sciences **19**:33-59.

Treasury Board of Canada Secretariat. 2001. Integrated Risk Management Framework. Treasury Board of Canada Secretariat. Available from http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/riskmanagement/rmf-cgr_e.asp (accessed June 10 2007)

Tucker, J. K. 2000. Body size and migration of hatchling turtles: Inter- and intraspecific comparisons. Journal of Herpetology **34**:541-546.

Turner, R. K., J. Paavola, P. Cooper, S. Farber, V. Jessamy, and S. Georgiou. 2003. Valuing nature: Lessons learned and future research directions. Ecological Economics **46**:493-510.

UN/DESA (United Nations/ Department of Economic and Social Affairs). 2002. Johannesburg Summit 2002: Key Outcomes of the Summit. UN, New York, USA.

UNEP/CBD (United Nations Environment Program/Convention on Biological Diversity). 2002. Report of the Sixth Meeting of the Conference of the Parties to the Convention on Biological Diversity. CBD, The Hague, Netherlands.

Vedung, E. 1998. Policy instruments: Typologies and theories. Pages 21-58 in M-L. Bemelmans-Videc, R. C. Rist, and E. Vedung, editors. Carrots, Sticks and Sermons: Policy Instruments and their Evaluation. Transaction Publishers, New Brunswick, New Jersey, USA.

Weber, M., and W. Adamowicz. 2002. Tradable land-use rights for cumulative environmental effects management. Canadian Public Policy **28**:581-595.

White, G. C., and R. A. Garrott. 1990. Analysis of Wildlife Radio-Tracking Data. Academic Press, San Diego, California, USA.

Wildlife Habitat Canada. 2007. Wildlife Habitat Canada. Wildlife Habitat Canada/Habitat Faunique Canada. Available from http://www.whc.org/EN/home.htm (accessed June 20 2007).

Wildlife Habitat Canada/Habitat Faunique Canada. 1999-2007a. WHC – Grant Program. Wildlife Habitat Canada/Habitat Faunique Canada. Available from http://www.whc.org/EN/grant/grant_program.htm (accessed July 3 2007).

Wildlife Habitat Canada/Habitat Faunique Canada. 1999-2007b. Wildlife Habitat Canada. Wildlife Habitat Canada/Habitat Faunique Canada. Available from http://www.whc.org/EN/home.htm (accessed July 3 2007).

WWF-Canada. 2007a. Endangered Species Recovery Fund. WWF-Canada. Available from http://www.wwf.ca/NewsAndFacts/Projects/ESRF.asp?lang=EN (accessed July 3 2007).

WWF-Canada. 2007b. Welcome to WWF-Canada. WWF-Canada. Available from http://www.wwf.ca/ (accessed July 3 2007).

Zar, J. H. 1999. Biostatistical Analysis. 4th Edition. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Zhang, Y., and Y. Li. 2005. Valuing or pricing natural and environmental resources? Environmental Science and Policy **8**:179-186.

Appendix A. Transmitter Attachment Protocol

Individual hatchlings from selected nests will be outfitted with radio-transmitters to allow researchers to follow their movements during fall and winter. Transmitters are attached to the hatchlings in the field after hatchlings have been removed from the nest cages following emergence, processed, and given individual notch codes, and before they are released near the nest site.

- Ideally, the transmitter and Velcro together should be under 10% of the hatchling's weight. Transmitters may be attached to hatchlings 7.0g or larger; hatchlings around 6.8g or 6.9g should be assessed on an individual basis and used in the study only if they appear healthy and active. No transmitters will be attached to hatchlings with missing limbs or other deformities that may interfere with growth and survival.
- The transmitter should be checked to make sure it works before attaching to the hatchling. The transmitter serial number and frequency as well as the individual notch code of the hatchling to which it is attached must be recorded on the lists provided.
- Radio-transmitters are attached to the rear of the carapace and oriented so the antenna extends to the rear. Transmitters are attached to the carapace through a small piece of Velcro glued to the carapace and the transmitter by 5-minute epoxy (Home-Bond 5 Minute Rapid Setting Epoxy Gel works well).
- Before gluing the Velcro to the hatchling, ensure that the carapace is clean and dry. Apply a thin layer of the epoxy to the adhesive of the Velcro, then press the Velcro firmly but carefully to the rear of the carapace, off to the left or right side. The Velcro must be held on to the carapace for 5 minutes or until the epoxy sets, ensuring that the Velcro does not shift or fall off.
- A similar procedure is used to glue the Velcro to the transmitter. First, cut out a small piece of matching Velcro just big enough to cover the broad, flat side of the transmitter. Remove the tape covering the adhesive, spread a thin layer of epoxy onto the adhesive and gently place the transmitter, serial # side down) on top of

the epoxy. Again, wait at least 5 minutes for the epoxy to set, keeping it dry and ensuring that the Velcro does not shift positions. It is recommended that this procedure be performed prior to going out in the field.

- Once the epoxy has set and the Velcro does not appear to be in danger of shifting or falling off, the transmitter can be attached to the carapace by carefully pressing the two sides of the Velcro together. Ensure that both sides are in full contact with one another and that gaps are minimized as much as possible to prevent snagging.
- Hatchlings are kept for 45 minutes to 1 hour before being released to ensure that the hatchling stays dry and that the epoxy dries properly. Reweigh the hatchlings before releasing to determine how much weight has been added by attaching the transmitter.
- Hatchlings must be initially monitored following release to ensure that movements are normal and unimpeded. Record any unusual behaviour that may have been due to transmitter attachment. If hatchling movements are severely hampered by the transmitter, remove the transmitter from the hatchling.
- It is important that the transmitter is removed before batteries are drained. This will occur around 12 days for a 0.42g/0.44g transmitter and 3 weeks for a 0.55g/0.59g transmitter. Transmitters can be removed by simply peeling apart the 2 pieces of Velcro. A new transmitter is then attached to the hatchling.
- If the transmitter will not be replaced, remove the Velcro piece from the carapace by gently peeling it off. The epoxy should easily come off with the Velcro.

Appendix B. Hatchling Observation Data Cards

BLANDING'S TURTLE HATCHLING OBSERVATION CARD - 2006

ID: ___,___-___,___ **Name** __________________
Nest ID: __________ **Female ID:** ___,___-___,____
Date(dd-mmm-yyyy)_______________ **Time**________

Capture method □ Habitat measurement □ Powder Tracking
□ Radio Tracking (Freq.__________) □ Incidental to tracking

Capture type □ Turtle Seen □ Pinpointed but not seen
□ General location (clarify in comments)
□ Not found (clarify in comments)

Observers________________________________

Population____________**Project** ____________
Area ______________**Section** ____________
Location description ____________________

UTM (please use NAD 83 datum)
East:3 __ __ __ __ __ **North**:4__ __ __ __ __ __
Source □ GPS-Avg. □ GPS-Single Pt. □ Other (put in comments)
Accuracy __________m

Weather
Precipitation:______________Cloud Cover:__________%
Wind speed: □ Calm □ Light □ Moderate □ Strong
Wind Direction (direction wind is from): __________
Air Temp:_______°C Water temp: _____°C

Behaviour (*check only 1*) □ Foraging/Eating □ Atmospheric Basking
□ Aquatic Basking □ Terrestrial Active □ Aquatic Active
□ Terrestrial Stationary □ Aquatic Stationary □ Other:________
Did the hatchling appear disturbed by observers? □Yes □No

Position
In water: □ Submerged □ Carapace Exposed □ Head Exp.
On land: □ All Exposed □ Partially Covered □ Covered
Dist. from: *nearest water* _____m *or nearest land* _______m
Orientation of hatchling: ___________° from True North

Substrate/Perch □ Water □ Sphagnum □ Grass
□ Forest leaf litter □ Outcrop □ Cobble/Rock □ Soil/Mud
□ Beach leaf litter □ Sand □ Gravel/Pebble □ Beneath organic
□ Emergent veg. □ Bottom □ Log/Sticks □ Other:________
Temperature: ____________°C
Moisture: *surface:* □ Dry □ Moist □ Wet □ Saturated/Flooded
1-2 cm below surface: □ Dry □ Moist □ Wet □ Saturated/Flooded

Comments ____

Figure B.1. Front side of the observation card, with data collected at the time that each hatchling was radio-tracked and located.

Habitat (*check only 1*) □ Lake □ Bog □ Offshoot Channel □ Trench/Ditch □ Paved Road □ Roadside
□ River □ Cove □ Fen □ Cut-off Channel □ Beach □ Gravel Road/Track □ Other:______
□ Brook/Creek □ Pond □ Swamp □ Bog Pool/Channel □ Woodland □ Gravel Pit/Borrow Pit
Microhabitat at sighting □ Terrestrial □ Flooded □ Normally aquatic

Observers:______________________________ **Date:**__________________
Within 1m radius of hatchling % aquatic_____
Water: Depth_________m **Width**_________m
Velocity □ No flow □ Slow □ Fast **Shoreline** □ Linear □ Convoluted □ Hummocky
Exposed bank type (*rank*) ____Undercut ____Vertical ____Sloping ____Flat
Submerged bank type (*rank*) ____Undercut ____Vertical ____Sloping ____Flat
Bottom Substrate (*rank*)____Soft Mud/Organic ____Hard Mud ____Clay ____ Sand
____Gravel Pebble ____Cobble/Rock ____Outcrop
Microrelief: □ Flat □ Constant slope: slope______° aspect________° □ Hummocky: avg. height__________
□ Uneven/irregular: avg. maximum height________ distance between max. height__________
Vegetation (*rank the 5 most abundant species in the 1m radius circle; include "open water/open" in rank)*
Aqu. submerged: 1. ________ 2. ________ 3. ________ 4. ________ 5. ________
Aqu. emergent: 1. ________ 2. ________ 3. ________ 4. ________ 5. ________
Bank Overhang: 1. ________ 2. ________ 3. ________ 4. ________ 5. ________
Terr. ground level: 1. ________ 2. ________ 3. ________ 4. ________ 5. ________
Terr. overstory: 1. ________ 2. ________ 3. ________ 4. ________ 5. ________
Vertical Structure Height above ground/water: 1. ________ 2. ________ 3. ________ 4. ________
Type (graminoid, forb, shrub, tree, etc.): 1. ________ 2. ________ 3. ________ 4. ________
Estimated % cover: 1. ________ 2. ________ 3. ________ 4. ________
Cover height above hatchling (from ground to vegetation directly above hatchling):________________
Photos: Ground ________ Canopy ________.
From 1m outside radius: North ________ East ________ South ________ West ________.

Figure B.2. Back side of the observation card. Habitat and microhabitat data were recorded at the time each hatchling was radio-tracked and located, while the rest were collected one to several days after the hatchling has moved away from the area.

Descriptions of data collected in the radio-tracking study

ID	- the unique notch code assigned to individual hatchlings in the study
Name	- the name of hatchling, if one was given
Nest ID	- unique code of the nest (assigned during the nesting season) from which the hatchling emerged
Female ID	- notch code assigned to the female that laid the clutch
Date	- date of observation
Time	- time of day that the hatchling was located
Capture Method	- method used to locate the hatchling. Hatchlings may be powder-tracked, radio-tracked, located while doing habitat measurements, or located while radio-tracking another individual.
Capture Type	- indicates how closely hatchlings were tracked and located
Observers	- names of individuals collecting the radio-tracking data
Population	- sub-population of Blanding's turtles that the hatchling is from
Project	- research project for which the data is collected, in this case, the project is Hatchling Tracking 2006
Area	- general area where hatchling is located, consistent with pre-defined areas used by Blanding's turtle research group
Section	- specific section where the hatchling is located, consistent with pre-defined sections used by Blanding's turtle research group
Location Description	- general description of the location of the hatchling,
UTM	- coordinates of the hatchling location, based on NAD 83 UTM Zone 20
Source	- method of determining UTM coordinates, whether by GPS-Avg (average of at least 60 single points), GPS-Single Pt, or Other (using a map or geo-referenced air photos)
Accuracy	- accuracy of the GPS reading, in metres

Weather	
Precipitation	- amount of precipitation at the time of observation, according to the following categories: None, Drizzle/Mist, Light Rain, Moderate/Heavy Rain, Flurries, Snow
Cloud Cover	- estimate of the percentage of cloud cover at the time of observation
Wind Speed	- estimated wind speed at the time of observation
Wind Direction	- approximate direction where the wind is coming from (*e.g.* N, NE, E, SE, S, SW, W, NW)
Air Temperature	- temperature in the shade
Water Temperature	- temperature in the water, if aquatic habitat is present
Behaviour	- observed activity of the hatchling at the time it is first seen
Position	- amount of exposure of hatchling on land or in water
Distance from nearest	- estimated distance (in metres) of hatchling location from the nearest land or water
Orientation	- direction, in degrees, that the hatchling is facing relative to true North
Substrate/Perch	
Type	- type of substrate or perch hatchling is on, or covered by
Temperature	- temperature of the substrate
Moisture	- moisture content of the substrate, both at the surface and 1 or 2 cm below
Comments	- other relevant information or detailed descriptions
Habitat Type	- type of habitat where the hatchling is found, generally
Microhabitat	- type of habitat at the specific location of hatchling, *i.e.*, whether hatchling is on dry land, in normally aquatic habitat, or in a flooded area
Observers	- names of individuals collecting habitat data
Date	- date when habitat characterization was conducted
% Aquatic	- amount of habitat submerged in water within a 1m radius of the hatchling location

Water	
Depth	- estimated average water depth in flooded or normally aquatic habitats within a 1m radius of the hatchling location
Width	- estimated average width of flooded or normally aquatic habitats within a 1m radius of the hatchling location
Velocity	- speed of water flow in flooded or normally aquatic habitats within a 1m radius of the hatchling location
Shoreline	- shape of the shoreline of flooded or normally aquatic habitats within a 1m radius of the hatchling location
Exposed Bank Type	- types of exposed banks of flooded or aquatic habitats within a 1m radius of the hatchling location, ranked based on dominance of specific types in the given area
Submerged Bank Type	- types of submerged banks of flooded or aquatic habitats within a 1m radius of the hatchling location, ranked based on the dominance of specific types in the given area
Bottom Substrate	- type of substrate at the bottom of flooded or normally aquatic habitats within a 1m radius of the hatchling location, ranked based on the dominance of specific types
Microrelief	- description of the unevenness of terrain within a 1m radius
Vegetation	- a list of the five most abundant plant species in each plant category within a 1m radius. "Open" or "open water" were used to represent the absence of vegetation
Vertical Structure	
Height	- different height classes of vegetation cover within a 1m radius of the hatchling location
Type	- types of vegetation at each recorded height class
% Cover	- estimate of the % cover provided by each height class
Cover Height	- height of the vegetation cover immediately above the hatchling
Photos	- file names/numbers of field photos showing different views of the microhabitat area within a 1m radius

Appendix C. Contingency Tables

Table C.1. Contingency table for testing the independence of hatchling behaviour and air temperature. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Behaviour			
Temperature†	Active	Basking	Stationary	Total
Freezing	0	0	17	17
	(1)	(0)	(16)	
Cool	10	1	203	214
	(13)	(6)	(196)	
Warm	19	13	227	259
	(15)	(7)	(237)	
Hot	2	0	30	32
	(2)	(1)	(29)	
Total	31	14	477	522

$X^2 = 17.0741$, d.f. = 6, p = 0.009

†Temperature data were grouped into discrete categories for the analysis. "Freezing" includes temperatures below 0°C, "cool" is from 0 – 10°C, "warm" is from 10 – 20°C, and "hot" includes temperatures above 20°C

Table C.2. Contingency table for testing the independence of hatchling behaviour and precipitation. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Behaviour			
Precipitation	Active	Basking	Stationary	Total
None	32	14	374	420
	(26)	(11)	(383)	
Drizzle/Mist	0	0	22	22
	(1)	(1)	(20)	
Light Rain	0	0	92	92
	(6)	(2)	(84)	
Moderate/Heavy Rain	3	0	3	6
	(0)	(0)	(5)	
Flurries	0	0	10	10
	(1)	(0)	(9)	
Snow	0	0	7	7
	(0)	(0)	(6)	
Total	35	14	508	557

$X^2 = 35.3129$, d.f. = 10, p = 0.0001

Table C.3. Contingency table for testing the independence of hatchling behaviour and cloud cover. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Behaviour			
Cloud Cover†	Active	Basking	Stationary	Total
None	2	0	30	32
	(2)	(1)	(29)	
Light Cloud	4	7	68	79
	(4)	(2)	(73)	
Partly Cloudy	5	3	33	41
	(2)	(1)	(38)	
Cloudy	18	1	342	361
	(20)	(8)	(332)	
Total	29	11	472	513

$X^2 = 27.0493$, d.f. = 6, p = 0.0001

†Cloud cover data were grouped into discrete categories for the analysis. "None" represent no cloud cover, "light cloud" includes cloud cover between 0 – 30%, "partly cloudy" is from 30 – 60%, and "cloudy" is from 60 – 100% cloud cover.

Table C.4. Contingency table for testing the independence of hatchling behaviour and time of day. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Behaviour			
Time of Day†	Active	Basking	Stationary	Total
Morning	1	0	38	39
	(2)	(1)	(36)	
Midday	26	10	323	359
	(23)	(9)	(327)	
Afternoon	8	4	146	158
	(10)	(4)	(144)	
Total	35	14	507	556

$X^2 = 4.3201$, d.f. = 4, p = 0.3644

†Observation times were grouped into discrete categories for the analysis. "Morning" includes observations occurring before 10:00, "midday" is from 10:00 – 14:00, and "afternoon" includes observations occurring after 14:00.

Table C.5. Contingency table for testing the independence of hatchling behaviour and hatchling position. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Behaviour			
Position	Active	Basking	Stationary	Total
All Exposed	12	8	44	64
	(4)	(2)	(58)	
Partially Covered	11	2	111	124
	(8)	(3)	(113)	
Covered	0	0	178	178
	(11)	(4)	(162)	
Head Exposed	3	1	12	16
	(1)	(0)	(15)	
Carapace Exposed	5	2	14	21
	(1)	(1)	(19)	
Submerged	4	1	149	154
	(10)	(4)	(140)	
Total	35	14	508	557

$X^2 = 82.8754$, d.f. = 10, $p < 0.0001$

Table C.6. Contingency table for testing the independence of hatchling behaviour and substrate/perch type. Expected frequencies for each cell are shown in parentheses below observed frequencies.

	Behaviour			
Substrate/Perch	Active	Basking	Stationary	Total
Bare Ground	3	2	17	22
	(1)	(1)	(20)	
Bottom	1	0	6	7
	(0)	(0)	(6)	
Emergent Vegetation	1	0	3	4
	(0)	(0)	(4)	
Ground Vegetation	27	11	413	451
	(29)	(11)	(411)	
Other	0	0	6	6
	(0)	(0)	(5)	
Water	2	0	44	46
	(3)	(1)	(42)	
Woody Vegetation	1	0	10	11
	(1)	(0)	(10)	
Total	35	13	499	547

$X^2 = 11.1677$, d.f. = 12, $p = 0.5146$

Table C.7. Contingency table for testing the independence of hatchling behaviour and microhabitat type. Expected frequencies for each cell are shown in parentheses below observed frequencies.

	Behaviour			
Microhabitat	Active	Basking	Stationary	Total
Flooded	7	3	103	113
	(7)	(3)	(103)	
Normally Aquatic	6	1	75	82
	(5)	(2)	(75)	
Terrestrial	22	10	328	360
	(23)	(9)	(328)	
Total	35	14	506	555

$X^2 = 0.9324$, d.f. = 4, $p = 0.9199$

Table C.8. Contingency table for testing the independence of hatchling behaviour and major habitat type. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Behaviour			
Habitat	Active	Basking	Stationary	Total
Terrestrial	20	6	195	221
	(14)	(6)	(201)	
Wetland	15	8	311	334
	(21)	(8)	(305)	
Total	35	14	506	555

$X^2 = 4.6654$, d.f. = 2, $p = 0.097$

Table C.9. Contingency table for testing the independence of hatchling position and air temperature. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Position						
Temperature†	All Exposed	Partially Covered	Covered	Head Exposed	Carapace Exposed	Submerged	Total
Freezing	0	1	6	0	0	10	17
	(2)	(4)	(5)	(0)	(1)	(5)	
Cool	10	41	72	6	11	76	216
	(27)	(48)	(69)	(6)	(7)	(60)	
Warm	51	64	74	7	7	58	261
	(32)	(58)	(83)	(7)	(9)	(72)	
Hot	4	10	15	1	0	2	32
	(4)	(7)	(10)	(1)	(1)	(9)	
Total	65	116	167	14	18	146	526

$X^2 = 61.6088$, d.f. = 15, $p < 0.0001$

†Temperature data were grouped into discrete categories for the analysis. "Freezing" includes temperatures below 0°C, "cool" is from 0 – 10°C, "warm" is from 10 – 20°C, and "hot" includes temperatures above 20°C

Table C.10. Contingency table for testing the independence of hatchling position and precipitation. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Position						
Precipitation	All Exposed	Partially Covered	Covered	Head Exposed	Carapace Exposed	Submerged	Total
None	50	98	132	12	16	116	424
	(49)	(94)	(135)	(12)	(16)	(118)	
Drizzle/Mist	3	4	8	1	1	5	22
	(3)	(5)	(7)	(1)	(1)	(6)	
Light Rain	8	20	29	3	3	29	92
	(11)	(20)	(29)	(3)	(3)	(26)	
Moderate/	4	1	1	0	0	0	6
Heavy Rain	(1)	(1)	(2)	(0)	(0)	(2)	
Flurries	0	1	5	0	1	3	10
	(1)	(2)	(3)	(0)	(0)	(3)	
Snow	0	1	3	0	0	3	7
	(1)	(2)	(2)	(0)	(0)	(2)	
Total	65	125	178	16	21	156	561

$X^2 = 23.3572$, d.f. = 25, p = 0.5567

Table C.11. Contingency table for testing the independence of hatchling position and cloud cover. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Position						
Cloud Cover†	All Exposed	Partially Covered	Covered	Head Exposed	Carapace Exposed	Submerged	Total
None	2	6	12	0	1	11	32
	(4)	(7)	(10)	(1)	(1)	(9)	
Light	8	17	29	2	3	20	79
Cloud	(9)	(17)	(25)	(2)	(3)	(22)	
Partly	4	5	12	1	5	14	41
Cloudy	(5)	(9)	(13)	(1)	(1)	(12)	
Cloudy	48	80	113	13	9	102	365
	(44)	(76)	(117)	(11)	(13)	(104)	
Total	62	108	166	16	18	147	517

$X^2 = 15.0652$, d.f. = 15, p = 0.4467

†Cloud cover data were grouped into discrete categories for the analysis. "None" represent no cloud cover, "light cloud" includes cloud cover between 0 – 30%, "partly cloudy" is from 30 – 60%, and "cloudy" is from 60 – 100% cloud cover.

Table C.12. Contingency tables for testing the independence of hatchling position and time of day. Expected frequencies for each cell are shown in parentheses below observed frequencies

Time of Day†	All Exposed	Partially Covered	Covered	Head Exposed	Carapace Exposed	Submerged	Total
	Position						
Morning	4	8	13	1	0	13	39
	(5)	(9)	(12)	(1)	(1)	(11)	
Midday	47	88	119	10	15	84	363
	(42)	(80)	(115)	(10)	(14)	(101)	
Afternoon	14	28	46	5	6	59	158
	(18)	(35)	(50)	(5)	(6)	(44)	
Total	65	124	178	16	21	156	560

$X^2 = 15.6947$, d.f. = 10, p = 0.1087

†Observation times were grouped into discrete categories for the analysis. "Morning" includes observations occurring before 10:00, "midday" is from 10:00 – 14:00, and "afternoon" includes observations occurring after 14:00.

Table C.13. Contingency tables for testing the independence of hatchling microhabitat and air temperature. Expected frequencies for each cell are shown in parentheses below observed frequencies

Temperature†	Flooded	Normally Aquatic	Terrestrial	Total
	Microhabitat			
Freezing	7	3	7	17
	(4)	(2)	(11)	
Cool	59	35	122	216
	(45)	(30)	(141)	
Warm	40	35	187	262
	(54)	(36)	(172)	
Hot	3	0	29	32
	(7)	(4)	(21)	
Total	109	73	345	527

$X^2 = 31.9899$, d.f. = 6, p < 0.0001

†Temperature data were grouped into discrete categories for the analysis. "Freezing" includes temperatures below 0°C, "cool" is from 0 – 10°C, "warm" is from 10 – 20°C, and "hot" includes temperatures above 20°C

Table C.14. Contingency tables for testing the independence of hatchling microhabitat and precipitation. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Microhabitat			
Precipitation	Flooded	Normally Aquatic	Terrestrial	Total
None	94	52	280	426
	(86)	(64)	(277)	
Drizzle/Mist	4	3	15	22
	(4)	(3)	(14)	
Light Rain	11	26	55	92
	(18)	(14)	(60)	
Moderate/Heavy Rain	0	0	6	6
	(1)	(1)	(4)	
Flurries	2	2	6	10
	(2)	(1)	(7)	
Snow	2	1	4	7
	(1)	(1)	(5)	
Total	113	84	366	563

$X^2 = 21.4517$, d.f. = 10, p = 0.0182

Table C.15. Contingency tables for testing the independence of hatchling microhabitat and cloud cover. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Microhabitat			
Cloud Cover†	Flooded	Normally Aquatic	Terrestrial	Total
None	9	3	21	33
	(7)	(5)	(21)	
Light Cloud	16	10	55	81
	(17)	(12)	(52)	
Partly Cloudy	10	10	21	41
	(8)	(6)	(26)	
Cloudy	72	55	237	364
	(75)	(55)	(234)	
Total	107	78	334	519

$X^2 = 5.7642$, d.f. = 6, p = 0.4501

†Cloud cover data were grouped into discrete categories for the analysis. "None" represent no cloud cover, "light cloud" includes cloud cover between 0 – 30%, "partly cloudy" is from 30 – 60%, and "cloudy" is from 60 – 100% cloud cover.

Table C.16. Contingency tables for testing the independence of hatchling microhabitat and time of day. Expected frequencies for each cell are shown in parentheses below observed frequencies

	Microhabitat			
Time of Day[†]	Flooded	Normally Aquatic	Terrestrial	Total
Morning	7	9	24	40
	(8)	(6)	(26)	
Midday	72	38	253	363
	(73)	(54)	(236)	
Afternoon	34	37	88	159
	(32)	(24)	(103)	
Total	113	84	365	562

$X^2 = 17.1004$, d.f. = 4, p = 0.0018

[†]Observation times were grouped into discrete categories for the analysis. "Morning" includes observations occurring before 10:00, "midday" is from 10:00 – 14:00, and "afternoon" includes observations occurring after 14:00.

Appendix D. Circular Scatter Diagrams of Hatchling Movement Directions

Circular scatter diagrams of the direction of movements of 18 individual hatchlings were created using the rectangular coordinates of each movement direction (angle). X coordinates are shown on the vertical axis, while Y coordinates are on the horizontal axis, following the convention in circular statistics (see Zar 1999).

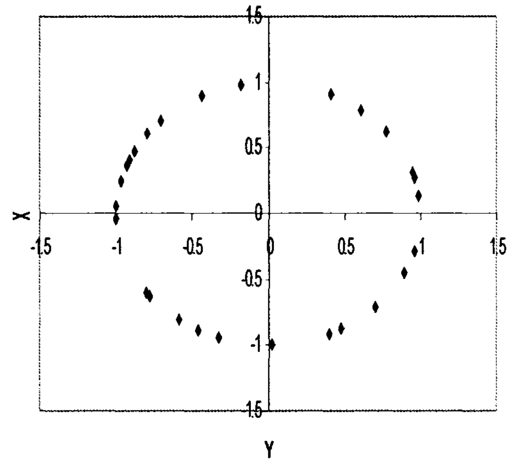

Figure D.1. Circular scatter diagram for hatchling 8,10-1

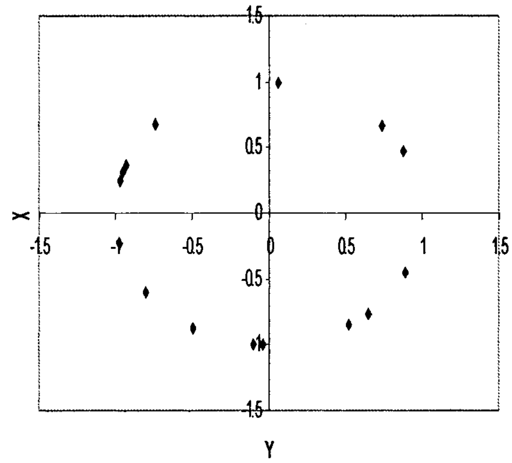

Figure D.3. Circular scatter diagram for hatchling 8,10-1,3

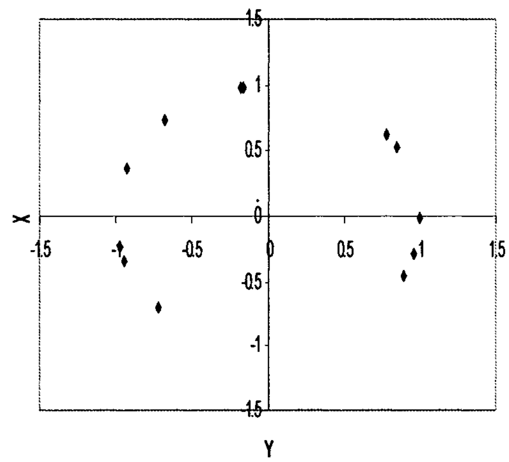

Figure D.2. Circular scatter diagram for hatchling 8,10-1,2

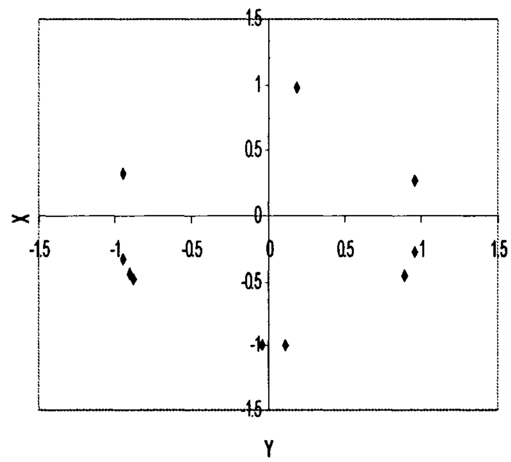

Figure D.4. Circular scatter diagram for hatchling 8,10-1,8

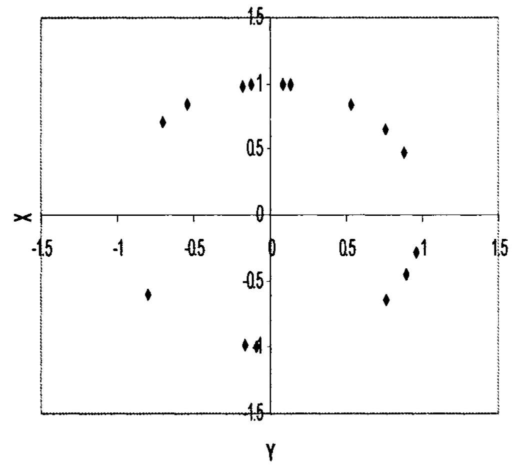

Figure D.5. Circular scatter diagram for hatchling 8,10-10,11

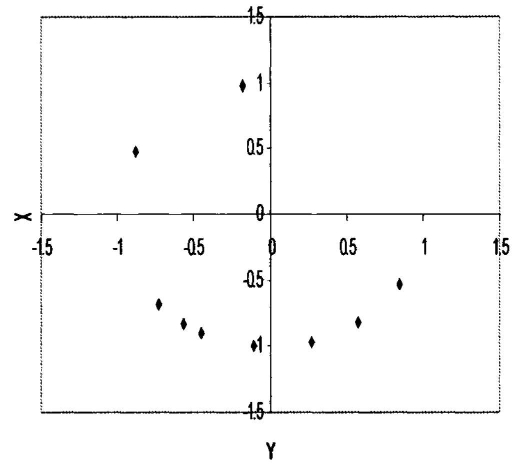

Figure D.7. Circular scatter diagram for hatchling 8,10-2,3

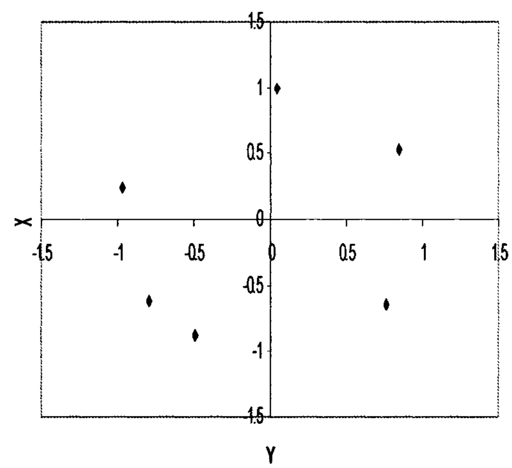

Figure D.6. Circular scatter diagram for hatchling 8,10-2

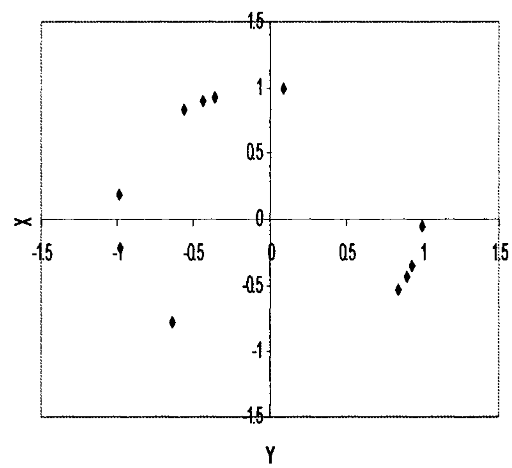

Figure D.8. Circular scatter diagram for hatchling 8,10-2,8

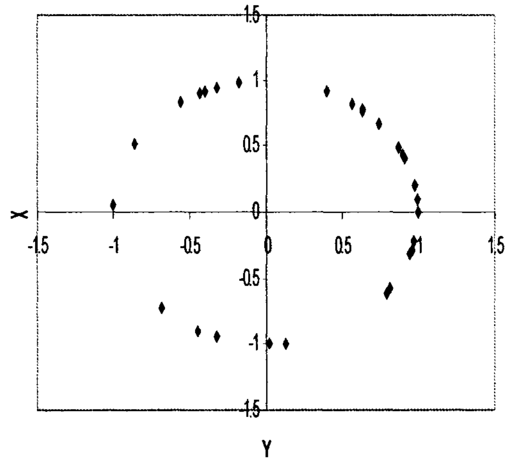

Figure D.9. Circular scatter diagram for hatchling 8,10-2,9

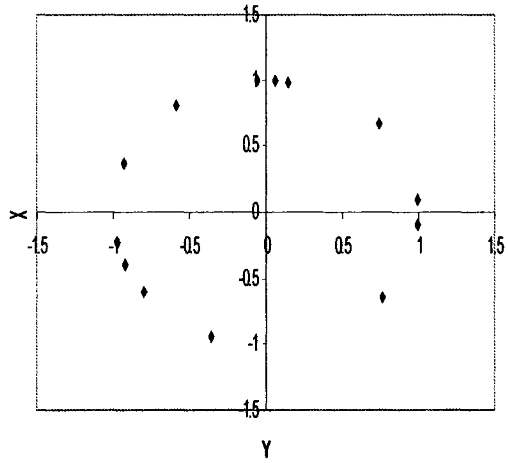

Figure D.11. Circular scatter diagram for hatchling 8,10-3,10

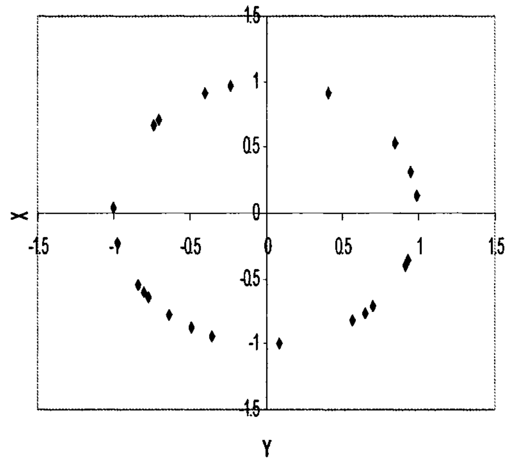

Figure D.10. Circular scatter diagram for hatchling 8,10-3

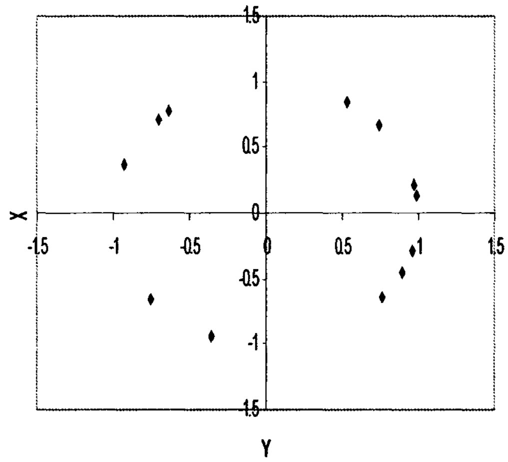

Figure D.12. Circular scatter diagram for hatchling 8,10-3,11

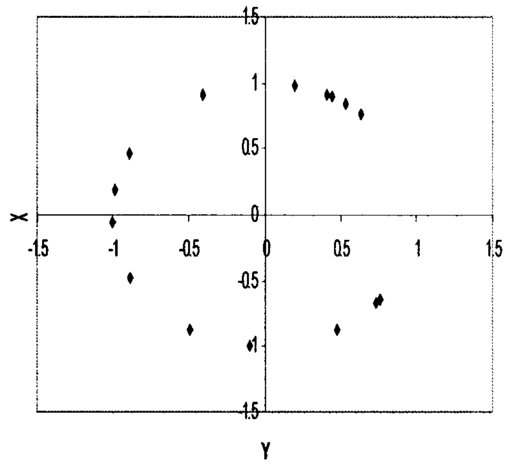

Figure D.13. Circular scatter diagram for hatchling 8,10-3,8

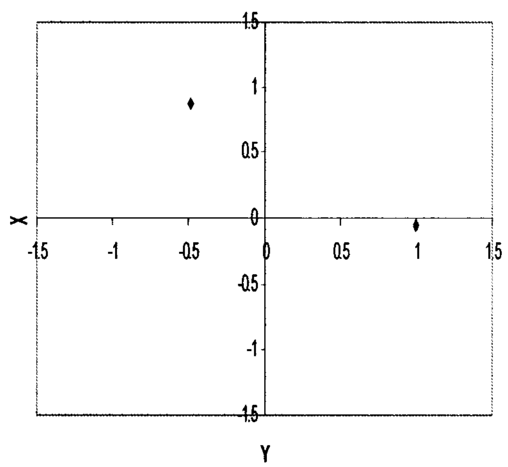

Figure D.14. Circular scatter diagram for hatchling 8,10-3,9

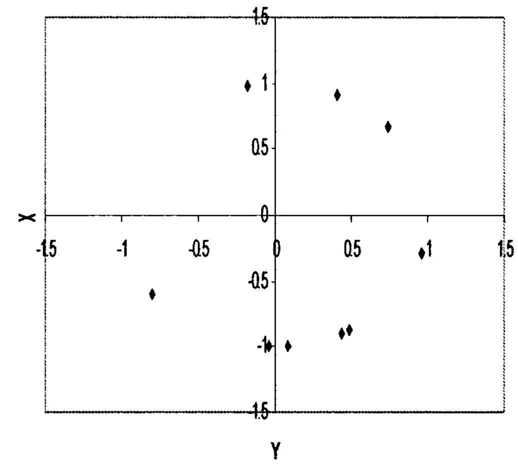

Figure D.15. Circular scatter diagram for hatchling 8,10-4

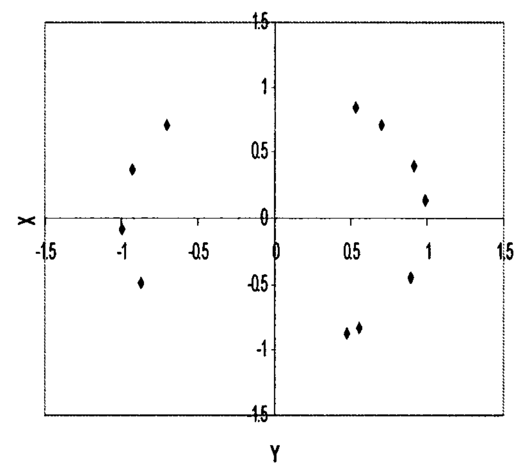

Figure D.16. Circular scatter diagram for hatchling 8,10-8

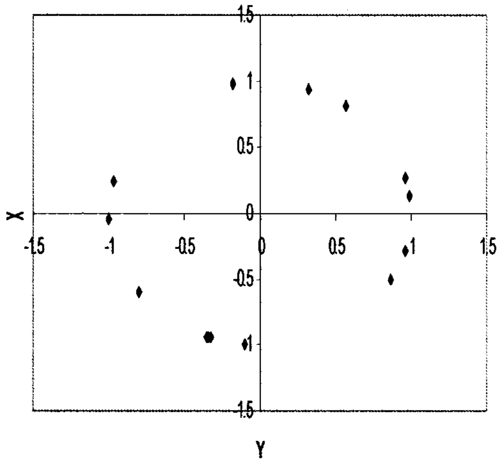

Figure D.17. Circular scatter diagram for hatchling 8,10-8,11

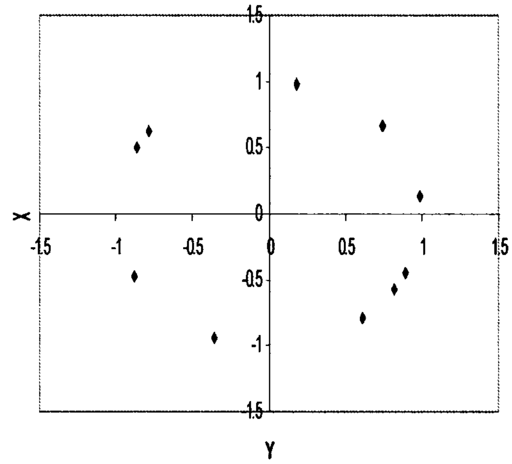

Figure D.18. Circular scatter diagram for hatchling 8,10-9,10