EXPERIENCING AMPHIBIANS: INSTRUCTION FOR BIOPHILIA, ECOLITERACY, AND SUSTAINABILITY

by

Mark Thompson

B. Sc., University of Northern British Columbia. 1998
M. Sc., University of Calgary. 2003

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF EDUCATION
IN
MULTIDISCIPLINARY LEADERSHIP

UNIVERSITY OF NORTHERN BRITISH COLUMBIA

April, 2014

Abstract

The current crisis in ecology, identified as a sixth mass extinction, may be addressed by providing children with opportunities to experience nature. Without these experiences, *biophilia*, or affinity for nature, may lie dormant. This study was designed by a conservation biologist who delivered and evaluated a community-education curriculum based on local amphibians. Fifteen youth were divided into three treatment groups: *rural parkland, urban parkland,* and *indoor* to alter educational experience. A pre-post study design was used to study potential treatment effects on biophilia and ecoliteracy. A Modular Ecoliteracy Instrument (MEI) was used to collect item scores on various ecological concepts. The piloted study design was partly limited by a small sample size and an ineffective control group. After reviewing the general outcomes of the study, the author advocates for further development of the MEI and hypothesizes that *niche construction* in the learning environment presents new opportunities for biophilia and ecoliteracy.

TABLE OF CONTENTS

Table of Contents

List of Tables

List of Figures

GLOSSARY OF TERMS

abduction A scientific inference where facts are considered in the imaginative genesis of new conceptions and are intuited into theories and hypotheses. Abductive inferences are "adopted on probation, and must be tested" (Peirce, 1901/1994, para 202), deemed worthy of pursuit, and economically fashioned "to obtain the most valuable addition to our knowledge" (Peirce, 1876/1994, para 140). "But suddenly, while we are poring over our digest of the facts and are endeavoring to set them into order, it occurs to us that if we were to assume something to be true that we do not know to be true, these facts would arrange themselves luminously. That is abduction." (Peirce, 1903, quoted from Hoffmann, 1999, p. 279). "Abduction is the "inference of an explanatory hypothesis accounting for observed effects" (Fitzhugh, 2005, p. 156). (see also *induction*)

alternative conceptions Defined in educational literature as uncritically held cognitive representations, myths or assumptions that affect two states of learning intelligence (accommodation and assimilation); alternatively defined in this thesis as *unreasoned conceptualizations.*

biodiversity Article 2 of the convention on biological diversity defines biodversity as "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" (United Nations, 1992). Naeem, Duffy, & Zavaleta, (2012) also make a connection between biodiversity and ecosystem functioning. In these terms, biodiversity is the observable product of evolving interactions, functional relations, and processes shared among genes, individuals, populations, and species. This definition recognizes different dimensions to the term, with examples including taxonomic, phylogenetic, genetic, functional, spatial, temporal, interactive, and landscape diversity. A logical consequence "if conservation is the act of conserving something, and that something is conveyed by the term biodiversity, then clearly we are not conserving species...or any taxon for that matter" (Fitzhugh, 2013, p. 24).

cognitive niche construction Recognition of an evolved sophistication in the language and sociality that can adjust to the moment to moment conditions that ecological fluctuations impose. It is the cognitive ability of foresight and adjustment for survival by deploying "information and inference, rather than particular features of physics and chemistry, to extract resources from other organisms in opposition to their adaptations to protect those resources" (Pinker, 2010, p. 8994). Hyperdeveloped cognition in humans coupled with technological exploitation of resources has accelerated and created an evolutionary transition in the ecological rates of consumption, disturbance, and the feedback this generates on the emergent niche.

concept Conscious generalizations and subconscious abstractions that motivate our behaviour to make sense of, understand, and describe the world we perceive. Concepts "govern our everyday functioning, down to the most mundane details. Our concepts structure what we perceive, how we get around in the world, and how we relate to other people" (Lakoff & Johnson, 1980, p. 3). They are embedded into the neural synapses of mind located specifically in the medial temporal lobe and the hippocampus, where the specialized system for declarative memory operates. Declarative memory "is a memory for facts and events-for people, places, and objects" (Kandel, 2009, p. 12748). Concepts are derived from feelings acquired by the gain of experience (Peirce, 1891) and accepted according to our perceptions of things, usually understood to be factual and thus believed.

conceptual inventory An assessment tool that gathers information on the associations that people use to relate and map out their concepts. A conceptual inventory is used to create concept maps. They are usually studied by using multiple choice questions with distractors.

concept map A graphical representation how people cognitively organize knowledge about a topic and how they communicate their understanding of the concepts onto others.

consilience Coined and defined originally by William Whewell: "The *Consilience of Inductions* takes place when an *Induction*, obtained from one class of facts, coincides with an *induction*, obtained from another class. This Consilience is a test of the truth of the Theory in which it occurs" (1860, *italics* added). Importantly, Whewellian induction differs from classical eliminative induction and is more similar to Peirce's concept of *abuduction* (Laudan, 1971); hence, a *Consilience of Abductions* is important to its definition.

deduction A logical mode of inference where the conclusion is a necessary outcome of the propositions contained in the premise. It is used in science as an "inference of predicted test consequences that should be observed, if the hypothesis is true" (Fitzhugh, 2005, p. 156). "[T]he first thing that will be done, as soon as a hypothesis has been adopted, will be to trace out its necessary and probable experiential consequences. This step is deduction" (Peirce, 1901/1994, para 203).

discounting An economic concept that looks at values accruing in the future. Discounting requires investment in the present and consideration for the temporal life of that investment. It relates to sustainability as present generations discount future generations.

distractor An unreasoned conceptualization that is included in a multiple choice list and serves the purpose of drawing attention to the common mistake.

ecology The interdisciplinary science on the economy of nature that builds upon our collective knowledge on the relations of life and how the interactions of organisms relate to the energetic and physical structure of a niche, patterns of evolution, and biogeochemical pathways in the environment.

ecological guild A concept that is used in community ecology to group species together, not because they are taxonomically related, but because they overlap in the way they are similarly adapted to the environment.

ecoliteracy Accumulated knowledge, values and understanding of ecology.

ecosystem services Materials, energy and resource information that flows from natural capital into society. Natural capital is created, processed, and stored in Earth's ecosystems.

Biodiversity sustains these services and performs ecological functions that contribute to a heritable well-being and survivability.

environment All factors and scales of study that are external to an organism, including abiotic factors such as temperature, radiation, light, chemistry, climate and geology, and biotic factors, including genes, cells, organisms, members of the same species (conspecifics) and other species that share a habitat.

environmental myopia Short-sight belief that nothing important environmentally extends beyond the range of ones limited cognitive scope, temporally or spatially.

equity analysis A valuation assessment of how materials and resources of the commons are fairly and ethically partitioned among the group.

exurban "Exurban areas refer to rural residential development beyond the urban/suburban fringe where extensive landscape changes occur in housing densities of 1 per 0.4-16ha. Exurban areas with <1 house per ha occur in native landscape matrix such as forests, prairies, and deserts" (Mitchell & Brown, 2008, p. 3).

fact According to scientific realism, a fact is "either the being of a thing in a given state, or an event occurring in a thing" (Mahner & Bunge 1997, p. 34). It is anything that exists independent of our imagined beliefs. Theories and hypotheses do not turn into facts, but they refer to facts through our perceptions and memory of phenomena. Facts are referred to by the "conjunctions of theories and observed effects" (Fitzhugh, 2007, p. 2). "Phenomena are causal events within the sensory apparatuses of organisms, but in so being, are themselves facts" (Fitzhugh, 2006, p. 40). However, for irrealists (see Hacking, 1988) "reality' cannot be used to explain why a statement becomes a fact, since it is only after it has become a fact that the effect of reality is obtained" (Latour & Woolgar, 1979, p. 180). In other words, the irrealists do not reject the existence of facts or reality, but they suggest that facts become established and only after they are discovered and socially constructed through the "negotations among small groups of involved research workers" (Hacking, 1988, p. 282). Facts are primarily known through our perception, but others may be known indirectly by means of logical inference (Jones, 1909).

heritable A gene or trait that is faithfully replicated or transmitted from one generation to the next. Niche construction theory proposes an extended context of ecological heritability, whereby the constant actions of organism engineers collectively modifies the physical parameters of the environment. This cumulatively connects the coevolution of all the species co-adjusting to such conditions across generations and leads to a faithful replication and legacy of environmental parameters that persist in the niche. This is a kind of niche ancestry. Organisms inherit genes plus the cumulative modifications that their parental generation engineered into the niche, which influences the organization and developmental potentiality of the offspring.

hypotheses A formal postulate based on theory that can explain classes of fact and predict testable effects. A consilient hypotheses "can successfully predict or explain the occurrence of phenomena which, on the basis of our background knowledge, we would not have expected to occur" (Laudan, 1971, p. 371).

induction A process of rational scientific "inference of predicted test consequences that should be observed, if the hypothesis is true" (Fitzhugh, 2005, p. 156). Induction is the experimental stage of bringing the hypotheses to bear on observed test effects. There are different classes of induction having different levels of strengths and weakeness on the likelihood of convergence to truth and reality. William Whewell's (1840) concept of *induction* is more akin to *abduction* using Peirce's (1994) terminology. As such, Whewell's (1860) mode of induction (Peirce's abduction) "is not reasoning: it is another way of getting at truth" (p. 454).

learning community A network of individuals that intentionally share ideas, explore values, self-organize and collectively coordinate their behaviour. Successful learning communities employ social intelligence as they communicate knowledge that enhances the creativity or learning potential of individuals that organizationally sustains and amplifies knowledge into the group structure.

natural capital Capital is a stock supply of goods, services, or information. Capital stocks generate a flow of services to the welfare of humans and they exist in different forms, such as: physical capital (for example, fish, trees, minerals); manufactured capital (for example, tools, buildings); and abstract or intangible capital (information storage in computers and minds or species and ecosystems). Natural capital is the stock of resources that maintains the flow of ecosystem services.

niche "The set of abiotic and biotic conditions in which a species is able to persist and maintain stable population sizes" (Weins & Graham, 2005, p. 519).

niche construction A process that is governed by the active agency of organisms as they modify the conditions of their habitats and those of others that inhabit the same ecological community. The habit of organisms interacting with their environments induces the expression of phenotypes beyond their "skin" and into the surrounding ecosystem. This dynamically transforms natural selection pressures by creating an extended feedback of ecological inheritance. The preservation of niche constructed artifacts, such as inheriting a nest or nutrients from decomposing bodies, has an effect on both the genetic and ecological descendants that persist in the same environments. (see *cognitive niche construction*)

novel ecosystem A human disturbed ecosystem that has regenerated and self organized into a community of life with a novel admixture and complex of introduced and native species. Novel ecosystem is a term that urban ecologists are using to replace negative terms such as degraded in recognition that these types of ecosystems provide ecosystem services as well.

peri-urban "The "edge" of the city expands into surrounding rural landscape, inducing changes in soils, built structures, markets, and informal human settlements, all of which exert pressure on fringe ecosystems. These peri-urban environments are the glue that link core cities in extended urbanized regions" (Grimm et al., 2008, p. 756).

percept The mental organization of sensory information or memories on phenomena that stimulate higher order cognitive thought processes. Phenomena stand as the percepts of fact.

rural Human settlement that extends beyond urban areas.

self-delusion A belief or perception about an unreasoned conceptualization that is maintained for the reason that it leads to the desired or expected outcome of the belief. It is a hypotheses about the world that can be demonstrably proven false.

suburban A residential district on the outskirts of a city (Mitchell & Brown, 2008).

theory "A word hobbled by multiple meanings" (Wilson, 1998, p. 57). Theories are formulated in the imagination. They begin through creative inference to abduction, or a guess on a mechanism or causal explanation of facts. They provide a cognitive explanatory conception for evidence. Theories are emotionally rewarding as they simplify understanding of cause effect relations or emergent systems. To remain relevant in the pursuit of scientific inquiry they have to survive the continuity of critical test. Scientific theories provide a systematic reference to facts and they are involved in the process of postulating a testable inference to an hypotheses. Theories that become more complex, artificial, or ad hoc lose their fecundity, whereas those that simplify matters, become more generally applicable, and generate a coherent and consilient understanding of independent classes of facts are true motivators of inquiry and increased skepticism.

unreasoned conceptualization Concepts that are founded on ideas exchanged or individual percepts that fail to add to knowledge and understanding. Unreasoned conceptualizations are motivated by low-effort quick thinking and distract from theory that otherwise interlinks facts and concepts together. They tend to lack moral, ethical, or logical considerations. Unreasoned conceptualizations are easily susceptible to social and personal bias, they are resistent to change, they reinforce belief through fanfare, they stifle inquiry, and explain nothing as they have otherwise been subject to scientific test and falsified.

urban Populated areas that are dominated by human activities and structures, including the fringes of nature that are noticeably affected by the juxtaposition.

Acknowledgements

I would like to acknowledge my supervisor, Dr. Willow Brown and co-supervisor, Dr. Peter MacMillan for the assistance they provided during the development of my thesis. I would like to extend my sincere gratitude to all my committee members for making the defense possible and memorable. Dr. Loraine Lavallee provided expert guidance and inspiration in conservation psychology and Dr. Dennis Proctor offered his philosophical insight. I would also like to thank the chair of my thesis defense, Dr. Ian Hartley. I am also grateful for the support I received from the graduate office, especially Kara Taylor and Dr. Kevin Smith. I would like to extend my sincere gratitude and thanks to Dr. William McGill for his patience, understanding, brilliant guidance, and direction that he provided in the final revisions, which greatly improved this thesis. Students who participated in the study also deserve special thanks; this thesis was about trying to find ways to improve on their quality of education.

A special thanks to my parents, Louise and Pius Synard, and to my community of friends who have been there to support me through the years. I would like to extend both my love and gratitude to my fiancée, Sarah Heinrichs. I am so proud of your recent accomplishment and very happy that we will be graduating together. Thank you for being patient with me during late nights of revision, discussions about the thesis, for your kindness, and for your loving support. I am so happy that we have a passion to share and to continue on this path, to create new experiential learning opportunities in our community, which truly starts at the roots of empathy. I would like to both acknowledge and dedicate this thesis to my two sons, Jaime Peterson and Rowan Thompson. I hope that you will be able to share a biophilic future with families of your own.

In those areas where human land use pressure is greatest, amphibian habitat may supply a useful template with which to manage growth and ensure the provision of some ecosystem services.

- Baldwin, Powell and Kellert (2011, p. 324)

CHAPTER I: INTRODUCTION

At this point in history, human beings are facing a *sixth mass extinction* (Barnosky, Matzke, Tomiya, Wogan, Swartz, Quental, et al., 2011; Hooper, Adair, Cardinale, Byrnes, Hungate, et al., 2012; McElwain & Punyasena, 2007; Rockstrom, Steffen, Noone, Persson, Chapin, Lamgin, et al., 2009; Wagler, 2011; Wake & Vredenburg, 2008). The loss of earth's ecosystems may be due to a lack of ecological literacy, or ecoliteracy, as industry-based human activity continues to cause an increase in the measured levels of global forcings of biological change (Barnosky, Hadly, Bascompte, Berlow, Brown, Fortelius, et al., 2012). This crisis in ecoliteracy has occurred in conjunction with increasing urbanization and the alienation of human beings from the natural environment. As the current trends to urbanization and human focus on technological media increases, fewer citizens are likely to develop *biophilia,* a complex behaviour that describes our affinity for nature resulting from early interactions with the natural world (Wilson, 1984; Kellert & Wilson, 1993). Biophilia and the valuing of non-commercial ecological services, or *natural capital*, are the foundations of ecoliteracy, the combination of knowledge and values that may inform and guide the collective human behaviour required to sustain the world's ecology.

Biophilia for Ecoliteracy and Sustainable Ecology

The concept of *biophilia* (Wilson, 1984), combined with *niche construction theory* (Laland, Kendal, & Brown, 2007; Laland, Odling-Smee, & Feldman, 2001; Rendell, Fogarty,

& Laland, 2011) suggests that an educational contribution to long-term ecological sustainability is viable. If the problem is the waning of ecoliteracy due to increasing numbers of human beings living lives removed from nature, one potential solution is to develop, through community-based or school-based education, curricula that provide direct experiences with nature and catalyze biophilia, or deep human connections to nature, among young learners. The long term effect of such programs may be compounded when these young people become aware of themselves as *niche constructors* (Flynn, Laland, Kendal, & Kendal, 2013; Rendell, Fogarty, & Laland, 2011; Rowley-Conwy & Layton, 2011; Shennan, 2011) whose actions have an impact on the natural environment.

Eventually, niche constructing behaviours may lead today's young people to create and preserve green spaces that will become their biophilic legacy. Given niche construction of an urban environment that affords interaction with nature, such as one rich with green spaces, wetlands, and accessible wilderness, the potential for future generations to develop affinity with nature may be increased. To apply a concept from biology, affinity with nature will become *heritable* when catalyzed and strengthened in a nature-rich urban environment that was constructed as a result of the biophilic values of those who have gone before. However, it must be acknowledged that biophilic values are not likely to develop to their full potential in a biologically impoverished urban landscape.

Connections to Leadership

Conservation biologists have recently recognized the importance of adopting and applying some of the new developments in leadership theory (Manolis et al., 2008). Classical leadership theory posited and failed to find a coherent pattern of stoic leadership traits, whereas modern leadership theory resonates with niche construction theory by suggesting a situational form of social influence where anyone can take initiative and inspire the mobilization of others as they see the need for change (Chemers, 1995; Manolis, Chan, Finkelstein, Stephens, Nelson, Grant, & Dombeck, 2009). Modern leadership theory builds on the idea that the learning is not based on pre-specified programs but develops through cycles of contingency through constant feedback between the learner and the learner's environment. This idea is developed in social organization leadership theories, organizational learning or professional learning groups, for example (Fullan, 2007; Hargreaves & Fink, 2005; Mitchell & Sackney, 2008). Professional learning groups are a form of cultural niche construction mobilizing different kinds of social environments where individual leaders can thrive. "Humans can and do modify their environments mainly through ontogenetic and cultural processes, and it is this reliance on learning, plasticity and culture that lends human niche construction a special potency" (Flynn, Laland, Kendal & Kendal, 2013, p. 298).

Amphibians as an Instructional Resource

Amphibians are an ideal subject for biophilic conservation education in and near urban areas. Scientific assessments of global extinction rates measure more rapid declines in amphibians compared to any other taxonomic group (Collins & Crump, 2009; Wake & Vredenburg, 2008). Furthermore, amphibians are a safe and accessible kind of vertebrate that often fascinates children. In this study, amphibian-focused conservation education was based on previous conservation education material that I developed for NAMOS BC (Northern Amphibian Monitoring Outpost Society), a charitable non-profit organization that I initiated in 2008 and operated, with a Board of Directors, until 2012. Although the NAMOS BC organization is no longer functioning, the educational material and philosophy that I developed as a part of that initiative have contributed to this study.

Purpose of this Study

To move toward achieving my theory-informed, long-term vision of conservation leadership and to draw on amphibians as an accessible resource for biophilic instruction in urban environments, I addressed short term goals in this study. Specifically, I developed instructional approaches focused on amphibians and devised a means of evaluating the effectiveness of instruction for promoting biophilia and ecoliteracy. Therefore, the purpose of this study was to design and implement amphibian-focused nature study curricula and evaluate them for their effectiveness in leading learners to value nature and develop ecoliteracy, as evident in children's awareness of the value of ecological services.

In the chapters to follow I provide a review of literature to provide context, theoretical constructs, insight into the content and underlying perspectives of the curricula that I developed, and a perspective on conservation science, biophilia, and ecoliteracy (Chapter II); the methods used, (Chapter III); results obtained and observations made (Chapter IV) a discussion of sampling, statistical outcomes, module characteristics, a comparative analysis, strengths and weaknesses, and finally biodiversity and niche construction (Chapter V), with a summary and conclusions in Chapter VI. Appendices include the Junior Amphibian Ecologist League Announcement Poster, Curriculum Booklets and the Modular Ecoliteracy Instrument.

CHAPTER II: LITERATURE REVIEW

The function of this literature review is to provide context for the problem that I have identified, the *current extinction*, and the theoretical constructs that point to the potential of educational solutions: *niche construction, biophilia,* and *ecoliteracy.* I have built on my professional experience as an ecologist and conservation biologist to develop the perspectives most applicable to the aims of my study. Concepts identified in this process contributed to the items of the Modular Ecoliteracy Instrument (MEI) and helped me to set the polarity on item scores and values. The material that I have reviewed also provides insight into the content and underlying perspectives of the curricula that I developed for the *Junior Amphibian Ecologists League*.

Moreover, in reviewing these topics I provide a perspective on conservation science, biophilia, and ecoliteracy that presents an alternative to some of the plans or directives for sustainable development that are presented more generally. For example, my curricular aim is less "akin to developing knowledge and skills necessary for participation in the 'green economy' envisioned by the top-down promoters of Education for Sustainable Development such as United Nations Educational, Scientific, and Cultural Organization (UNESCO)" (Kopnina, 2012, p. 700). A second major section of this literature review sifts through the historical literature of nature study and moves into the transition that occurred during the 1970's. Several authors have identified this transition (for example, Kopnina, 2012), which has become known as *education for sustainable development* and has become evident in various environmental education or nature study instruments. The review serves a dual function of giving a historical overview of educational research related to my topic of study and the instruments that have been used to study values and perceptions of students following intervention into various nature-based or environmentally orientated education programs.

The Current Extinction

One hundred years ago, the famed British biologist, Ray Lankester, forecast a theory on the state of the "effacement of nature by man":

> It is, however, in cutting down and burning forests of large trees that man has done the most harm to himself and the other living occupants of many regions of the earth's surface...Forests have an immense effect on climate, causing humidity of both the air and the soil, and give rise to moderate and persistent instead of torrential streams and from regions far remote from the Arctic complaints come of an even more reckless destruction of helpless animals. (Lankester, 1913, p. 370)

Lankester's (1913) theory was one of the earliest summations and forecasting of the Anthropocene mass extinction The process has not abated and it is rapidly getting worse (Ehlrich, Kareiva, & Daily, 2012). With the exception of Greenland and Antarctica, 83% of the global terrestrial biosphere has now been converted to human habitat and 36% of the Earth's biologically productive surface has been engineered into a human niche (Haberl, Erb, Krausmann, Gaube, Bondeau, Plutzar, Gingrich, et al., 2007). A major ecological transition is taking place globally. As the greatest physical ecosystem engineer to have evolved, humanity may be able to *niche construct* solutions to this problem, vicariously through instruction and by direct investment, which requires participation and long-term engagement in ecosystems that retain their resilience and productivity.

The motivation behind the amphibian-based curricula that I have developed and the problems I address in this study derives from the problem of extinction. My premise is that the parallel extinction of direct experience in nature (for example, Hanski, 2005, 2008; Miller, 2005) including the study, play, and direct physical engagement in the local ecological engineering processes, is causally linked to the sixth or Anthropocene mass extinction

(Hooper et al., 2012; Wake & Vredenburg, 2008) . There is reciprocity or feedback of extinction with the loss of species and the loss of experience, which are both increasing. Intertwined with this extinction are the values that influence and motivate human social and ecological behaviours. Biophilic values, for example, cannot develop to their full potential in a biologically impoverished world. Hence, curricula that can encourage direct engagement with local nature to stimulate a sense of biophilia may counter this dual problem of extinction.

Researchers continue to report on the trends of the current extinction, which qualifies as a sixth major extinction paralleling in magnitude the previous five major extinctions in the fossil record (McElwain & Punyasena, 2007; Wake & Vredenburg, 2008; Wagler, 2011). The current extinction pattern, however, differs from previous mass extinctions in terms of scale and the evolutionary transition of human intelligence that has engineered a new technological context. Wagler (2013) conducted an extensive review of educational standards related to the sixth mass extinction and concluded that the topic is missing from most educational programs on environmental science and there are few curricular packages that have been developed on this topic. This study and the curriculum development that is part of it were motivated by my concern for the extinction crisis and the inescapable deterioration of human well-being that will occur if the trend continues.

Governments, conservation biologists, and citizens have put extensive plans and efforts toward the management, protection, and recovery of endangered species. Different pieces of endangered species legislation have been put into effect in different parts of the globe, but usually only after hard fought legal battles. Many conservation biologists, however, are raising concerns that species endemism, species richness, and endangered listings are not the most effective means to prioritize conservation action, let alone to determine where to establish protected areas (Smith, Bruford & Wayne, 1993; Cowling, Knight, Faith, Ferrier, Lombard, Driver, et al., 2004; Wood & Gross, 2008; Thompson, 2010; Gratwicke, Lovejoy & Wildt, 2012; Fitzhugh, 2013). One basis for their argument is that species only cover the taxonomic component to biodiversity, whereas the whole of biodiversity includes additional dimensions that are more directly linked and applicable to the functional ecology of the planet (Naeem, Duffy, & Zavaleta, 2012). Even more disconcerting is the observation that children's conservation values tend to reflect the popular, virtual, and exotic species over local species (Ballouard, Brischoux, & Bonnet, 2011), a bias that may persist into adulthood and that removes emphasis from other important dimensions of biodiversity. The prioritization of species for conservation legislation, funding and action has more to do with human psychology than with what is actually relevant to the ecology of the problem.

Conservation Leadership and Niche Construction Pedagogy

This study is a response to the clarion call for conservationists to address the amphibian extinction crisis (Gascon, Collins, Moore, Church, McKay, & Mendelson, 2007). Conservation biologists have also recognized the importance of adopting and applying some of the new developments in leadership theory that "emphasize emotional over technological intelligence" (Manolis et al., 2008, p. 880). Hence, this study is a journey in my own leadership development for conservation science education.

New approaches to education are required to meet the increasing and diversity of challenges that the Anthropocene extinction poses for education. Toward this end, this study is as much a leadership initiative in conservation education as it is a study of ecology as it relates to education. Niche construction theory is adopted in the educational approach that was applied and incorporated into the curricula of this thesis. It forms a complement to biophilia theory and ecoliteracy in general. Niche construction theory has yet to mature in the educational literature but a large body of theoretical, mathematical and experimental research has provided "unambiguous evidence that niche construction is of considerable ecological and evolutionary importance" (Odling-Smee, Erwin, Palkovacs, Feldman, & Laland, 2013, p. 5). Flynn, Laland, Kendal, and Kendal (2013) identify one of the first educational linkages consistent with the theory as "...children direct their own learning by shaping their own learning environment. Also in natural settings, children often learn from other children" (p. 303).

Modern leadership theory resonates with niche construction theory and builds on the idea that the learning is not based on pre-specified programs but develops through cycles of constant feedback between the learner and the learner's environment. Parallel understandings and conclusions about the importance of feedback for development have also been featured in educational leadership research, for example, in social organization leadership theories that focus on organizational learning or professional learning groups (Fullan, 2007; Hargreaves & Fink, 2005; Mitchell & Sackney, 2008). In this manner, professional learning groups provide an example of *cultural* niche construction where groups mobilize to create the kinds of social environments where individuals as well as innovation can thrive.

Niche construction is closely related to the concept behind ecosystem engineering, initiated by Charles Darwin in 1881 in the nascent science of pedogenesis and bioturbation. The behavioural activities of other organisms making tunnels, burrowing for food, and displacing soils is called bioturbation (Hastings, Byers, Crooks, Cuddington, Jones, Lambrinos, et al., 2007). The importance of this process was recognized by Charles Darwin but the significance of this research was unfortunately overlooked by an agronomic science that focused on crop production rather than the production of ecosystem services by other organisms. Thus the science of organisms in soils, the primary process of soil formation and a critical ecosystem service (Figure 1), was largely ignored, forgotten, and shelved to the scientific periphery for an entire century (Wilkinson, Richards, & Humphreys, 2009).

Service	Sub-category	Functions
Provisioning		
	1 Food	1 Food
	2 Fibre	2 Raw materials
	3 Genetic resources	3 Genetic resources
	4 Biochemicals, natural medicines & pharmaceuticals	4 Medical resources
	5 Ornamental resources	5 Ornamental resources
	6 Fresh water	6 Water supply
Regulating		
	7 Air quality regulation	7 Gas regulation
	8 Climate regulation	8 Climate regulation
	9 Water regulation	9 Water regulation
	10 Erosion regulation	10 Disturbance prevention
	11 Water purification and waste treatment	11 Waste treatment
	12 Disease regulation	12 Soil retention
	13 Pest regulation	13 Biological control
	14 Pollination	14 Pollination
	15 Ornamental resources	15 Nursery function
		16 Habitat functions
		17 Refugium function
		18 Nutrient regulation
Cultural Services		
	16 Cultural diversity	19 Information functions
	17 Spiritual and religious values	20 Spiritual and historic information
	18 Knowledge systems	21 Science and education
	19 Educational values	22 Aesthetic information
	20 Inspiration	23 Cultural and artistic information
	21 Aesthetic values	24 Recreation
	22 Social relations	
	23 Sense of place	
	24 Cultural heritage values	
	25 Recreation and ecotourism	
Supporting Services		
	26 Soil formation	25 Soil formation
	27 Photosynthesis	26 Production function
	28 Primary production	
	29 Nutrient cycling	
	30 Water cycling	

Figure 1. Ecosystem services and functions listed by the Millennium Ecosystem Assessment (2005) and deGroot et al. (2002).

Darwin (1882) was the first to propose that the ecological actions of one organism can alter the constructed state of the environment for other organisms. In this regard, Darwin (1882) noted on the "service performed by worms in loosening, &c., the soil" (p. 312):

> Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds...The plough is one of the most ancient and valuable of man's inventions; but long before he existed the land was in fact regularly ploughed by earth-worms. It maybe doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly organized creatures... other animals, however, still more lowly organised, namely corals, have done far more conspicuous work in having constructed innumerable reefs and islands in the great oceans (p. 316).

Jones, Lawton and Shachak (1994) re-introduced and expanded on this concept by reviewing the physical interactions of organisms noted in ecological studies. Emphasis on the physical modification, creation, or maintenance of habitats by "organisms that directly or indirectly modulate the availability of resources (other than themselves)" (Jones, Lawton & Shachak, 1994, p. 374) to other organisms was a new development in the ecological sciences. Ecology had for a long-time been primarily concerned with trophic (i.e., feeding) dynamics and relations. This switch in emphasis from trophic dynamics to understanding that the physical alterations of the environment also modified the availability and flow of resources was called ecosystem engineering.

Like much of the evolutionary sciences, educators have treated the student as a receptacle of curricula as opposed to being active agents in the curricular environment. Niche construction theory can be used to gain a better understanding of educational theory and build on the initiative that has been encouraged to bring human niche construction into interdisciplinary focus (Kendal, Tehrani, & Odling-Smee, 2011). Acknowledging niche construction, as it was first introduced by Lewontin (1983), students are one of the causes of their own learning. A student is not simply an object of a learning environment that is imposed externally but is the subject of the learning environment as well. Using logical expressions that are modified from Lewontin (1983), this concept can be illustrated in as follows:

i. $dS_{grp}/dt = f(S_{grp} + T, LE_{grp})$
ii. $dLE_{grp}/dt = g(S_{grp} + T, LE_{grp})$
iii. $d(S_{grp}, LE_{grp})/dt = h(S_{grp} + T, LE)$
iv. $dT/dt = i(S_{grp} + T, LE_{grp})$
v. $d(T, S_{grp}, LE_{grp})/dt = j(S_{grp} + T, LE)$

Whereby: S = student; LE = Learning Environment; T = Teacher; grp = group; and *f,g,h, i, j* are functions. Formula's i-iii describe:

i. groups of students learning over time, which is a function of the student group, the teacher and the learning environment where the student group learns,

ii. the learning environment over time as a function of the student group, the teacher and the learning environment where group of students learn, and

iii. the student group and the learning environment co-develop over time as a function of the student group, the teacher and the wider learning environment.

Part iii of the equation is important, because it explicitly shows that the student-learning environment system is not a closed system; student groups participate outside of the treatment. Formula's iv-v integrate the relationship of the teacher in this model where cultural niche construction applies (Laland, Odling-Smee, Myles, 2010). These logical expressions relate back to the way that niche construction based curricula are themselves developed by way of dynamic and integrated interaction.

Themes in the Modular Ecoliteracy Instrument

Several authors in environmental education have posited concerns regarding a modern transformation in the content in curricula on *sustainability* that has shifted from earlier practices that used to focus on nature or conservation study. Characteristic of this shift, the "moral obligation for caring about other species or the entire ecosystems is less often part of [the] discourse" (Kopnina, 2012, p. 701). For example:

> the dominant models of environmental education abstract the ecosphere from developments in the economy, science, and technology, and are generally uncritical of the existing society. Hence, they are unable to provide real insight into the causes of our ecological crisis and to mobilize on behalf of adequate responses. (Kellner & Kneller, 2010, p. 154)

The theoretical framework for this study, including *biophilia* (Wilson, 1984) combined with *niche construction theory* (Laland, Kendal, & Brown, 2007; Laland, Odling-Smee, & Feldman, 2001; Rendell, Fogarty, & Laland, 2011) suggests an educational contribution that shifts the emphasis back to nature and conservation as a means to achieve long-term ecological sustainability. If the problem is the waning of ecoliteracy due to increasing numbers of human beings living lives that are removed from nature, one potential solution is to develop, through community-based or school-based education, curricula that provide direct experiences with nature and catalyze biophilia, or deep human connections to nature, among young learners. The long term effect of such programs may be compounded when these young people become aware of themselves as *niche constructors* (Flynn, Laland, Kendal, & Kendal, 2013; Rendell, Fogarty, & Laland, 2011; Rowley-Conwy & Layton, 2011; Shennan, 2011) whose actions have an impact on the natural environment.

Eventually, niche constructing behaviours may lead today's young people to create and preserve green spaces that will become their biophilic legacy. Given niche construction of an urban environment that affords interaction with nature, such as one rich with green spaces, wetlands, and accessible wilderness, the potential for future generations to develop affinity with nature may be increased. To apply a concept from biology, affinity with nature will become *heritable* when catalyzed and strengthened in a nature-rich urban environment that was constructed as a result of the biophilic values of those who have gone before. However, it must be acknowledged that biophilic values are not likely to develop to their full potential in a biologically impoverished urban landscape.

Constructing Ecological Capital

It is important to understand how ecosystem services relate to ecoliteracy generating functions in order to understand the production or inhibition of ecological capital in any given learning environment or treatment. Ecosystem services and functions listed by the Millenium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) and de Groot et al. (2002) are included in Figure 1. Ecosystems regulate the biogeochemical cycles of the planet, which include energy, climate, soil nutrients, water, and other formulations of matter and energy that in turn support and add to the growth of natural capital in the environmental, physiological, cognitive, and cultural dimensions of life. All of these dimensions impinge on the educational system as a whole.

Capital is a stock of materials or information that can be utilized to create goods and services, whereas natural capital is the portion of the planet's capital that comes from biodiversity and is regenerated by ecological processes (Costanza, d'Arge, de Groot, Farber, Grasso, Hannon et al.,1997). Natural (or ecological) capital is based on more than the traditional concept of natural resources that are traded as commodities in markets. In contrast to natural capital, natural resources are defined as marketable commodities, such as minerals, fuel, lumber, and fish. Natural resources of the marketable form are only a minor component of the diverse set of ecological resources that have value. Capitalist market systems were never designed for investment in natural capital (Reese, 2002).

Chiesura and de Groot (2003) reviewed some of the more intangible factors or products of natural capital that cannot be quantifiably valued by conventional economic means. For example, marketable fish stocks are monitored by the Department of Fisheries and Oceans Canada, fish stream inventories are regularly conducted in forestry by consulting firms, whereas wild amphibian stocks and their wetland habitats are not included in these inventories. The capital of fish and amphibian stocks have overlapping roles that cannot be so easily segregated in quantified terms to say that one contributes more to the production of ecosystem services, yet only fish receive consideration in forestry management.

Biophilia and Ecoliteracy

Biophilia describes the connections that human beings subconsciously seek with the rest of life (Wilson, 1992, p. 350). Biophilia is a complex behavioural trait that is shared among cultures and motivates our innate attraction to nature. Biophilia theory posits an innate "emotional affiliation of human beings to other living organisms "(Wilson, 1993, p. 31). Edward O Wilson's (1984) biophilia hypothesis has improved understanding of the unique cognitive relationship and complexly intertwined behaviours that bond humanity to nature:

> We are human in good part because of the particular way we affiliate with other organisms. They are the matrix in which the human mind originated and is permanently rooted, and they offer the challenge and freedom innately sought. To the extent that each person can feel like a naturalist, the old excitement of the untrammeled world will be regained. I offer this as a formula of reenchantment to invigorate poetry and myth: mysterious and little known organisms live within walking distance of where you sit. Splendor awaits in minute proportions (p. 139).

Conservation Psychology

Human perceptions, values, beliefs, and motives toward nature fall under the purview of conservation psychology (Saunders, 2003). Perceptions of each human generation are modified by the influence of the local ecological context. Conservation psychology offers an explanation as to why society has become so concentrated on conserving the big familiar organisms or *charismatic megafauna* versus the more unpleasant or smaller creatures, such as snakes, amphibians, insects, other invertebrates and even fungi. Evolutionarily, this focus is not surprising because human beings are, ourselves, large omnivorous predators.

"The last 50,000 years were witness to the extinction of approximately two-thirds of all genera and one-half of all species of mammal weighing >44 kg (about the size of a sheep)" (Avise, Hubbell, & Ayala, 2008, p. 11455). Although many species are threatened with imminent extinction, fewer than 1400 of all species have gone extinct in the past 400 years (Stork , 2010). For amphibians, only 9-122 species out of 5,918 extant species have become extinct since 1980 (McCallum, 2007). However, McCallum (2007) has presented a more alarming view:

> The current extinction rate of amphibians could be 211 times the background amphibian extinction rate. If current estimates of amphibian species in imminent danger of extinction are included in these calculations, then the current amphibian extinction rate may range from 25,039–45,474 times the background extinction rate for amphibians. (p. 483)

The psychology of contemplating scale in nature may also have bearing on conservation priorities being swayed by an irrational discounting of natural systems, such as investing in species now (large/spatially distant) and worrying about populations later (small/spatially close). The discipline of conservation psychology reveals some convincing reasons for conservation biologists to shift their primary focus toward local biodiversity from exotic species. Biodiversity is complex, which makes it difficult to manage conceptually and communally without falling victim to some of the numerous psychological phenomena that change our perceptions of conservation value. Examples of psychological phenomena that influence conservation values include the social-psychological phenomena of shifting baselines (Papworth, Coad, & Milner-Gulland, 2009), environmental myopia (Silvertown, Tallowin, Stevens, Power, Morgan, Emmett, Hester et al., 2010), prioritizing virtual exotic species over local biodiversity (Ballouard, Brischoux, & Bonnet, 2011), prioritizing more colourful animals over inconspicuous animals (Prokop & Fanĉoviĉová, 2013), priority for different types of landscapes (Ulrich, 1993), and gender and cultural differences (Fuller, Irvine, Devine-Wright, Warren, & Gaston, 2007; Heerwagen & Orians, 1993). I have considered these psychological phenomena in the design of a curriculum geared specifically to support youth engagement with local biodiversity. Elements of these psychological phenomena are also evident in items of the MEI because of their relevance to conservation.

Energy Conservation

Ecosystems include streams of biomass, calories, nutrient cycling, and food webs that need to be replenished. Items that are most on the radar for sustainability, including recycling plastics, bioenergy plants, fuel efficient cars, and many other technological substitutes for ecology, do not address the issue of nature conservation (Rull, 2011). "There remains a disconnection, though between biodiversity conservation and emerging issues in sustainability" (Baldwin, Powell & Kellert, 2011, p. 322). There is much evidence showing that investments in nature improves the economy and the climate as well as human health, psychology, and attitudes toward biodiversity conservation (Baldwin, Powell & Kellert, 2011; Mitchell & Popham, 2008; Fuller et al., 2007). Ecological investments focus on the true core of sustainability.

The problem of meeting energy demands for sustainable development is not an isolated human systems and technological problem. Energy efficiency can only be addressed by meeting the reciprocal needs of ecosystems and human systems combined. Energy efficiency and the conservation of biodiversity may be seen as separate issues. Items within my MEI test this assumption. Energy flow through salamander populations, for example, in the Hubbard Brook Ecosystem, is about 11,000 kcal/ha· yr (=46,000 kJ /ha yr). This is approximately 0.02 % of the net primary productivity and is approximately 20% of the energy flow through bird and mammal populations (Burton & Likens, 1975a, p. 1068).

> To put the estimated 1.165 kcal/m^2 caloric contribution of these southern Appalachian salamander populations into perspective the annual average human harvest of the world's marine fishery was reported as 0.3 kcal/m^2. (Davic & Welsh, 2004, p. 407)

Notice that the common unit in energy efficiency research is also measured in joules in terms of human use per unit of biomass. Clearly the scientific units of energy (kJ = Kilo Joules) apply equally in terms of power generation for human systems (Voivontas, Assimacopoulos & Koukios, 2001) and natural systems alike. In the latter, however, these energy values are understood in terms of ecosystem function (Burton & Likens, 1975ab). An important difference is that the energy that flows through eco systems powers ecosystem services, whereas the energy in human systems powers a variety of technological artifacts.

A more comprehensive or holistic understanding of ecology adds greater conceptual value to the utilities and services that ecosystems provide. Conservation biology is hardly conceived as or presented as a serious plan for energy savings. This is an economic error and is considered an alternative ecological concept that my curricula addresses by highlighting the energy systems contained in nature.

Alternative Ecological Conceptions

It is important for students of ecology to learn to understand, link, and explain concepts as others do and apply the same rationale and mental skills to solve related problems. However, novice learners often attempt to rationalize *alternative conceptions.*

Alternative conceptions are explanations and conclusions that are derived from uncritically held assumptions (Klymkowsky & Garvin-Doxas, 2008). They are nodes in a web of knowledge that "are usually held by a significant proportion of students and are highly resistant to instruction" (Anderson, Fisher & Norman, 2002, p. 952). Alternative conceptions differ from those that stem from the historical development of scientific thought, discovery, and understanding of factual reality. Thus, educators need to identify alternative conceptions that may be held by their students and become fully aware of the role this kind of thinking can play in preventing new learning to take hold.

Concept maps that link ideas into propositions can be used to study patterns of knowledge held by groups of students. Concept maps are built from a list of terms, for example: *population*, *decomposers*, *community*, or *food-webs*. Participants are asked to consider how the terms relate and to link them into a network of propositions. Each proposition consists of two terms that are connected by linking words (for example, communities *consist of* populations, or food-webs *have* decomposers). Once completed, concept maps, or the network of propositions, can show how many members of a group are conceptualizing, thinking, retrieving, learning, and communicating about the subject matter in the same way (Karpicke & Blunt, 2011; Zak & Munson, 2008). Concept maps are a useful tool for understanding alternative conceptions, which "are not simply loosely organized fragmentary ideas, but deeply seated personal theories of the world that—until corrected—constrain students' abilities to understand modern explanations of natural phenomena" (Sneider & Ohadi, 1998, p. 266).

The constructivist perspective on pedagogy suggests that true learning involves cognitive change that restructures rigid personal views. Compelling evidence coupled with an internalized logical understanding of a discipline, such as ecology or economics, translates into socially replicable concept maps. In other words, as new ideas are introduced new concepts will independently, cognitively, and empirically connect to related concepts in similar ways. The shared transition in perspective has been likened to a scientific revolution or paradigm shift occurring on a personal cognitive level (Sneider & Ohadi, 1998). Teaching the history of science with a constructivist–historical teaching strategy replicates the process of discovery for ideas that have provided an overarching explanatory context for disparate facts through supporting evidence.

The act of reconstructing knowledge through retrieval practice has been found to induce more learning than elaborative study activities that use concept maps to structure knowledge into memory. Elaborative study is the common practice as students are taught to retrieve concepts that have been encoded into memory through the linkages of an organized knowledge structure. "Far less attention has been paid to the potential importance of retrieval to the process of learning...Retrieval is not merely a readout of the knowledge stored in one's mind; the act of reconstructing knowledge itself enhances learning" (Karpicke & Blunt, 2011, p. 774). Likewise, learning in an ecoliteracy based teaching philosophy is not as strongly directed in the traditional manner of concept mapping, such as memorizing food-web linkages as concept maps, but encourages the practice of retrieval by having students recall information and cognitively restructure their direct experiences in nature.

Educators have identified and compiled a number of *"alternative ecological conceptions"* (Klymkowsky & Garvin-Doxas, 2008) or *"naive conceptions"* (Sneider & Ohadi, 1998). They tend to be common answers given by students in response to open ended questions (Stamp et al., 2006; Klymkowsky & Garvin-Doxas, 2008). A function of many of the environmental psychometric instruments in use has been to identify and then "correct" alternative concepts. However, this method of repairing knowledge by reference to alternative conceptions is counterintuitive to the process of inquiry and learning. Inquiry into alternative conceptions may be unreasonably blocked by intrinsic social and ecological prejudice. The first rule of reason is: "Do not block the way of inquiry" (Peirce, 1931/1994, para 135). The naming of concepts as "alternative concepts" or "misconceptions" by educators (for example, Klymkowsky & Garvin-Doxas, 2009) has the negative consequence of downplaying the value of alternatives that are both necessary and valuable in the process of discovery. The enterprise of science, as a model for social viability, builds theory out of alternative conceptions.

> Thus, an idea which may be roughly compared to a composite photographsurges up into vividness, and this composite idea may be called a general idea. It is not properly a conception; because a conception is not an idea at all, but a habit. But the repeated occurrence of a general idea and the experience of its utility, results in the formation or strengthening of that habit which is the conception (Peirce, 1898/1994, para 498).

In the preceding quote by Peirce (1898/1994), an instinctual idea (the habit) transforms into the conception. Alternative conceptions push the boundaries of knowledge into experimental phases of rejection, retention, or modification as new evidence comes to light. Rather than using an inexact reference to what Francis Bacon called "the idols of the human mind" (Bacon, 1990, p. 49), a more appropriate educational reference would be to concepts without reason or *unreasoned conceptions*. Francis Bacon (1990) referred to these preoccupations of the mind as idols of the tribe, cave, marketplace, and theater. "I would argue that their [the idols] intrusive inevitability fractures all dichotomous models invoked to separate science from other creative human activities" (Gould, 2000, para. 12). Educational instruments used to locate unreasoned conceptualizations (e.g., Klymkowsky & Garvin-

Doxas, 2009) may help to identify impediments to reasoned inquiry and to research teaching methods as they relate to change in perception and the thought process. Rather than trying to correct for errors of conception, the curricular approach adopted in my thesis brought students into environments where they could experience directly the facts of nature.

Items within the MEI give students a subjective outlet to express their feelings qualitatively by means of an abstract scaling (disagree strongly to agree strongly). If the scaling corresponds to a common understanding, conception, or construct of what constitutes a favorable ecoliterate conception or a closer connection to nature, then the scaling will correspond to the expected polarity across modules. However, some items or constructs may by multidimensional and invoke different ways of conceptualizing the issues under consideration.

Complexity and Emergence

When challenged to explain complex behaviour, students will often respond with alternative rational explanations. Alternative explanations that are communicated will often preclude randomness from the process, even though students clearly understand and can explain randomness as it applies in an isolated system, such as diffusion of water across membranes (Klymkowsky & Garvin-Doxas, 2008). Ecosystems are complex systems that require an understanding of pattern and scale stemming from random based agents, such as interacting molecules of water or genes on a molecular level to emergent patterns of complexity at higher levels, such as communities (Levin, 1999, 2005).

Complexity and *emergence* are key concepts in the life sciences. The concept of emergence is linked to Aristotle's precept that the whole is more than the sum of its parts (Molnar, Marvier, & Kareiva, 2004). A complexity of interactions leads to emergence.

Forecasting of complex systems cannot be accomplished by reduction to the minute parts; they have to be studied over larger scales by testing patterned relations in a comparative context.

Teaching about complexity and its application toward understanding sustainability in the life sciences is a challenge. Learning and teaching about complex social-ecological issues may be inhibited by ignorance. Ignorance motivates a chain of reliance and trust in the status-quo of governance and further avoidance of information about the nature of complexity issues (Shepherd & Kay, 2012).

Remaining sections in this literature review consider the principles of complexity in context of other theories and their effectual relations in social-ecological systems. An unreasoned ecological conception that I sought to address in the design and delivery of the curricula for *Junior Amphibian Ecologists League* was the preclusion of random agents and their role in the patterned organization of complex systems. Randomness can lead to emergent complexity that is expressed from but not predicted by the interaction of randomly interacting parts (Knapp & D'Avanzo, 2010; Robert, Hall, & Olson, 2001). I believe this conception can be addressed by teaching about various scales of complexity through direct engagement in nature study using local examples of biodiversity.

History of Ecoliteracy Education

The term environmental literacy first appeared in 1968, ecological literacy appeared in 1986, and then ecoliteracy was coined in 1997. Each of these terms has been adopted in various ways with different interpretations and meanings (McBride, Brewer, Berkowitz & Borrie, 2013). The following section of my literature review provides a deeper historical account of an ecoliteracy or environmental pedagogy prior to the coining of the phrase, because some of the earlier literature provides important insight into the pedagogical theory developed in my thesis.

First Nations Considerations

The First Nations peoples of British Columbia have extensive and deep historical ties to the land because they gathered foods and other materials directly. Turner, Ignace, and Ignace (2000) noted that roots of plants were dug, harvested, and planted from areas that were left fallow for three or four years. This activity of cultivating the land required a foundation of knowledge that was learned through generations of cultural transmission by means of oral communication and social interaction (Turner, Ignace, & Ignace, 2000).

Current studies of First Nation's Traditional Ecological Knowledge (TEK) (Turner, Ignace, & Ignace, 2000) inform us that much information has been lost but there remains much that can be learned about sustainability by engaging directly in local nature. TEK has an important role in natural study education and the future development of conservation biology around the globe (Kimmerer, 2002).

Local First Nations. First Nations peoples and Elders in Prince George and surroundings areas have cultural ties to local amphibians. However, TEK with respect to amphibians is not very well known or understood by outsiders. Some of the relations to amphibians are discussed here in the context of the frog clans among the First Peoples of BC. In an educational context, however, there are concerns about the conservation of cultural rights. Turner, Ignace, and Ignace (2000) provided a set of guidelines that stress the importance of acknowledging the people who are consulted for ecological knowledge resources. In Prince George, for example, I have held informal discussions with local First Nations Carrier (Dakelh) Elders, peoples, and chiefs about their TEK with respect to amphibians. I have been hesitant to write about all that I have learned but, with permission, one account about the Dakelh views about long-toed salamanders can be shared.

Salamanders in a Dakelhe narrative. Grace Rossetti, a Nak'azdli or Carrier/Dakelh Elder, was kind enough to meet and discuss her traditional knowledge of salamanders. Altrhough Rossetti was born in Nak'azdli territory, she has lived in Prince George and so prefers to be identified by name rather than associated with a specific First Nation. Salamanders are not an animal that Dakelhe people will talk openly about. Before Rossetti could speak to me about the salamanders she had to voice some words in private that were taught to her by her mother. If a salamander was found by a child in the woods it had to be returned immediately and the right words had to be spoken for the child's protection. The understanding is that salamanders can make you sick, cause death, and steal your soul. They are an animal that is not to be touched. This narrative is similar to the information supplied by Carl (1966) that long-toed salamanders are portend of death, places to avoid, or bad omens among First Nations peoples of BC.

During the interview I explained that NAMOS BC was interested in ethical research from a First Nations perspective and asked about collecting voucher specimens for study. Rossetti said if a salamander was killed that a tiny piece of the salamander's heart, liver and other organs had to be buried near its place of capture. Tobacco would have to be lit at the site as we voiced words of respect and thanks to the land and the salamander.

Multiple connections can be made between this First Nations narrative and conservation, ecology, and educational ethics. The traditional activities of the First Peoples collecting roots would mix soil habitats (Turner, Ignace, & Ignace, 2000) where salamanders and toads would have undoubtedly been commonly encountered as debris was turned and children explored nearby. Hence, these harvesting activities of the First Nation's peoples would have been an active agent in the ecological niche of amphibians. Common among Aboriginal peoples is a conservation ethic that expresses a deep respect for nature, as expressed in current documents: "We respect and love our Land and know that, as our Mother, it has provided for us; and according to our Teachings we will stand as one to respect and protect our Land and all life on it" (Carrier Sekani Tribal Council, 2007, p. 4).

Traditional ecological knowledge. There are concerns about intellectual property rights that must be considered when communicating about First Nations traditional ecological knowledge (TEK). Including local TEK in this thesis or in my teaching requires attention to guidelines and acknowledgment. Turner and Cocksedge (2001) provided guidelines for sustainable harvesting of non-timber forest products with respect to First Nations that included cultural and social factors applicable to traditional knowledge of salamanders that has been shared. However, the cultural taboo related to salamanders makes this a complex area for ethical decision making. For example, conflict of interest could occur if a local Dakelh child were to join the *Junior Amphibian Ecology Program*. Respectful inquiry on such issues is, for me, an ongoing pursuit in the development of educational curricula.

Cultural edges. *Ecological edges* was the term used by Turner, Davidson-Hunt, and O'Flaherty (2003) to describe ecological transition zones where different assortments of biodiversity come together. A dynamic interrelation at the edge of these ecological transition zones affects resilience and functional trait diversity and it threads emergent complexity into the planet's environment. These authors have connected ecological edges to cultural edges as follows:

> More than simply a metaphor, we would like to propose that, like ecological edges, cultural knowledge systems can intergrade producing a richness of knowledge and practices that enhances the resilience of local societies. Cultural edges, rather than being border zones between discrete social entities, are zones of social interaction, cross-fertilization, and synergy wherein people not only exchange material goods but also learn from one another. (Turner, Davidson-Hunt, & O'Flaherty, 2003, p. 440)

The survey methods of the MEI were not specifically designed for inference on cultural diversity among the student groups. However, the cultural narrative from local First Nations presents an ecological and historical context that impinges on the development of local nature study curricula. I have encountered a cultural edge in the relations between First Nations and animal care and the effect on researching biophilia or teaching ecoliteracy. Gaining an improved understanding of this cultural edge may assist in the further development of an ecological ethics (Minteer & Collins, 2005) supporting ecoliteracy curricula.

The Dakelh Chuntah Educational Society creates opportunities to teach children about First Nations values and ecological sciences upon recognizing a common thread in these two philosophies – an eco-cultural edge. Through NAMOS BC, I collaborated with the Dakelh Chuntah Educational Society and, along with local Elders, I taught an amphibian module. The activity occurred in Fort St. James in October, 2008, with approximately 30 children (see Figure 2). A traditional ceremonial smudge for good-hunting was performed by an Elder before I taught my module on amphibian ecology. I took the children on a "hunt" for amphibians. We caught frogs, toads, salamanders, and snakes. Each time a creature was caught we gathered and talked about their ecological and cultural relations to the land.

Figure 2. Dakelh Chuntah Educational Society collaboration, October, 2008.

During field trips that I have organized and taught since 2004, children inevitably capture creatures along trails. They find joy in handling them as they gently touch their skin. Animal ethics committees and government scientists (Dr. Purnima Govindarajulu - BC herpetologist - personal communication) are concerned about children touching wild caught amphibians. This parallels the First Nations taboo of handling salamanders. The cultural root of this response to amphibians has independent or parallel origins, yet the outcome is similar. The relative degree of salamander encounters and relations is encouraged to remain low.

The ethics of handling creatures is a common problem in biophilia research and education. A biophilia-based psychological study by Abell (2012), for example, examined social identity theory in relation to human-animal relationships. The study searched for motivations that would lead to voluntary assistance in the conservation of endangered animal species. "However, the benefits of facilitating direct contact experiences to encourage empathy, concern and helping behaviour need to be weighed against the potential cost to the welfare of the animal" (Abell, 2012, p. 12).

Early History of Nature Study

Natural history, science, and philosophy have been partnered in formal educational curricula going back to the thirteenth century but dwindled by the sixteenth century (Thorndike, 1940). Prominent naturalists from the 19th century, including Johann Pestalozzi, Charles Darwin, Louis Agasiz, and Thomas Huxley (Krupa, 2000) inspired an educational philosophy of nature-study that is captured in Agasiz's dictum to "study nature, not books" (Weaver, 1947, p. 162). Animals, plants, agriculture and educational programs geared toward the outdoor experience held prominent roles in this early period of nature-based educational studies (Fairbanks, Hodge, Macbride, Stevens, & Bigelow, 1905). In the early 20th century there was an initiative by naturalists and educators to design nature study programs (Kohlstedt, 2005).

A contemporary, Fairbanks (1905), explained:

> Nature-study has developed in our schools as a result of impulses from several different directions. On the one hand, we can trace its beginnings through object teaching to Pestalozzi and other educational leaders of the still more distant past, all voicing the feeling that the child's education should deal more with things and less with books. From another side has come the growing influence of science in the university and high school also emphasizing the importance of contact with nature. (p. 52)

Nature study. Educational research on outdoor education, nature study, natural sciences, and direct contact with nature gained momentum and attention through the publication of *Nature-Study Review* in 1905 (Kohlstedt, 2005). The stated mission of the journal "devoted primarily to all scientific studies of nature in elementary schools" was printed prominently on the cover of most issues. The journal was launched with much discussion on what defines nature study, how it is distinguished from science, and its demonstrated importance for children’s intellectual development. The issue of importance needed to be answered because there was concern about devoting less attention to other subjects while also finding the time needed to add nature-study to an already stressed workload for teachers and students.

> To summarize very briefly, the materials of nature-study are incidental, its intellectual purpose is the supreme thing. If it becomes an efficient means of securing a symmetrical intellectual development, there must exist a definite conception of its functions and limitations. The amount of work presented must be much reduced and the method of presentation carefully adapted to the child's mental development. Direct observation of nature must take the place of much time now taken by the teacher, and the results of these observations must replace much that is now given in readings from the multitudinous so-called 'nature-books'. (Coulter, 1905, p. 51)

Trafton (1913) sent out a questionnaire to nearly 1000 student that asked simple questions, such as: "1) Make a list of all birds, insects and other animals that you have seen living in Passaic. (Do not name animals that you may have seen in a menagerie) [and] 2) Describe briefly the one most noticeable thing about each" (p. 152). Trafton's (1913) assessment instrument was designed to study general knowledge about plants, animals, their related likes and dislikes, and conceptions about animal intelligence. Trafton (1913) determined that the children could name very few wild species, had little understanding about animal intelligence, and expressed an irrational dislike for snakes. Moreover, it was determined that the amount of interest in animals increased as children knew more about their habits. Trafton (1913) outlined his specific reason or philosophy for teaching nature-study:

> The development of the child and the demands of our civilization necessarily require the child to spend a large amount of his time in preparing to become a part of that civilization, but just as truly do they demand that these ties which bind the child to Mother Nature shall not be entirely broken, but that these chords from Nature's heart shall be fastened more securely to the child's life in order that through them may be absorbed the inspiration that Nature can furnish. How to teach Nature so that these ends may best be accomplished is the problem that teachers are now solving. (p. 150)

Propaganda in the schools. The outcome of nature-study for the development of a child's civic relations in the domain of conservation was a common theme in nature study (for example, Downing, 1912; Shufeldt, 1922) and this extends into the modern literature (for example, Barnett, Lord, Strauss, Rosca, Landford, Chavez, & Deni, 2006; Cachelin, Paisley, & Blancard, 2009). This approach to encourage civic duty was also evident in the United States School Garden Army that was initiated in 1917 after World War I. The School Garden Army enlisted trained experts to teach on the modern science of agriculture and encouraged production in home gardening as a first principle of education with the goal of leading youth into the life of the state (Hayden-Smith, 2007).

Remmers (1938) lectured students with the intent "to change their attitudes in a given direction" (p. 354). He felt it was the role of schools to inculcate educators with the power of educational propaganda to change attitudes among students that would lead to socially desirable outcomes. Item (1) “Allowing the government to tell the farmer how to farm” and (4) “Taxing all the people to plant new forests” were considered favourable outcomes, whereas and items (2) “Allowing each farmer to farm as he pleases”; (3) “Clean farming”; and (5) “Draining swamps” were less favourable. The study design lacked a control group but there was a statistically significant change in favour of the desired outcome in attitude scores following instruction. The urban group looked more favourably than the rural group on item 1 after instruction, item 2 before and after instruction, and item 4 before and after instruction. Both groups, however, showed the same general trend in attitude scores after instruction. The first post-test assessment showed a dramatic shift in attitude, although subsequent assessments in following months did not maintain the same degree of attitude shift. The method created a baseline shift in attitude scores at the end of the study.

Lessons from the early history of nature study. There is a precautionary tale in a review of the Williamson and Remmers (1940) historical study. Government intervention and taxation were considered to be measures that would assist in the conservation of soils, forests, and related problems. These researchers demonstrated the feasibility of changing attitudes toward the intended outcomes of the program. Their intended outcomes also resonate in Hardin's (1968) landmark paper on *tragedy of the commons*. Both suggest that government intervention is needed to stem the loss, through over-consumption, of communal resources. However, evidence has shown that community harvesters of a local resource can and do self-organize to manage their common pool resources sustainably (Ostrom, 2009; Persha, Agrawal, & Chhatre, 2011; Wilson, O'Brien, & Sesma, 2009). Local participation in rulemaking without external and well-crafted macro-level government intervention creates environments that are richer in biodiversity while benefiting the local economy.

Hence, government intervention from afar to manage local natural resources is not always going to be the desired outcome. Conceptions of how to conserve nature have changed. For example, Rands, Adams, Bennun, Butchart, Clements, Coomes, Entwistle et al.'s (2010) modern view of conservation is at odds with Remmers (1938) conceptions of favorable outcomes:

> To address the continued global loss of biodiversity, we propose the pursuit of three interconnecting priorities: (i) to manage biodiversity as a public good, (ii) to integrate biodiversity into public and private decision-making, and (iii) to create enabling conditions for policy implementation. (p. 1300)

Similar concerns have been raised with respect to the dominant social paradigm and how it promotes mainstream notions of environmental sustainability that are ecologically defunct (Manoli, Johnson, & Dunlap, 2007; Rees, 2009). Modern approaches to conservation have not progressed to a better outcome because resources remain in steady decline and there is little sign of a predictable transition to come. There is a historical lesson on the danger of teaching sets of goal orientated and conscious behavioural responses through rhetoric describing them as environmentally or planet friendly. The kinds of environmental behaviours advocated often result in adverse outcomes. From an ecological point of view, there is sound reason to be highly skeptical of this approach.

Uncertain propaganda. A goal-orientated, environmentally friendly style of education is also inconsistent with the concept of uncertain theory in scientific philosophy. Teaching students to adopt some kind of "good" environmental behaviour, such as encouraging them to help or care for endangered species (for example, Abel, 2012), is a theory of conservation that is arguably more perilous in the larger scales of complexity where outcomes are highly unpredictable. Pro-environmental teaching aids reinforce the conception that the behaviour being taught is a good thing; however, upon historical reflection many errors have been revealed. Enabling critical thinking skills through ample supply of educational resources (for example, ecosystem services) is more philosophically consistent with scientific inquiry as an enabler and motivator of behaviour that can lead to a better understanding of local ecological economics and the means to deal with complex matters.

Recycling exemplifies a modern example to which this lesson of environmental or conservation-orientated propaganda applies. The term *recycling* applies to ecosystems and to the environmental notion of recycling technological artifacts, although the dynamic process is not the same. Many educational programs are promoting pro-environmental propaganda to change attitudes that will lead to a behaviour outcome in favour of recycling (for example, Kollmuss & Agyeman, 2002). During outdoor educational excursions I stress to students that there are fundamental differences between recycling in nature and recycling in human systems.

Environmental Education and Research Post 1974

Behaviour has been of particular importance to the environmental educator. Accumulation of knowledge or changes in attitude, however, do not necessarily translate into strong behavioural change (Leeming, Dwyer, Porter, & Cobern, 1993). For example, Kollmuss and Agyeman (2002) concluded that "research showed that in most cases, increases in knowledge and awareness did not lead to pro-environmental behavior" (p. 242). Varied educational factors, such as group size, duration of the program, teachers, teaching location, and other environmental conditions can alter the outcomes. None-the-less, many studies have identified significant changes through nature-based education (Cachelin, Paisley, & Blanchard, 2009; Stern, Powell, & Ardoin, 2008).

Most environmental educators believe that the best ecological outcomes are nurtured through direct outdoor experience (Cachelin, Paisley, & Blanchard, 2009; Stern et al., 2008). There is a different pedagogical emphasis in nature-study outcomes that is more than knowing the material; it is also about *feeling* the temperature, rain, or sunshine and being sensorialy inundated by the complex nature of the biosphere. There was a transition in the 1970s, however, moving away from nature study education to focus more on the technological side of environmental concerns.

Ecological instruments. Leeming et al. (1993) provided a review of environmental education research that was published after 1974. The review focuses on studies that sought change in environmental knowledge, attitudes, or behaviours and provides a methodological critique of classroom versus out-of-class interventions. Additional instruments have been developed, modified and tested since then (Dunlap & Van Lier ,1978, 1984; Manoli, Johnson, & Dunlap, 2007; Hagenbuch, Bynum, Sterling, Bower, Cigliano, Abraham et al., 2009; Smith-Sebasto & Cavern, 2006; Farmer, Knapp, & Benton, 2007; Cachelin et al., 2009).

Examination of instruments in use by environmental educators reveals common goals and themes. There is a common goal to increase environmental awareness using quantitative response instruments. These instruments are used to assess the impact of various programs on attitudes toward the environment. These researchers have used qualitative observation to examine affective reactions to the program interventions. These goals differ from the goals of this thesis, however, which is not based on environmental awareness or about measuring attitude changes toward the environment. This thesis is directed at the biophilia hypothesis as I try to gain a better understanding of this complex behavior in relation to different kinds of ecological experience.

Biophilia is a complex behavior where forecasting and intentional factors needs to be integrated into the theory beyond a simple genetic correlate of innateness. The rules of biophilia, however, go beyond genetic instinct as gene-culture coevolution is also identified as an important part of the theory (e.g., Mitchell & Mueller, 2011). Evolutionary psychologist Mark Baldwin (1886) was the first to recognize that the intentional process is a distinct cultural factor in evolution. Niche construction also brings the context of ecological heritability into the mix, where modifications to the environment, artifacts, and homes, feed a longer-term legacy of influence back into the degree of selective pressure that modules fitness in the evolutionary process (Odling-Smee & Turner, 2011). This feedback loop has important implications for testing the innateness components of the biophilia hypothesis in looking at the ways that learners modify their environments, what role forecasting has in the process, how this influences behaviour, and if the response is heritable on both genetic and ecological levels. Response instruments or observations on behaviour will not be able to provide a critical test of these more complex aspects to the biophilia hypothesis and may only provide supporting evidence.

Biophilia behavior may indirectly be measured, however, by outcomes in an attitude response instrument in the way that other studies have used attitude responses to study environmental behavior. However, this is unlikely to serve as a critical test of the biophilia hypothesis. Although attitude responses to an instrument represent one kind of behaviour, an attitude response instrument may only provide supporting evidence behind some of the cognitive aspects that are involved in the behaviour of interest.

Other types of evidence can be collected to determine if a behavioural response occurs. For example, Ruiz-Gallardo, Verde & Valdés (2013) studied garden-based learning, which uses a garden as a teaching tool. Ruiz-Gallardo, Verde & Valdés (2013) gathered data on academic success, number of disruptive behavior episodes, and notes on general qualitative change in the student's behaviour. They identified an increase in academic performance, less disruptive behaviour, and other benefits to the program.

Educational Philosophy of this Thesis

Student perceptions about urban ecology and the nature of their learning environments is a critical component of this study. The traditional focus of ecologists on pristine and wild nature requires a shift in emphasis onto urban ecology for many reasons (Grimm, Faeth, Golubiewski, Redman, Wu, Bai, & Briggs, 2008; Mitchell & Brown, 2008) but perhaps most important are the implications for conservation psychology. The impoverished remnants of nature in urban environments are all that remains in the front lines of ecoliteracy experience.

Urban education. *Urban, peri-urban, rural, natural, disturbed, domesticated*, and *novel* are different kinds of labels that grade and complicate the taxonomy and nomenclature of human settlement. "At one extreme are anthropogenic soils, where the main soil forming factor is human influence; at the other extreme are natural soils that have not been used by humans but have nevertheless received inputs of contaminated dust or precipitation" (Rossiter, 2007, p. 1). Pre-industrial indigenous modifications to the landscape versus modern transformation adds an important historical dimension to the taxonomy of human settlements (Jackson & Hobbs, 2009). Some researchers use information on housing density to classify suburban, exurban, and urban sprawl (Mitchell & Brown, & Bartholomew, 2008), which does not satisfactorily define the entire cross section of urban ecology (Grimm et al., 2008).

In relation to education, however, the history and continued practice of urban design largely lacks the means to preserve or invest in the ecological infrastructure of school yards. Ecological infrastructure is needed to generate ecosystem services that will yield long-term dividends in educational outcomes. From a bioengineering perspective, however, there is ample evidence of urban design flaws:

> Designed or altered streams, rivers, flood channels, canals and other hydrosystems serving urban areas neither replicate the aquatic ecosystems they replace nor preserve the ecosystem services lost (except for those, like flood conveyance or water delivery, for which they are designed). (Grimm et al., 2008, p. 758)

Conservation biologists require social, political and economic means to invest in local populations linking biodiversity loss to local urban processes (Puppim de Oliveira, Balaban, Doll, Moreno-Peñaranda, Gasparatos, Iossifova, & Suwa, 2011). Organisms in populations are the more sensitive bio-indicator of natural capital (Ceballos & Ehrlich, 2002), because they underpin the mass provision of ecosystem services (Gaston, 2010), many of which are cultural in nature (Chiesura & de Groot, 2003). Populations and the organisms in them are the familiar part of our cultural experience, such as those in the local urban park, wetland or forest that was likely cleared some point in recent memory (Miller, 2005). The urban environment has the greater demographic share of nature experience.

Niche constructing pedagogy revisited. The detritus of technology creates a heritable legacy of technological cycles, or *technosols*, that are produced in construction as synthetic and mined materials are managed and distributed. The *World Reference Base for Soil Resources*, for example, added technosols as a new reference soil group in the taxonomic scheme. Technosols are defined as urban soils that are dominated by human technical activity, including the presence of artifacts, impermeable liners and technic hard rocks such as pavement (Rossiter, 2007). Sterilization by pavement, combustion of fuels, and decay of technology pollutes the living environment with admixtures of materials inadvertently and consciouslay, for example, the mercury cycle or other plastic/nano 'recyclables'. This technological infection neuters the biological metabolism of ecosystems that otherwise fuel the capital production of ecology and our general well-being through ecological services.

While on nature hikes unrelated to my teaching I have observed children tossing toads and bashing them with sticks as they play freely and unattended. In this contemporary world that is depleted in its urban capital of biodiversity, it is a minor sacrifice, if it is one at all, to let children connect to vanishing pieces of this planet. Active ecoliterate pedagogy may equip children with a sense of compassion and morality when active with free play without adult supervision. These types of connections can be made the ecological niche beyond the urban periphery, where children learn about the value of nature directly, as an important part of human development toward an ecologically sustainable future. I envision natural spaces in urban areas, such as schoolyards, that can both support and provide a healthy demographic of niche construction activities and opportunities to nurture children's joy and ecoliteracy education.

Without direct relations to amphibian ecosystems, children will be inhibited in their ability to niche construct an understanding of our ecological dysfunctions. It is challenging to fully recognize and contend with the diversity of urban and cultural edges that create barriers in the educational development of a behavioural ethos toward ecoliteracy, the conservation of amphibians, and biodiversity in general. I often tell children to dirty their hands in the soil before handling; they bioturbate the soils. In contrast, latex, nitrile or vinyl gloves, used routinely by herpetologists and field biologists in general, are known to be eco-toxicologically lethal to amphibians (Cashins, Alford, & Skerratt, 2008). From an ecoliteracy perspective, using toxic gloves for the care and handling of amphibians is irrational. Not only are they toxic but they obstruct a valuable bond that can otherwise be obtained through direct skin to skin contact.

> We cannot win this battle to save species and environments without forging an emotional bond between ourselves and nature as well – for we will not fight to save what we do not love (but only appreciate in some abstract sense). (Gould, 1991, p. 14)

Children identify animals among their list of things that they like most (Randler, Ilg, & Kern, 2005). Invariably, I have observed that children are keenly interested when a salamander, frog, or any kind of wonder is discovered wild on the land. They crowd in quickly, chatter rises, and they ask if they can hold or touch it. When they touch or hold a salamander, joy is invariably expressed. A minority of children will opt to just look, sometimes expressing fright, disgust, or repulsion. Children hold the salamander gently, they communicate handling ethics amongst their peers, and they anthropomorphize the salamanders by talking to them directly.

Experiential treatment. Curricula developed, implemented, and tested in this thesis were designed to span a metabolic rift or ecological gradient from a technological niche to a niche populated by amphibians. I drew on the example of Aristotle teaching while strolling around a garden to develop a *peripatetic* approach to instruction:

> Aristotle returned to Athens, together with Theophrastus, and founded the Lyceum...Theophrastus became the second director of the Lyceum and the Peripatetic School (the name of the school was derived by the habit of lecturing while strolling around the gardens of the Lyceum)...The function of this institution was to train the leaders, officials and experts of the new era (Thanos, 1994, p. 4).

However, in the design of this study, I used a gradient approach to investigate the niche constructing activities of students in: (a) an indoor group vicariously engaged in the learning activities under the direct influence of human engineered environments and tools, and (b) outdoor groups attempting to further span the transect from urban parklands to rural forests.

Peripatetic curricular design encourages students to engage indirectly (indoor) or directly (outdoor) in the kinds of ecological behaviour, such as bioturbation of soils while hunting for salamanders, that otherwise engenders functional diversity and a dynamic resilience in places at the margins of urban technology. The peripatetic gradient in the study design reaches into environments of the planet's ecosystems that become more speciose, such as salamanders bioturbating soils while hunting for bugs. My sampling gradient stretches from the urban niche into parkland places where organisms niche construct away from the webs of technology.

The design of the study was intended to compare direct, indirect, and vicarious modes of teaching about amphibian ecology and conservation. Direct experience included physical contact and immersion into a natural setting where biodiversity could be encountered and sensed, such as students visiting amphibian habitats on a field trip. Indirect experience involved controlled and restricted contact with biodiversity and components of biodiversity were removed from their natural habitat, such as plants and animals in a terrarium in a classroom or museum. Indirect experience also included a field trip to an urban park environment lacking the indigenous species. Vicarious or symbolic experience, the main forum of public education, requires no physical contact with the natural world; the experience is synthetically contrived (Kellert, 2002). A vicarious nature experience includes watching nature programs on television, reading about nature in books, or learning about amphibian conservation science using internet resources.

Perception from experience. Students in my study were asked to reflect on the historical presence of biodiversity in each environment they visited during field trips or via GoogleEarth. Children emphasized differences in importance between biodiversity that they could illustrate in comparison to the actual local abundance or biomass of local species (Snaddon, Turner, Foster, 2008). Thus, vicarious experience may cause cognitive distortion in perceptions about the status of nature. Magazines and movies often give the most scenic, spectacular and impressive views of the Earth, which makes the biomass of species seem more abundant than it really is. Perceptions of biodiversity in novel urban environments may seem mundane, dull, tame, domesticated and of less value. However, nature videos and magazine articles on biodiversity may induce the alternative ecological conception that a greater number of pristine environments, intact ecosystems, and species remain on the planet relative to the few that actually remain (Hanski, 2005).

Why amphibians? Scientific assessments that measure the changing state of nature with respect to the extinction crisis measure more rapid declines in amphibians compared to any other taxonomic group (Collins & Crump, 2009; Wake & Vredenburg, 2008). This is of great concern to conservation-oriented scientists (Ehlrich & Pringle, 2008), myself included, because amphibian losses and ecosystem services are intricately and tightly linked. Amphibians not only fill a dynamic role that stabilizes the taxonomic composition of food-webs but their eggs also deliver significant annual contributions of energy and nutrient flux through aquatic sites to upland forests (Colon-Gaud, Whiles, Kilham, Lips, Pringle, Connelly, & Peterson, 2009; Regester & Whiles, 2006).

Amphibians are important indicators for ecosystem integrity because they are often keystone predators with biomass levels that exceed that of most other vertebrates in forest soil ecosystems (Davic & Welsh, 2004). They are energetically efficient and function as ecological conveyor belts, moving energy and nutrients through food webs. Amphibians are also relevant to the issue of climate change because they are global regulators of large supplies of carbon that are stored and cycled through the wetlands and forest soils where they live (Wyman, 1998). Some have even postulated that the declines of amphibians are enough to explain contemporary patterns in climate change (Davic & Welsh, 2004). Amphibians are energetically efficient animals that can convert 50-60% of energy from their food into new tissue, which is very high compared to the 2% efficiency in most birds and mammals (Collins & Crump, 2008).

Losing one amphibian species is equivalent to losing two ecological species and this is due to their complex life cycles metamorphosing from aquatic to terrestrial environments (Whiles, Lips, Pringle, Kilham, Bixby, Brenes, et al., 2006). Global amphibian loss also means that there will be significant long-term changes in ecological trophic structures, food-webs, and levels of primary production across the planet (for example, Colon-Gaud, Whiles, Kilham et al., 2009). The list of regulating ecosystem services that are directly linked to and subject to disturbance as amphibians decline, include: organic matter dynamics (nutrient regulation), predators-prey dynamics (biological control, pest regulation, disease buffer), nutrient and energy transfers among habitats, carbon stocks and nutrient cycles (air quality/climate regulation), and economics (food, medicine, eco-tourism).

Experience of amphibians and the local economy. The psychological link between amphibians and profit is a difficult idea for the average person. However, the metapopulation biology and local scale migration networks of amphibian populations (Gill, 1978) makes them a particularly suitable *ecological guild* for spatially addressing social-ecological connectivity in urban land development plans (for example, see Termorshuizen, Opdam, & van den Brink, 2007). What would an urban environment look like if it had amphibians in its center connected to populations on the periphery? How could such a human-nature niche be constructed? Why would we want to construct such a thing? Amphibians are an ideal subject group for making this seemingly odd connection between amphibians and profit, because the status-quo or common answer is that there is no economic link between the two. This is an alternative ecological conception and addressing it can help to bridge missing conceptual links between the economy and ecosystems in general. It is simpler to understand economic arguments for conserving fish, for example, because this food item can readily be bought at the super market; but even with a high monetary valued price, global fish stocks are facing near imminent extinction (Jackson, 2008).

Thinking about the odd links between amphibians and the economy requires new perceptions and values that have not been regularly exercised by a large segment of the population. In other parts of the world, the market value for amphibians for material goods including frog legs, lab specimens, skins used for making wallets. There are also cases of *bioprospecting* (for example, searching for unique compounds in amphibian skin) and eco-tourism is a multi-million dollar industry, although much underground trade in amphibians goes unreported (Collins & Crump, 2008). In British Columbia, however, amphibians are not harvested as an apparent market resource. In contrast, they are an exploited byproduct of forestry. Forestry operations kill amphibians (Waldick, 1997), yet neither provincial nor federal governments have departments or biologists dedicated to monitoring or implementing sustainable management plans for amphibian stocks. Hence, local society largely assumes that amphibians have little value and for the most part, are indifferent to the services they offer. As an educator, I see this attitude as an alternative ecological concept that may be changed with biophilic community education programs.

Empirical biophilia. As students flip over decomposing logs to observe salamander habitats, I point out the evidence that tells an ecological story about the history of complex processes operating in nature. Students learn about the diets of bugs, worms, mollusks, fungi, bacteria, spiders, frogs, and salamanders and how these organisms interact, break down the materials, respire, and migrate to supply nutrients to plants. Children and youth learn about food-webs, trophic levels, resilience, ecosystem engineering, and how biodiversity stabilizes and sustains the system over extended time periods on the order of tens of thousands of years

(Laland, Odling-Smee, & Feldman, 2001). They experience the scientific enterprise by collecting their own facts about natural materials on a local scale, which allows them to visualize how the materials are recycled in a very direct way. The students can see bits and pieces of leaves, sticks, eggs, and bones breaking into smaller components and they can gain a perspective in scale; the connections can be verified by looking at large trees or micro-pieces of debris in soils. Children learn through experience that biodiversity is employed in the flux and flow of energy and materials that can move rapidly from local scales. They begin to understand how this flux and flow stretches slowly across the global ecosystems.

Chapter Summary

The literature review in this chapter explored the history and broader philosophical implications of ecoliteracy education in the context of a precipitous mass extinction. In addressing these topics I have pondered a range of problems in the practice of conservation and education that I seek to remedy with a peripatetic, niche-constructing and biophilia-inducing approach to community-based education programs. There is a vast scale and complexity in the problems that one encounters in the process of developing a personal philosophy of ecological sustainability. First Nations and other cultural considerations, such as animal care ethics, add to the complexity. However, in the process of reviewing this literature from an ecoliteracy perspective, I developed a somewhat unique pedagogical philosophy that is well-supported. I also identified and made inferences about several thematic areas in which students may hold alternative ecological conceptions. Thematic values that were identified in this chapter are integrated in the design of the Modular Ecoliteracy Instrument (MEI); described in chapter three.

In the earlier part of the 20th century there was a great amount of educational effort and academic research directed toward the benefits of nature study. In contrast to environmental education programs, nature study education tends to focus more heavily on the ecological sciences. The pedagogical emphasis also invested more in gardening and niche construction (less so) related activities. Both nature study and environmental education have had an emphasis on learning experiences through social or civic relations. The kind of investment that nature study or niche construction pedagogy can put into local biodiversity, however, may lead to ecological engineering or artificial selection that can embed a range of ecosystem services into urban learning environments.

However, the emphasis on nature study started to dwindle after the mid-1970's in parallel with an increasing urbanized landscape (including school yards) and educational programs switched to environmental studies with fewer connections to local biodiversity. Nonetheless, an international effort to restore school grounds biophilically, "as educational resources has been under way for decades" (Moore & Marcus, 2008, p. 168). Environmental education is more anthropocentrically aimed at changing behaviour to make decisions perceived to be moral by spreading awareness of the consequences of certain actions. The literature that I have reviewed revealed the danger of the environmental educational approach. In contrast, nature study is more ecocentrically aimed at encouraging niche construction behaviour as an instrument for learning. There are many pedagogical challenges for teaching an ecoliterate curricula and adopting a niche constructing pedagogy that must be considered carefully to address the Anthropocene mass extinction that is happening right now.

CHAPTER III: RESEARCH METHODS

Details on the methods used for setting up the sampling design, enrolling students, and the manner in which the material content for the study is presented first. A comprehensive description of content contained in the MEI follows because it is a component of the study design for sampling student perspectives on many of the themes that are reviewed in Chapter II. I consider the limitations of the study design before moving into the specific details on the analytical methods, including statistics, used in the investigation of the MEI responses. Methods adopted in this thesis were reviewed and approved by the UNBC research ethics board.

Convenience Sample and Enrollment

The target sample for enrollment was children aged 10-14, although some parents asked if they could enroll younger siblings. Hence, younger children were also admitted into the program. I used a convenience sampling of children and youth, with the baseline demographics summarized in Table 1. Glossy coloured posters about a *Junior Amphibian Ecologists League* nature study program (see Appendix A) were posted at public libraries, coffee shops, Exploration Place, the College of New Caledonia, and at UNBC.

Table 1

Demographics of Student Attendance Including Male:Female Ratios

Age	#Students	m:f
8	2	2:0
9	3	2:1
10	6	3:3
11	3	3:0
12	2	1:1
13	1	1:0
14	1	0:1

Teaching Initiative

The *Junior Amphibian Ecologists League* was an initiative that I designed for NAMOS BC to fulfill its educational outreach mandate and to serve as a conservation leadership program for children. Parents were given a disclaimer that although younger children would probably find much of the program enjoyable, they might also find it too advanced. E-mail postings were sent out through various educational lists, a young naturalists club, and by teachers.

Teaching materials. Since 2004 I have been teaching outdoor educational modules on amphibian ecology to various groups and ages, from pre-school to university students and adults. My teaching program integrates, in various kinds of educational events, the materials and lessons that I have developed, adopted (with permission), or adapted over the years. In the educational event described in this study, the *Junior Amphibian Ecologists League*, I taught variations of the curriculum for five days to each of three treatment groups, according to the schedule shown in Table 2.

Table 2

Scheduled Dates and Times for Treatment Groups

Group 1 (rural parkland)	Group 2 (urban parkland)	Group 3 (indoor-vicarious)
Thurs. Aug. 25, 2011 8:30am-4:30pm	Tues. Aug. 30th, 2011 9am-4:30pm	Fri. Sep. 9, 2011 6pm-8:30pm
Fri. Aug. 26, 2011 8:30am-4:30pm	Wed. Aug. 31st, 2011 9am-4:30pm	Sat. Sep. 10, 2011 9am-4:30pm
Sat. Aug. 27, 2011 8:30am-Noon	Fri. Sep. 2nd, 2011 9am-Noon	Sun. Sep. 11, 2011 9am-4:30pm
Sun. Aug. 28, 2011 8:30am-4:30pm	Sat. Sep. 3rd, 2011 9am:4:30pm	Sat. Sep. 17, 2011 9am-4:30pm
Mon. Aug. 29, 2011 8:30am-4:30pm	Sun. Sep. 4th, 2011 9am:4:30pm	Sun. Sep. 18, 2011 9am-4:30pm

I reviewed pamphlets or booklets from an assortment of wetland or amphibian ecology programs for children, for example, *Project WebFoot* through *Ducks Unlimited*, *Wetland Keepers* (Southam & Curran, 1996), and *BC FrogWatch* (Ovaska & Govindarajulu, 2010). I looked for activities, assignments, and the kind of layout that I thought would be most effective. My initial plans were to use the free resources and activities offered by government or non-profit organizations. However, after reviewing the material I decided that it was not specific enough to the ecology of Prince George's amphibians. Therefore, I borrowed ideas from this material and also used other resources on amphibian ecology, including data from some of my own ecological studies, to create three booklets (see Appendix B) for the Junior Amphibian Ecologist program.

The Junior Amphibian Ecologist booklets contained detailed information on each activity, including learning objectives, activity terms, methods, illustrations, color photographs, maps, and background information on the ecological material children and youth would be learning about. The booklets had the NAMOS BC logo on the cover. Students in each group were supplied with a copy of the wetland ecosystem journal by Ducks Unlimited Project WebFoot, a pamphlet guide to amphibians of BC (Ovaska & Govindarajulu, 2010), a frog pencil, and a lined notebook. I explained that learners would not be graded but I asked that they do their best to attend each day of the program with all the supplies that I had handed out. The curriculum booklets (Appendix B) explain in greater detail what the participating youth were taught directly and with my assistance during the activities.

The three curriculum booklets were specifically tailored to each of the *rural parkland, urban parkland,* and *indoor* treatment groups. Each activity outlined the same kind of learning material across treatment groups and much of the written work was duplicated, although sections were shuffled slightly. The indoor booklet, in particular, had to refer more to the indoor teaching tools such as the computer, a slide show, and the mapping exercise. Although the nature of the activity was modified, the ecological background material remained substantially the same. Key words were presented through different activities. The reading materials in the curriculum booklets were used as activities progressed and I would bring students together to read out sections, highlight keywords, and discuss as a group.

Curricular activities. Beyond the written materials, however, I designed the learning activities to encourage niche constructing behaviours. These behaviours modify the learning environment, such as when children break a decaying log apart, so that the children become both cause and effect in the modification of the materials of study and the environments they learn from. The statistical inductive component involving the MEI, was a pilot to gather evidence and spatial information on educational values in relation to a research design that could potentially induce a biophilic response in the treatment group.

The curricula immersed students in the study of amphibians in the learning context of urban and peripheral ecosystems in Prince George. The study design transected an environmental teaching gradient running from (a) direct learning in *peri-urban, rural* to *parkland environments,* such as city parks and peri-urban parks that are accessible to the general public where amphibians are known to occur; (b) indirect learning spanning *urban/suburban/peri-urban/exurban parkland environments* where local species amphibians are mostly absent; (c) *urban* vicarious teaching indoors with school yard play environments and urban ecosystems where wild amphibians are very likely to be absent.

The Modular Ecoliteracy Instrument

This section describes the methods used to pilot the MEI in a quasi-experimental design. The goal of the approach described is to improve on the research methodology and to consider its inferential relations to the biophilia hypothesis. I designed content within the items of the Modular Ecolitearcy Instrument (MEI) to match information that was written into the curricula (Appendix B) and taught peripatetically to students enrolled in the junior amphibian ecologist league. Many of the ecological concepts and alternative forms reviewed in chapter 2 were targeted in the curricular design and contrastive elements of the item contents. The literature review was also used to construct the thematic content of each module abductively.

Modular design and rationale. Six modules were organized thematically into the MEI (Appendix C). Module 1 was designed to collect baseline demographic information and student perceptions of the amount of time they spend on outdoor versus indoor type activities. Prior to analysis, activities were sub-divided into three thematic groups, including: (a) outdoor motorized activities (e.g., riding an ATV) or watching nature programs (nature tech); (b) nature based outdoor recreation (nature rec); and (c) general electronic media (tech). Module 2 is the recently revised NEP instrument by Manoli, Johnson, and Dunlap (2007). Module 3 was designed to measure conceptions and attitudes about natural capital. The items within this module target economic issues, including management, forestry, and comparisons between technological things we pay for and processes in nature that are free.

Items in module 4 (Appendix C) continue on the theme of natural capital and this module was organized further into four sub-units measuring conceptions and values related to ecological discounting. The items within this module were designed to gather information on temporal and spatial perceptions of natural capital over small to large scales. This module integrates common findings in psychological research into discounting within environmental, ecological, and economic theory (Fenech, Foster, Hamilton, & Hansell, 2003; Hardisty & Weber, 2009).

The nature of the questions for module 4 complicates the analysis of pre-post effects. I designed questions in module 4 to look at ways that participants value ecological, economic, or environmental goods and services over time, distance, and in context of the complexity of issues concerning conservation ecology and sustainability. For example, Unit A of this module presents the following scenario: "In forestry, reduce the total amount of area that is usually harvested in the province by 50% and leave the rest alone to let amphibian ecosystems and migration routes return to normal." The scenario was followed by five options: "This sounds like a wise economic policy for the next: 1. 10 years, 2. 20 years, 3. fifty years, 4. one-hundred years, 5. ______years." Participants could write their own value in the final option, but few gave an answer here, which is an indication that this item was beyond comprehension or not well designed.

Items 6 to 11 in unit B of module 4 presents the following scenarios (paraphrasing the actual items – see Appendix C), "It is better to": **item 6:** conserve amphibians now to prevent losses in the future, **item 7:** conserve fewer bigger instead of many small wetlands, **item 8:** spend more to conserve local amphibians with fewer species rather than spending on amphibians in Vancouver where there are more species, **item 9:** same as item 8, but it contrasts local amphibians to more distant species in Amazonian rainforests, **item 10:** spend more to conserve wild and distant from the city instead of local and urban, **item 11:** spend more on threatened or endangered than the common local species. These items were designed to contrast conservation values at different scales of time, place, and complexity. Unit C in this module presents a scenario that compared the value of conserving amphibians in economic terms: "The economics of government, industry, and society would improve greatly if everyone decided it was best to spend money on..." The options were either to *sustain* things giving perspective that runs from global to local and present to future, or *invest* in biodiversity. The more complex design of module 4 means that inferences are more sensitive to sample size. Module 5 is a 9 item value topology assessment that I devised to focus specifically on amphibians, according to the value themes in Kellert (1999). Module 6 is the nature relatedness scale (Nisbet, Zelenski, & Murphy, 2009).

The comparative modular design (Appendix C) provides an inferential framework for the analysis of MEI student responses. The contrastive context provides a measurable index on validation. Validation is a measure of the degree of confidence in the evidence "to support the types of inferences that are to be drawn from test scores" (Crocker & Algina, 1986, p. 217). Validated test scores are utilized in the abductive inference to hypotheses that are further scrutinized by the observational components of my study. Given that the new structure of the MEI has yet to be trialed except in this study, and my sample size was kept low for pragmatic reasons, the degree of confidence for inductive statistical inference in reference to treatment groups and their MEI responses is largely reserved for future study. In other words, a goal behind designing the curricula and piloting the MEI in this study was to develop an effective test for my biophilia hypotheses. According to my statistical hypothesis, I expected that direct niche constructing experience with live amphibians in their natural habitat would respond more favorably to the MEI ecological values and students without direct experience in nature study (that is, group 3) will remain indifferent (no effect).

The modular design of the MEI may prove a useful comparative link to the various instruments in use and may assist in the development and analysis of the newly developed modules (Appendix C). Leeming et al. (1993), however, stressed the importance of using or revising instruments already in use. Nonetheless, researchers continue to experiment with new types of instruments that are designed and tailored to their particular program needs and questions of interest. Moreover, some instruments address multiple yet parallel themes (for example, Barnett et al., 2006; Stern et al., 2008). Partial consistency is maintained by joining instruments already in use with other modules using the MEI approach (Appendix C). The carryover of instruments that have already been tried creates a comparative baseline for a meta-analysis of results relative to other studies. Module 2, bringing the NEP into the MEI, is particularly useful, because the items were designed explicitly for children, specifically 10-12 years of age, following revisions after extensive sources of feedback including interviews and trials (Manoli, Johnson, & Dunlap, 2007). Module 6, the nature relatedness scale from Nisbet, Zelenski, and Murphy (2009) has been previously administered to undergraduate students with mean age 19.48 (*SD* = 2.83) and may have been more challenging for the younger students in this study, although no more so than module 5 that was based on Kellert's (1999) value typology (Appendix C). Items in both modules 5 and 6 use simple sentences that could make them more accessible to a younger age group.

Experimental Design

My research design enabled me to gather observations on the effects of the teaching environments in relation to student responses in pre- and post-administration of the MEI (Appendix C). Participants were asked to enroll in one of three groups scheduled to run at different times (Appendix A); a convenience assignment. Information within the postings

(Appendix A) did not supply information that would cause discrimination of the three treatment groups: (a) *rural parkland-direct*, (b) *urban parkland-indirect*, and (c) *indoor-vicarious*; note, that groups (a) and (b) were subsequently conjoined in the final analysis.

Another component of the study includes observations that I made while teaching the curricula. For this reason, a small sample size was a pragmatic component in my study design. It allowed me to focus on my teaching methods and style. It also allowed for careful observations of student behaviour in relation to their environments. The relative degree of inferential confidence in this study is raised by the merger of my observations of student behaviour, facts about their interactions within the respective teaching environments (treatments), and in relation to contrastive statistics from the MEI item responses.

Limitations to the Study Design

A small sample size is a key limitation of my quantitative analysis. Including only a few students in the study increased the likelihood that participants within each group would not be representative of the population as a whole. Students having highly different views or values from the rest of the group could have a strong effect on the results when placed in smaller groups. The smaller sample size, however, was intentional, so that I could focus on the practical side of developing the curricula, teaching, observing, and learning in the process. Learning during the process, for example, would suggest that I was more experienced by the time the final group was being taught. This would alter the treatment design, adding a further limitation or consideration when interpreting the final results. Ferraro and Pattanayak (2006) provide a concise summary of the common types of limitations that are encountered in ecologically orientated research and the kinds of controls that can be put into place to mitigate them:

> Examples of confounding effects include historical trends, unrelated programs or policies, and unobserved environmental and social characteristics. As in all scientific research, confounding effects are addressed through baselines, measures of covariates, and control groups. Baselines measure pre-intervention conditions and behaviors, and thus control for initial conditions that may affect measures of program effectiveness. Covariates are observable factors that also influence the outcome measure; these factors may be socioeconomic, biophysical, economic, or institutional. Control groups are individuals, communities, or areas that do not experience the intervention but are otherwise similar (on average). (p. 0484)

Furthermore, weather, season, sample size, independence, time, and socio-economics are examples of compounding factors that could plausibly alter the outcomes this study. Mosquitoes and unpleasant weather could leave participants with a negative attitude toward an outdoor program. Conversely, students in an indoor group may become restless. Studies of this kind generally suffer from the general applicability of the results across geographic regions, where different types of ecosystems are explored, which is why I included the NEP to serve as an additional standard for comparison with other studies.

Experimental Treatments

The MEI modules were printed on legal sized paper and followed a planned sequence of qualitative difficulty from 1 (Module 1), page 2 (Module 2), page 3 (Module 3), page 4 (Module 4), and page 5 (Modules 5-6) (Appendix C). The MEI was distributed to all students shortly after we went through our introductions. Approximately fifteen minutes was spent reviewing the instrument with page by page oral instruction explaining the format of each module and how the Likert attitude scales work. The same instructional procedures were repeated for each group (*rural parkland, urban parkland, indoor*). Students were informed that they could take as much time as they needed to complete their responses. They were instructed to read each item carefully and to raise their hands if they had a question. They were informed that completing the instrument was voluntary, that they would not be graded according to their responses, and to simply skip and leave a blank if they came across an item that they did not understand. The administration procedure for the MEI was repeated at the morning of the final day of the program, before the students in the control group were able to directly experience amphibians in the wild.

The *urban parkland* and *indoor* groups were informed, after they had completed filling in their responses, that the final day of the program would be a trip to see an abundance of amphibians in Forests for the World. They were told that this is where they would see baby salamanders developing in the water, toads hopping across trails, and quite possibly an adult salamander digging under a log. This research design ensured that all children would have an opportunity to experience amphibians directly while also controlling for disappointment they might feel about the group factors (outdoor, urban, indoor) by including a common field trip component toward the end after administering the post-test. The children were not informed about the study design and given no indication that their group would be treated differently than other groups.

A control group acts as an external measure for testing hypotheses and sets a baseline for possible confounding effects "that are contemporaneous with the intervention and could plausibly affect the outcome and thereby mask the intervention's effect" (Ferraro & Pattanayak, 2006, p., 0484). My quasi-experimental design used data from the MEI to investigate the effect of differing ecological contexts in relation. My treatment control was the indoor group that was removed from the direct experience of amphibians until after the post-test was administered. The indoor group was the experimental control because the members missed the direct biophilic experience on the topic being taught. "All quasi-experimental designs meet the following three requirements: (a) There must be a treated and untreated group. (b) There must be pretreatment and post-treatment measures, (c) There must be an explicit model that projects over time the difference between the treated and untreated groups, given no treatment effect. The third requirement is a synthesis of the other two and is at the heart of quasi-experimentation" (Kenny, 1975, p. 345).

Group one, urban parkland. Nine children were in attendance for the first group. The location of the first meeting was at the Forests for the World parking lot. Parents left after they dropped off their children, handed in the signed waiver forms, and held brief greetings. The students and I walked to Shane Lake where we formally introduced ourselves. I introduced myself as a graduate student in the education program and explained that this program was part of my research. The MEI was handed out and instructions were given. The group completed their responses at the picnic tables near the dock overlooking Shane Lake. It took students less than 45 minutes to complete their responses.

Group two, rural parkland. The rural parkland group first met at the Moore's Meadow parking lot. although six people had pre-registered for this group, only three students attended. During this module the parents stayed with the students as I went over the instructions for the MEI instrument. I had asked that only the children work on the responses but the parents remained and became involved in reading the items for their children, which had not occurred in group one. I found that administering the instrument was more challenging with the parents present. One student had minimal reading skills and he could not finish the MEI. He was happy to be excused from completing both the pre-test and post-test.

The parents left as we started the hike through Moore's Meadow. The three boys were excited to share their knowledge of places where they already knew to find amphibians. They were curious about Moore's Meadow and why we would be looking for amphibians in this park without obvious wetlands. They were concerned at the prospect of not finding amphibians. The activity on coarse woody debris paralleled the same activity that the outdoor group had experienced. The abundance, class, and types of coarse woody debris was similar to those that are encountered in Forests for the World.

Group three, indoors. The first day of the indoor program started at UNBC in front of the library. The students and their family members gathered in the rotunda gallery, where they sat to complete the MEI instrument. Some of the parents stayed and sometimes assisted their children by going over the items; one set of parents joined us for the entire program. I explained to the parents assisting their children and to the students directly that they should fill in their own independent responses to express how they felt about each item and if they did not understand an item to simply leave it blank and continue.

Statistical Item Analysis

Enumerated MEI responses were imported into jMetrik 3.01 (Meyer, 2013) where item response scores and indices of reliability were calculated. The jMetrik program provides a fast and effective method for item analysis to test if inferences can be drawn according to the degree of validity and reliability in the early piloting and development phase of the MEI instrument. Item analysis of the MEI instrument can improve upon the effectiveness of the instrument to measure change in values, enthusiasm, and concept learning relative to the environmental context of teaching for each treatment group (outdoor, urban, and indoor).

Biserial and point biserial correlations are calculated in jMetrik as in internal criterion of total test score as described in Crocker and Algina (1986) and Olsson, Drasgow, and Dorans (1982). The item correlation values provide an index of *internal* item reliability in each module of the MEI. It is an internal measure of the degree of linear relationship between the item score and the total Likert criterion scores.

Statistical calculations. Pre- versus the post-paired t-tests were calculated from students item responses. The t-tests were calculated manually in OpenOffice™ Calc utilizing formula notation from Hurlburt (2006) in an initial exploratory analysis of individual student responses to the treatments. R stats (v. 2.15.2, R Core Team, 2012) was used to run the t-test comparing total scores in the pre-post responses and to calculate Cohen's d (Cohen, 1988) for effect size in my power analysis. Two kinds of ANOVAs were calculated. However, *rural parkland* and *urban parkland* groups were amalgamated due to small sample size; the indoor group retained its status as an untreated control. The treatment variable from this collated analysis was direct skin contact with a wild local amphibian, which both the *rural parkland* and *urban parkland* groups experienced before the post-test. R stats (v. 2.15.2, R Core Team, 2012) was used to calculate results for the second type II repeated measures ANOVA, which included gender as a covariate to test the effect of treatment group relative to the total of the item responses. Item scores were summed to obtain the scored ecoliteracy index (that is, the total score) for each treatment group (Indoor (Pre, Post) X Oudoor (Pre, Post)). A Cohen's *d* power analysis was performed by utilizing an online SAS pearl script for a 2 X 2 factorial ANOVA (Friendly, n. d.).

CHAPTER IV: RESULTS

I present observations that were made during the execution of the study prior to moving into the results of the statistical analysis of the MEI responses. During the study I made notable observations that were related to biophilia and niche construction. Students exhibited many different kinds of behaviour in response to the different treatments and activities during execution of the curricula and study design. My observations of the students expressing various types of complex behaviours suggests that the more direct contact with amphibians caused an excitement and expression of joy that was not noticed in the indoor group. Results include my observations of the students and also observations of the learning environments as they became modified by the children who were engaged in learning activities.

Observational Results

This section presents my observations of the Junior Amphibian Ecologist League as I taught the programs for the three treatment groups. Details regarding social dynamics and descriptions of the curricular activities as they unfolded are included. There are also notes on student behaviour in response to the teaching context, on ecological effects in the respective teaching environments, and reflections from my experience of teaching the curricula. These details provide context for the statistical results and for my response to them.

Group one, urban parkland. The first lesson plan involved the study of decomposing logs. We hiked through the wilderness, flipped over logs, and sifted through the debris in search of invertebrates and amphibians. This activity created a complexity of learning opportunities and ecological material for children to manipulate as we discussed the life history of each creature discovered. The design of the lesson plan also meant that the first group became modifiers of the ecosystems in which they were learning. Their actions bioturbated the soil as their boots compacted their pathways and they dug in search of living creatures. We foraged for knowledge as we searched for amphibians. We found, handled, and identified centipedes, slugs, ants, beetles, larvae, eggs, spiders, pill bugs, worms, logs, plants, berries, fungi, roots, dirt, and salamanders.

We selected and studied a few large and well decomposed logs in great detail to keep the footprint of disturbance levels localized. Students were curious and asked about the berries in places where we were searching. In response I shared my naturalist knowledge of edibles. Some of the students ate wild berries and leaves as I taught about the ecological connections between the sun's energy and the nutrients they were ingesting. This direct experience connected the physiology of the learning environment to the senses of the students experiencing wild food, many for the first time in their lives. This experience related to the planned lesson activities and discussion on the lives of amphibians, other creatures in the decomposing log, the forest around us, and how the ecological process links to the recycling of energy, minerals, and nutrients across the entire planet.

The salamander became the prized find. Once discovered, students in the group gathered around and with their hands spread out they let the long-toed salamander, *Ambystoma macrodactylum*, walk across their skin. Every student smiled and expressed joy, excitement, and sometimes anxiety at the touch of the salamander. After allowing this *salamander effect* to run its course and releasing the salamander, I told an accurate salamander story (non-fiction narrative) that included aspects of its ecological life history, such as lifespan, anatomy, behaviour, diet, and other anecdotes from my accumulated knowledge on this species. To captivate their imaginations, I told them that salamanders were the ancient defenders and warriors of the soil that had been defending this territory since a time before the dinosaurs.

The log sampling and salamander discovery process helped the children to develop a perception of salamanders in their habitat. It provided an opportunity to teach about the ecological prevalence of salamanders relative to the prevalence of other species encountered, to decaying logs, and to the compacted recreational trail system that runs through Forests for the World. Students learned through direct visual and tactile experience how predators have less representative biomass than their prey and that plants, the primary producers, are the most abundant in size and number to support the large base of the ecological pyramid.

I took the class off trail purposefully for brief journeys into densely vegetated locations. At the start of the program I explained that they would learn about the kinds of techniques that an ecologist would use to study and understand amphibians so they could experience what it felt like to be an ecologist working in the field. We navigated past scratching thorns, biting mosquitoes, over fallen logs, and through dense thickets of leaves. Some students complained about the scratches but the group was generally expressing joy, excitement, and laughter throughout the experience. Teaching in an environment of bushy terrain engaged the physiology of their motor and sensory systems while the group experienced and imagined what it was like to be an amphibian ecologist.

After searching through logs, the moss, plants, and organic layer of the soil and the physical structure of the decomposing log was modified and visibly apparent to the group. Students could visibly perceive the effect or footprint of disturbance caused by their activities and we talked about this. After we searched through each log, I instructed the students to rebuild it carefully by piling the broken pieces of debris and re-attaching the moss layer, which they did.

Some activities did not work as well as planned. The Burlese funnel, for example, is commonly cited as a simple method for collecting insects. However, the students collected few insects using this method, likely due to a lack of a proper light source, technical difficulties, and other mistakes that were reported on the day they were returned. Nonetheless, many larger invertebrates were simple to catch, study, and learn about using our hands and empty containers.

Some of the activities had to be modified from the planned execution in the curriculum booklet. Methods that were incorporated into lesson plan 7, to sample the aquatic and wetland ecology, were impractical because students became too engaged with the wetlands we were visiting to follow a prescribed lesson plan. Frogs were jumping, invertebrates were swimming, and it was a sunny day. The students were excited, and so I encouraged free play and the use of their senses during independent exploration.

I sat along the path where the students could bring their discoveries back to me. I had my dissecting microscope set-up along the shore of the wetlands and we looked at magnified aquatic life. As the students brought their collections to the microscope we learned about each specimen in greater detail by searching through my library of aquatic and amphibian field books.

On one of the program days the scheduled activity was interrupted to play a game of tag. The students requested that we play a game, so I invented a game of tag involving salamanders, beetles, and logs to illustrate a trophic pyramid. Only one or two salamanders play against a greater number of beetles and decomposing logs. The design of the game was used to re-convey the message that keystone predators are lower in biomass than herbivorous beetles and the decomposing logs. We played and on rest breaks we gathered to discuss the ecology related to the game as we looked at the actual logs on the ground. They learned that the logs contained saprophytic mushrooms that feed on the death of these primary producers and provide food for beetles that feed the salamanders: these connections fit into a food chain that regulates the cycles of life in a perpetual game of tag.

During these breaks we discussed the rules of the game as a model for ecology. For example, we reasoned that the beetles could only stay safe at a log for a brief period of time before their food supply ran dry or the log decomposed completely. In the game, the students as logs held their arms in the air where beetles would hold on for safety. The log counted to ten as they decomposed or ran out of food for beetles. Once the logs drop their arms, the clinging beetles had to flee from the salamanders, or find another log for safety. Beetles tagged by salamanders would drop to their knees, but logs could regenerate a beetle by tagging them with an extended arm. Logs were only allowed to walk, where salamanders and beetles could run. The rules of the game can lead to a sustained ecology where nobody wins. Students playing the beetles could get caught, but the regeneration aspect to the game keeps the activity in play.

Students who participated in the program repeated the MEI at the start of the last day. Family and friends were welcomed to join us on the final day. This social gathering created an opportunity to share and discuss the program to others. Once the students completed their MEI responses, the entire group hiked through the woods to revisit sites we had learned from. We reviewed the material with the extended family and friends and shared some of the ecological knowledge that had been learned.

At the end of the last day of the group one session, everyone gathered in the parking lot. A food web exercise was completed. There were a large number of people in attendance (approximately 20) and everyone was allowed to be any creature of their choice. Everyone participated and each was given a sticker with a creature name. A ball of string was passed from creature to creature. Once the web was completed we discussed collectively how every creature was connected by feeding or by functional relations. We created an ecological web, tugged on the string, and removed some creatures out of web to see what would occur. This exercise was used to discuss how food webs and loss of species can change the connections and cause an effect for other species in the ecosystem. The final exercise also provided an opportunity to share the learning experience with extended family and friends.

Group two, rural parkland. Students were told that a salamander was last reported from Moore's Meadow in 2005. We surveyed the entire wooded circumference of the meadow and cut through the base as we discussed how there is no obvious wetland within the park where amphibians could breed, deposit eggs, and develop. Hence, any salamander that would enter Moore's Meadow must have migrated across a road as an adult. One student expressed his knowledge that Forests for the World was an excellent place to locate amphibians and suggested it would be a good place to look. We discussed these issues in relation to the abundance of amphibians in urban environments and the ecological impacts of roads on connectivity.

A single robust western toad was eventually found in a little gully that appeared to be an older remnant patch of the original forest. The coarse woody debris was older, covered heavily in moss, and larger sizes were decomposing. The boys were thrilled at this find and their enthusiasm for the program picked-up significantly after this discovery. Their response to the toad was similar to the salamander effect described for group one. Moore's Meadow provided a good starting point to learn about coarse woody debris where salamanders were unlikely to be found, yet all the classes and types could be located. There was still an apparent abundance of slugs, worms, and ants. The students were taught how to classify coarse woody debris and use this information to read the landscape, such as the age of the forest and whether it would provide a suitable habitat for amphibians.

The different places that were visited by this group provided opportunities to discuss the ecology, structure, and development of urban parks in relation to amphibian ecology and the environmental context. Amphibian migratory behaviours and habitats were discussed as we surveyed the environment. As I did for the first outdoor group, I taught the children how to navigate using a compass and showed them sampling techniques with transects.

The second day of the program continued at Cottonwood Island Park, where we discovered a salamander along a transect. This was the first record of a long-toed salamander in this urban area and the students were excited to be a part of this discovery. The salamander effect was observed in this group as it had been observed in group one. I encouraged their enthusiasm and suggested that they could do amphibian surveys on their own in local parks or near their homes.

The Hudson Slough trail system provided us with an opportunity to study a Duck's Unlimited wetland reclamation site. Although we could see that habitat for ducks was available, albeit polluted with garbage, the upland habitat for amphibians was missing. There were patches of young mixed-forest stands but there was very little to no pieces of coarse woody debris. We collectively inferred and agreed that amphibians could not live here. We discussed this in relation to the design of urban greenspace. Could this area be modified so that amphibians could live in the area? How could such modification be accomplished? We discussed the possibility of adding different classes and types of woody debris.

The fourth excursion brought us through a new urban development in the College Heights neighbourhood. The location provided a perfect opportunity to explore the recent impact of human development on amphibian habitats and soils. We discussed how humans were themselves great modifiers of the Earth and how this changed the structure and function of ecosystems that surround our living space. At the end of our walk, after finding a wetland with wood frogs along a dirt road, we came to a new development where the homes were still under construction. At the very edge of this site is an older growth forest with freshly cut soils at the edge. We walked a short way into the forested edge and found a salamander under a large piece of coarse woody debris.

This recently developed site presented an opportunity to discuss the effect of urban development, the edges they create, the depth, and the kind of effect they have on local ecosystem over time. The group expected that the salamander population would probably decline as families started to move into the homes, expecting trails and other modifications to the adjacent habitat. The sequence of the program armed them with the knowledge of coarse woody debris serving as an ecological clock to tell the age of patches of forest, provided them with a perspective on the age of the forest and how this fit in relation to the recent development. We learned about urban ecology and its effect on amphibian ecosystems.

On the final day of the program I repeated the MEI administrating procedure used for group one, meeting at the Greenway parking lot. The MEI instrument was handed out at the start of the morning before the students got to explore the larger ecology of the amphibians. Friends and families were invited to join us and we reviewed the ecological information that the students had learned as we hiked through the forested environment together. Once the MEI was completed, the group of children, friends, and family members was able to experience, through direct observation, the full scale of the abundance of amphibians and their complex life history from larvae and tadpoles, juvenile to adult. The larger scope of the amphibian life history with migration linking aquatic to terrestrial sites could not be observed in the urban setting but was experienced on this final day. The food web group exercise was also repeated at the end of the hike.

Group three, indoors. I began the indoor program by talking about a photo exhibit that displayed wildlife, nature scenes, and mining operation in Canada. We all noted how beautiful the nature scenes and photographs were as we tried to name all the creatures we could see. We could locate many large mammals, fish, sea stars, trees, and birds but no frogs, toads, or salamanders appeared in any of the images. In this context we talked about the awareness of amphibians in our art, our minds, in our culture, and in our surroundings. I introduced the Junior Amphibian Ecologist program to them as it was introduced to groups one and two by describing how they would learn about the ecology of amphibians in our local area.

We left the UNBC rotunda and walked through the UNBC David Douglass botanical garden. Two girls joined the program at this time but they did not complete the pre-test portion of the program. The wetland retention ponds in the botanical garden were a perfect location to discuss the impact of human construction on the ecology of amphibians. At the base of the wetlands from dusk shortly into a moonlit evening, the students were able to see frogs in the water, although we also found garbage and the students noted oil on the water's surface. Music was also blaring in the background from student festivities and the area was lighted artificially.

During this introductory meeting, we talked about the connectivity of these wetlands to the surrounding campus at UNBC. We looked at the species of plants that surrounded the shore of the wetland and the gardens: some were exotics and others were invasive species. For example, we located a *mullein* or *velvet plant*, which is very soft and provides one of nature's nicest and most effective substitutes for toilet paper. Other plants were located and discussed in this urban site surrounded by manicured trails, parking lots, and the glowing hum of street lights. The entire edge of the wetland is surrounded by dirt trails, cement, or pavement and there is no coarse woody debris along the edges. The students were excited to see the adult frog, although they were unable to catch it, and tadpoles could not be seen. I told the students that the last day of the program would be a field trip to Forests for the World where they would be more likely to see the material and amphibians that they would be learning about through the program.

The indoor program was based at the Prince George Exploration Place. The Exploration Place director had given permission for use of the entire museum space for the duration of the program at no cost. During breaks the children played in the museum's indoor play areas or we went out to the swings and slides in Fort George Park. The indoor teaching environment presented different kinds of opportunities but I found it more challenging to captivate the students, to focus and keep their attention, and to sustain my own focus on teaching the materials. In an effort to keep the children interested in persevering with the entire program, I told them that they would be learning how to become an amphibian ecologist and on the last day we would be going on a field trip to apply what we would learn in class.

I developed innovative techniques for hands-on experience tailored to the indoor environment. For the coarse woody debris activity, for example, I went out into the forest early in the morning and shoveled three decomposing logs into large plastic bins. The logs spanned different decomposition classes and types listed in their charts (Appendix B). This group learned how to classify the logs using the same charts that the outdoor and urban groups had used. The top A-horizon layer of the soil immediately surrounding and under the log was shoveled into the bin and I did my best to keep the logs intact and positioned as they were. The students were given an opportunity to study the logs ecological components in greater detail by tearing them apart (Figure 3). They classified their logs to the decomposition classification charts as we discussed the life history of decomposing logs. They were very excited about this activity, hoping that an amphibian could be found, and were able to look at all the creatures under the dissecting microscope. We did not find any amphibians.

Figure 3. Students from in the indoor control group dissecting decomposing logs; faces are blurred.

In another exercise, a large sheet of white paper was spread across the floor and students were supplied with pencil crayons. I asked the students to illustrate the creatures they found in their decomposing logs. We developed a list of local creatures and students were asked to illustrate a food web showing all the connections to the decomposing logs. Using the illustrations along the large sheet of paper we ran a line transect across the paper in the same way that I had shown to do a line transect for the outdoor and urban groups. However, this transect ran through their illustrations. We used this to discuss the methods that ecologists use to capture and study amphibians in the wild.

I took this group on a single half-day trip along Hudson's Bay slough from Exploration Place to Norway Street. We walked along the urban trail system; parts paved some gravel, adjacent to and sometimes running right through the riparian zone. In my previous and personal explorations of this area I have only ever discovered a western toad near the water's edge under clumps of debris. This activity paralleled the style of the urban group as we visited the same places and went over the same kind of material. We studied the Ducks Unlimited wetland reclamation project. There are Ducks Unlimited signs along the trail system, although they have been vandalized. There is almost no coarse woody debris in any part of the riparian zone. Ducks could be observed, birds heard, garbage found, but no amphibians could be located in the thinly forested edges.

This walk provided an opportunity to talk about ways to learn about the history of our environment by studying urban nature. In addition to wild edible berries, we also located apple trees and rhubarb, which were signs of an old farm. The lack of coarse woody debris informed us that the surrounding trees were a first generation that has not yet had enough time to create a coarse woody debris habitat. The classes of the coarse woody debris can inform a rough estimate of the time since a tree had fallen. However, in this area where there were no decomposing logs, we concluded that the area had been cleared at one time. One family who had participated in the entire program with their children shared some of their knowledge on the history of farming in the area as well. The discussions were similar to those of the urban group as we talked about wetland reclamation for ducks, the absence of decomposing logs for amphibians, and asked if they would like to have amphibians return to this area.

The museum provided an opportunity for the children to view some of the local amphibian species in cages. At the time, Exploration Place held long-toed salamanders (*Ambystoma macrodactylum*), western-toads (*Bufo boreas*), and spotted-frogs (*Rana luteiventris*). The children were not allowed to hold or touch the amphibians but some exotic snakes and reptiles were sometimes made available for the children to touch by the museum staff. The amphibians at Exploration Place are maintained in 30 gallon terraria and have a slightly different "domesticated" appearance (dilated pupils, larger bodied, different coloration, more lethargic) compared to their wild kin in the forest.

Some of the electronic media and map printing exercise did not work as planned. Computer volume and plug-in problems prevented us from watching a movie about amphibians. A local print shop misplaced a large map of Prince George that I had planned to use to get students to identify urban parklands and draw favorite amphibians on each spot. The point of finding urban parks large enough for amphibian drawing was to emphasize the problem of urban fragmentation. In lieu of these activity plans, we gathered around my computer and explored the Prince George area looking at urban parkland using GoogleEarth. We studied and discussed the different urban parks and talked about the amphibians in relation to where we lived. I also told stories about prehistoric amphibians and their paleontological history using coloured illustrations, which appeared to captivate the students. We also played games with an amphibian theme.

The final day of the program was a field trip with friends and family into Forests for the World. There was a slight mix-up in the morning and some parents were waiting at the wrong parking lot, which caused a delay in getting the children started on the post-responses of the MEI instrument. It was a cold, wet, and rainy morning and this had an obvious effect on the outcome and number of responses that were completed. The students huddled in cars to complete their responses, but I believe the delay, coupled with the poor weather, meant that some students rushed through their answers or did not fill in the instrument. However, a few of the students were committed to filling in their responses.

Summary feedback. Parents and children from all groups provided supportive feedback and praise for the program. Some asked if their kids could register in all three groups but I informed them that the groups had to remain independent. Many wanted to know if I would be running this program again next summer.

The MEI Instrument Analysis

The administered MEI took an average of 25 minutes for students to complete. Less than half of the students raised their hands for assistance on one or more questions. Some expressed the opinion that they found the instrument easy to complete, while others struggled with some of the items or modules. One student lacked basic reading skills and could not complete the instrument. A few students required items to be read aloud and a few of the younger participants were confused by the more difficult modules and were instructed to skip to the easy page at the very end. The majority of the participants understood the first page on demographics but many were confused by the item requesting "cultural background / ethnicity", which elicited the greatest number of questions.

Item response statistics. Reliability coefficients provide information on the instrument's consistency for replicated measures of test scores. Reliability coefficients can be estimated by *stability*, the same test on two separate occasions to the same group, by *equivalence*, administering the test on one occasion to the same group but with two formats that cover the same content, and by *precision,* "the repeated correlation between test scores when examinees respond to the same test items repeatedly and there are no changes in examinees over time, or as Cronbach (1951) preferred to describe it, when the elapsed time between testings becomes infinitesimal" (Crocker & Algina, 1986, p. 117). Comparison of the pre- post-administration of the MEI instrument provides an estimate of the coefficients of stability and precision.

Students returned 33 completed copies of the MEI instrument. Item frequencies and descriptives for the five different modules are reported in Table 3. The first module of the MEI (ACT = Activities) is most likely to exhibit a high degree of stability, because it had the lowest percentage of non-responses relative to the other modules (Table 3). Of students who completed the MEI instrument, all except one scored "never" on item 10 (motorcycling). This non-random pattern is an indication of honesty in responses, comprehension in the structure of this module of the MEI, and is evidence of reliability in the feedback (Ballouard, Brischoux, and Bonnet, 2011).

Table 3

Names, Counts, and Ranges of Item Module Response Characteristics

Item module	**# of items**	**Range of Total # of Responses[a]**	**Percentage Blanks**
Activity Demographics	17	32	3.57%
New Ecological Paradigm	10	29	10.91%
Natural Capital	20	21-27	26.21%
Ecological Discounting	20	20-24	35.30%
Value Typology Kellert	9	26-32	10.10%
Value Typology Nisbet	21	24-30	16.02%

a. The range includes the total number of responses for each module (score ≥ 1) from the total of 18 participants that completed the MEI instrument (pre + post) from groups 1-3 (indoors, urban, outdoors).

Eighty-seven percent of the students gave the same response score to the same item in pre- post-tests, which provides a measured index of stability and precision. One student in group 1 (outdoor education) provided significantly different responses in the pre- versus the post-paired t-tests ($p < .05$; calculated in OpenOffice™ Calc and discussed further below); likely due to increased comprehension of the instrument as the student reported significantly greater involvement in the listed activities in the post-test. Younger participants generally left more items unanswered than the older individuals (Table 4). There are too few representatives in each age category for a strong conclusive inference but it does appear as though the 12-14 year olds were able to complete the instrument more accurately (Table 4).

Table 4

Percentages of Blank or Ambiguous Responses According to Age, Pre, and Post Experience

	Age (# of respondents)								
Item Module	**8 (2)**	**9 (3)**	**10 (6)**	**11 (3)**	**12 (2)**	**13 (1)**	**14 (1)**	**Pre**	**Post**
1. ACT	0.2%	0.0%	0.4%	2.7%	0.2%	0.0%	0.0%	5.6%	1.2%
2. NEP	0.3%	3.0%	3.3%	0.0%	0.9%	0.0%	0.0%	8.9%	13.3%
3. NC	6.1%	5.0%	6.4%	4.1%	2.3%	0.0%	0.0%	26.0%	26.7%
4. ED	6.2%	4.1%	7.7%	8.2%	3.6%	0.2%	0.0%	32.5%	38.7%
5. VTK	0.7%	1.7%	1.0%	2.4%	2.0%	0.0%	0.0%	14.0%	12.7%
6. VTN	3.9%	6.1%	1.0%	3.5%	1.3%	0.0%	0.0%	16.4%	16.3%

In the first module on activity demographics, movies, motorcycling, television, and watching nature programs had among the highest correlation polyserial values (Table 6); these values were calculated in jMetrik. Motorcycling, water skiing, skidooing, and cell phones had the lowest level of endorsement. Internet had the highest level of endorsement, followed by television, movies, and then video games. Almost everyone reported that they never took part in motorcycling ($p = 1.00$; $r = .81$), whereas motor boating had variable responses spanning "never" to "often" and the lowest negative correlation polyserial ($p = 2.03$; $r = -.12$). Cell phone ($p = 1.67$; $r = .04$) and hunting or fishing ($p = 2.58$; $r = .12$) had the next lowest correlation polyserials (Table 5).

Table 5

Item Analysis Statistics on the Activity Module

Activity	Abductive Theme	Endorsement (p_i)	S. D.	Item-Total Correlation	Correlation Polyserial
Motorcycling	nature tech	1.00	0.25	.45	.81
Water skiing	nature tech	1.06	0.50	.46	.64
Skidooing	nature tech	1.42	0.90	.31	.38
Cell phone	tech	1.67	1.16	**.04**	**.04**
Quading	nature tech	1.79	1.05	.48	.53
Motor boating	nature tech	2.03	1.26	**-.11**	**-.12**
Watching nature programs	nature tech	2.12	1.22	.69	.73
X-country skiing	nature rec	2.21	1.22	.26	.28
Canoeing	nature rec	2.24	0.97	.61	.65
Mountain biking	nature rec	2.30	1.29	.32	.35
Camping in a tent	nature rec	2.48	1.06	.28	.30
Nature watching	nature rec	2.58	1.00	.46	.49
Hunting or Fishing	nature rec	2.58	1.15	**.11**	**.12**
Video-games	tech	2.67	1.16	.35	.37
Movies	tech	2.85	1.03	.66	.84
Television	tech	2.91	1.01	.68	.74
Internet	tech	3.00	1.00	.45	.50

Note. Using a minimal critical value at 2 standard errors above .00 and value obtained by the approximation method in Crocker & Algina (1986, p. 324), correlation scores ≤ .25 are flagged in underlined bold.

Item-total Pearson and correlation polyserial values have been used for item discrimination analysis when testing for knowledge and for identifying an item malfunction (Crocker & Algina, 1986). However, the MEI does not test knowledge retention but was designed to measure motivations, values, or attitudes. Hence, item difficulty is actually a measure of endorsement for these psychological parameters. The minimum acceptable total Pearson or correlation polyserial values are usually set at.00 + $2\sigma_p$, which equals .25 in the MEI response. This value is used to detect items that elicit atypical or random responses (Crocker & Algina, 1986). Items that are lower than this value in the sample of 17 activity items indicates that cell phone, motor boating, and hunting or fishing induced random responses.

The inferred themes for the activity module match with near precision when ranked according to the levels of endorsement (Table 5). The outlier is cell phone usage, which was not strongly endorsed and groups oddly with nature tech. The nature tech activities have the lowest endorsement, nature rec has the middle value, and tech is the most strongly endorsed activity. A one factor ANOVA (Theme) results in a significant difference in the between group means, $F(2,14) = 9.73$, $p = .04$, which lends support to the thematic groupings.

The total mean of endorsement scores for each module and Cronbach's alpha estimating the internal total module reliability is reported in Table 6. The Cronbach alpha values indicate high internal repeatability for each module. The ACT, NEP, VTK, and VTN elicited the majority of responses for each module (Table 3) indicating greater levels of comprehension and stability for these modules. The newly devised VTK module performed better than the VTN module that has been used in many other studies. Nonetheless, 73.8% and 64.7% of the participants supplied answers to the NC and ED modules (Table 3) indicating a high level of comprehension or confidence for these more difficult modules. Items were reverse score transformed for the negation items, for example, the negation of "I think salamanders are cute" would be "I think salamanders are ugly". A random set of items were put into the negation form to provide a measure of control over acquiescence (Friborg, Martinussen, & Rosenvinge, 2006). The VTN module had the highest total mean endorsement for pro-ecological values (Table 6). Standard deviations about the mean (Table 7) indicates greater variation in responses for the VTN module, which may be an effect of a) lower comprehension in the VTN items or b) the nature of the items eliciting more polarized attitudes.

Table 6

Item Analysis Statistics For each Module of the MEI

Item Module	Cronbach's alpha	SEM	Mean	S. D.	# of items
1. Activity Demographics	.76	3.90	36.91	8.02	17
2. New Ecological Paradigm	.90	3.37	33.70	11.55	10
3. Natural Capital	.92	4.68	48.76	25.86	20
4. Ecological Discounting	.97	5.21	45.67	31.48	20
5. Value Typology Kellert	.71	4.26	29.42	7.10	9
6. Value Typology Nisbet	.95	5.46	63.48	25.80	21

Reliability indices (i.e., Cronbach's α) indicate strong internal consistency and pre- to post-test stability. Fifteen students completed their responses on both the pre- and post-administration of the MEI for the majority of the modules. Tables 7-10 contain item analysis results showing endorsement and Pearson's correlation values for each separate module, excluding the ecological discounting module; correlation scores ≤ .25 are flagged in underlined bold and items have been sorted in descending order of endorsement in the total score. The ecological discounting module is treated separately because the structuring and design of the items were not conducive to the same type of item analysis. The SEM (standard error of measurement) is the standard deviation of a score. The SEM is smaller where the S.D. is small and also declines as sample size increases. It is also smaller for more reliable measures.

Table 7

Item Analysis Statistics the New Ecological Paradigm (NEP) Module of the MEI

	Item	Endorsement (pi)	S.D.	Item-Total Pearson	Endorseme nt (pi)	S.D.	Item-Total Pearson	Endorsement (pi)	S.D.	Item-Total Pearson
1	Plants and animals have as much right as people to live.	**4.22**	1.48	.72	**3.80**	1.70	.89	**4.03**	1.57	.82
2	People must still obey the laws of nature.	**4.06**	1.66	.59	**3.73**	1.71	.94	**3.91**	1.67	.77
3	People are supposed to rule over the rest of nature.	**3.78**	1.83	.57	**3.80**	1.86	.84	**3.79**	1.82	.70
4	When people mess with nature it has bad results.	**4.00**	1.37	.76	**3.53**	1.73	.89	**3.79**	1.54	.83
5	People are treating nature badly.	**3.83**	1.29	.77	**3.47**	1.55	.95	**3.67**	1.41	.88
6	Nature is strong enough to handle the bad effects of our modern lifestyle.	**3.44**	1.65	.66	**3.67**	1.72	.92	**3.55**	1.66	.78
7	a big disaster in the environment soon.	**3.22**	1.77	.53	**3.33**	1.68	.85	**3.27**	1.70	.68
8	People will someday know enough about how nature works to be able to control it.	**2.94**	1.55	**.19**	**2.60**	1.30	.76	**2.79**	1.43	.45
9	People are clever enough to keep from ruining the Earth.	**2.44**	1.38	.56	**2.60**	1.59	.73	**2.52**	1.46	.64
10	There are too many (or almost too many) people on Earth.	**2.72**	1.67	**.04**	**2.00**	1.36	.35	**2.39**	1.56	**.19**

Table 8

Item Analysis Statistics the Natural Capital (NC) Module of the MEI

Item	Endorsement (p_i)	S.D.	Item-Total Pearson	Endorsement (p_i)	S.D.	Item-Total Pearson	Endorsement (p_i)	S.D.	Item-Total Pearson
A. The economic cost of trying to conserve amphibians:									
Is necessary because amphibians sustain forest ecosystems and wetlands.	3.28	1.78	.68	3.27	1.83	.67	3.27	1.77	.68
Is not as important as conserving fish, bears or other large animals.	3.22	1.86	.88	2.40	2.03	.55	2.85	1.95	.71
Is too high and would reduce economic benefits, such as jobs.	2.67	1.85	.80	2.93	1.79	.79	2.79	1.80	.79
Wetlands need to be large enough to justify the cost of preserving them. Otherwise, companies will loose money as they are forced to reduce the harvest size by leaving so many trees around every small pond.	1.89	1.84	.68	1.87	1.88	.75	1.88	1.83	.71
Is mainly important if there are endangered or threatened species involved.	1.78	1.48	.32	1.73	1.49	.60	1.76	1.46	.44
B. Wide strips of vegetation should be left along the margins of every amphibian wetland when clear cutting									
Only if fish are also present.	2.61	2.03	.82	2.67	1.80	.90	2.64	1.90	.85
Would sustain the long-term economic situation for foresters because this would help enhance biodiversity functions, such as nutrient flow.	2.22	2.07	.61	3.00	2.04	.78	2.58	2.06	.67
Only within protected areas, like Jasper or Banff National Park, otherwise this practice would reduce forestry yields, industry profit, and threaten job markets.	2.22	1.86	.84	2.00	1.85	.79	2.12	1.83	.81
Only where, when, and if it is economically feasible to do so.	2.22	1.93	.78	1.87	1.64	.53	2.06	1.78	.67
Even if it reduces timber harvest supply in the short term as this measure is necessary for the conservation of amphibian biodiversity.	1.50	1.42	.30	2.20	1.61	.68	1.82	1.53	.46
C. Having ponds with amphibians in cities, like Prince George or Vancouver is:									
As important as having ponds with amphibians in a forest.	3.22	1.96	.48	2.87	2.03	.67	3.06	1.97	.57
Is a great idea.	2.67	2.03	.60	3.13	1.96	.35	2.88	1.98	.48
Should be drained to prevent mosquitoes from breeding.	2.67	2.03	.61	2.53	1.92	.76	2.61	1.95	.67
D. Recycling plastics, paper and metals:									
Is energy efficient and directly beneficial for amphibian ecosystems.	2.00	1.41	.60	1.60	1.50	.60	1.82	1.45	.60
Is more green, sustainable, and creates more jobs than investing in conservation programs for amphibians.	1.83	1.72	.72	1.73	1.58	.69	1.79	1.63	.71
Is very similar to the recycling process in nature, such as a decaying log.	1.94	1.55	.71	1.53	1.51	.57	1.76	1.52	.64
E. Amphibians:									
Are economically important.	3.22	2.13	.68	2.47	2.20	.78	3.33	2.07	.73
Have important roles to play in our health care system. For example, glands in their skin may contain potential medicinal properties and cures for disease.	2.78	2.16	.72	3.47	2.07	.80	2.73	2.08	.74
Not as economically valuable as fish, because there is an huge fishing industry and very little to no industry that relies on amphibians.	2.78	1.93	.90	2.67	2.06	.76	2.58	1.80	.86
Are not as complex as computers or other technological devises that humans can create.	2.44	2.04	.83	2.33	1.68	.82	2.45	2.08	.81

Table 9

Item Analysis Statistics the Value Typology Kellert (VTK) Module of the MEI

Item	Pre Response			Post Response			Total Response		
	Endorsement (p_i)	**S.D.**	**Item-Total Pearson**	**Endorsement (p_i)**	**S.D.**	**Item-Total Pearson**	**Endorsement (p_i)**	**S.D.**	**Item-Total Pearson**
It is important to be kind to amphibians. I feel empathy for the toads and salamanders that get squished on roads	**4.33**	1.03	-.06	**4.20**	1.42	.50	**4.27**	1.21	.26
I think salamanders are cute.	**3.56**	1.72	.56	**4.27**	0.80	.13	**3.88**	1.41	.33
Amphibians are a source of inspiration for artists and storytellers.	**3.89**	1.45	.24	**3.53**	2.00	.82	**3.73**	1.70	.55
Amphibians are fascinating and mysterious creatures. I hope to see and then learn more about them.	**3.28**	1.99	.13	**3.87**	1.88	.74	**3.55**	1.94	.42
The thought of a salamander or frog touching my cheek frightens me or grosses me out.	**3.22**	1.59	-.09	**3.33**	1.68	.85	**3.27**	1.61	.38
All wetlands can be restored, returned to a natural state, and populated by amphibians if foresters plant trees after	**3.06**	1.92	-.06	**3.27**	1.33	.26	**3.15**	1.66	.08
A frog does not feel pain the same way that I do.	**2.83**	1.69	.10	**2.93**	1.49	-.03	**2.88**	1.58	.04
Amphibians are an important scientific resource for medicine and education.	**2.78**	1.80	.49	**2.87**	1.85	.60	**2.82**	1.79	.54
The most important property of amphibians is that they serve an economic purpose by recycling soil nutrients,	**2.06**	1.47	.25	**1.67**	1.40	.14	**1.88**	1.43	.17

Table 10

Item Analysis Statistics the Value Typology Nisbet (VTN) Module of the MEI

	Pre Response			Post Response			Total Response		
Item	**Endorsement (p_i)**	**S.D.**	**Item-Total Pearson**	**Endorsement (p_i)**	**S.D.**	**Item-Total Pearson**	**Endorsement (p_i)**	**S.D.**	**Item-Total Pearson**
I enjoy being outdoors, even in unpleasant weather.	**4.00**	1.72	.84	**3.87**	1.55	.45	**3.94**	1.62	.67
want.	**3.56**	1.79	.62	**3.67**	1.45	.50	**3.61**	1.62	.57
I enjoy digging in the earth and getting dirt on my hands.	**3.78**	1.66	.76	**3.07**	1.94	.71	**3.45**	1.80	.73
I take notice of wildlife wherever I am.	**3.61**	1.85	.66	**3.13**	1.64	.89	**3.39**	1.75	.75
I don't often go out in nature.	**3.61**	1.85	.77	**3.07**	1.71	.80	**3.36**	1.78	.78
Even in the middle of the city, I notice nature around me.	**3.61**	1.82	.88	**3.00**	1.81	.84	**3.33**	1.81	.86
My relationship to nature is an important part of who I am.	**3.28**	1.67	.84	**3.13**	2.03	.84	**3.21**	1.82	.84
humans.	**3.22**	1.73	.68	**3.13**	2.00	.53	**3.18**	1.83	.61
My ideal vacation spot would be a remote, wilderness area.	**3.44**	1.62	.63	**2.80**	1.66	.75	**3.15**	1.64	.68
I feel very connected to all living things and the earth.	**3.17**	1.54	.86	**3.13**	1.64	.92	**3.15**	1.56	.88
I am very aware of environmental issues.	**3.11**	1.78	.65	**3.07**	1.71	.83	**3.09**	1.72	.73
Conservation is unnecessary because nature is strong enough to recover from any human impact.	**3.39**	1.85	.58	**2.73**	2.02	.74	**3.09**	1.93	.65
I am not separate from nature, but a part of nature.	**3.17**	1.65	.77	**2.93**	1.87	.82	**3.06**	1.73	.80
The state of non-human species is an indicator of the future for humans.	**2.67**	1.75	.62	**3.33**	1.59	.90	**2.97**	1.69	.71
I always think about how my actions affect the environment.	**2.94**	1.83	.74	**2.93**	1.71	.76	**2.94**	1.75	.75
The thought of being deep in the woods, away from civilization, is frightening.	**2.89**	1.81	.53	**2.60**	1.72	.65	**2.76**	1.75	.58
I think a lot about the suffering of animals.	**2.83**	1.79	.70	**2.60**	2.03	.76	**2.73**	1.88	.73
My connection to nature and the environment is a part of my spirituality.	**2.39**	1.97	.67	**3.07**	1.91	.64	**2.70**	1.94	.63
My feelings about nature do not affect how I live my life.	**2.39**	1.72	.68	**2.33**	1.50	.54	**2.36**	1.60	.62
Nothing I do will change problems in other places on the planet.	**2.00**	1.72	.42	**2.27**	1.33	.52	**2.12**	1.54	.45
Some species are just meant to die out or become extinct.	**1.61**	1.38	.40	**2.20**	1.47	.53	**1.88**	1.43	.44

A *t*-test and Pearson's regression analysis were used to inspect the responses of each individual student. In comparisons where *r*-values were significant, the pre-post item responses were graphed and visually examined for outliers. A low effect size due to low sample size means that the statistics are more sensitive to outliers that were often created by the asymmetry of blank items in the pre- or post-responses that were correspondently answered otherwise. These results were used as an exploratory analysis of the data to determine and justify the removal of students who may not have comprehended the MEI or failed to provide either a pre- or post-responses. A pairwise Pearson's correlation test was also performed for the total score of each module separately against the sum total of the remaining modules (Table 11); the total score is the sum of responses following reverse transformation of the negation items. A correlation was more often statistically significantly identifed ($\alpha = .05$) when the total score was compared against the individual modules, indicating that the total score of all modules responds similarly to justify a combined analysis. A Cohen's-d power analysis of the sample sizes for a "medium" effect, $d_{population}$ = 0.5, and for a "large" effect, $d_{population}$ = 0.8, gives a power level of 0.23 and 0.42 respectively. Combining the modules into a total score would increase the effect size.

Table 11

Pairwise Pearson's ~~*correlation matrix for four modules of the MEI*~~[1]

	NC	NEP	VTK	VTN	TOTAL SCORES
NC	X				
NEP	**.45**	X			
VTK	**.39**	**.36**	X		
VTN	**<u>.30</u>**	**<u>.13</u>**	**.66**	X	
TOTAL SCORES	**.45**	**.38**	**.66**	**.38**	X

[1]*Note:* NC = Natural Capital, NEP = New Ecological Paradigm, VTK = Value Typology Kellert, VTN = Value Typology Nisbet. Not significant values are bold underline.

Analysis of Variance. Summed items creating MEI total scores for each group were averaged and plotted to examine effect and interaction in the sample data (Figure 4). Interactions are shown for the partitioned modules and all modules combined. The results were inconsistent among the different modules. Outliers were present and removed for subsequent ANOVA tests. A one-way ANOVA comparing the two groups (*parkland* v. *indoor*) did not identify any significant difference ($\alpha = .05$) between the two groups in their pre-test responses (Tables 12-13). The repeated measures type II ANOVA including gender as a covariate identified significant differences ($\alpha =.05$) for gender in the NC module and by treatment (*parkland* v. *indoor*) when accounting for the total scores (Table 13). Power analysis utilizing Cohen's *d* (Cohen, 1988) suggests a sample size of 30 individuals would be required for a 2 X 2 ANOVA of moderate effect size ($d = 0.5$) to approach a power level equal to 0.8.

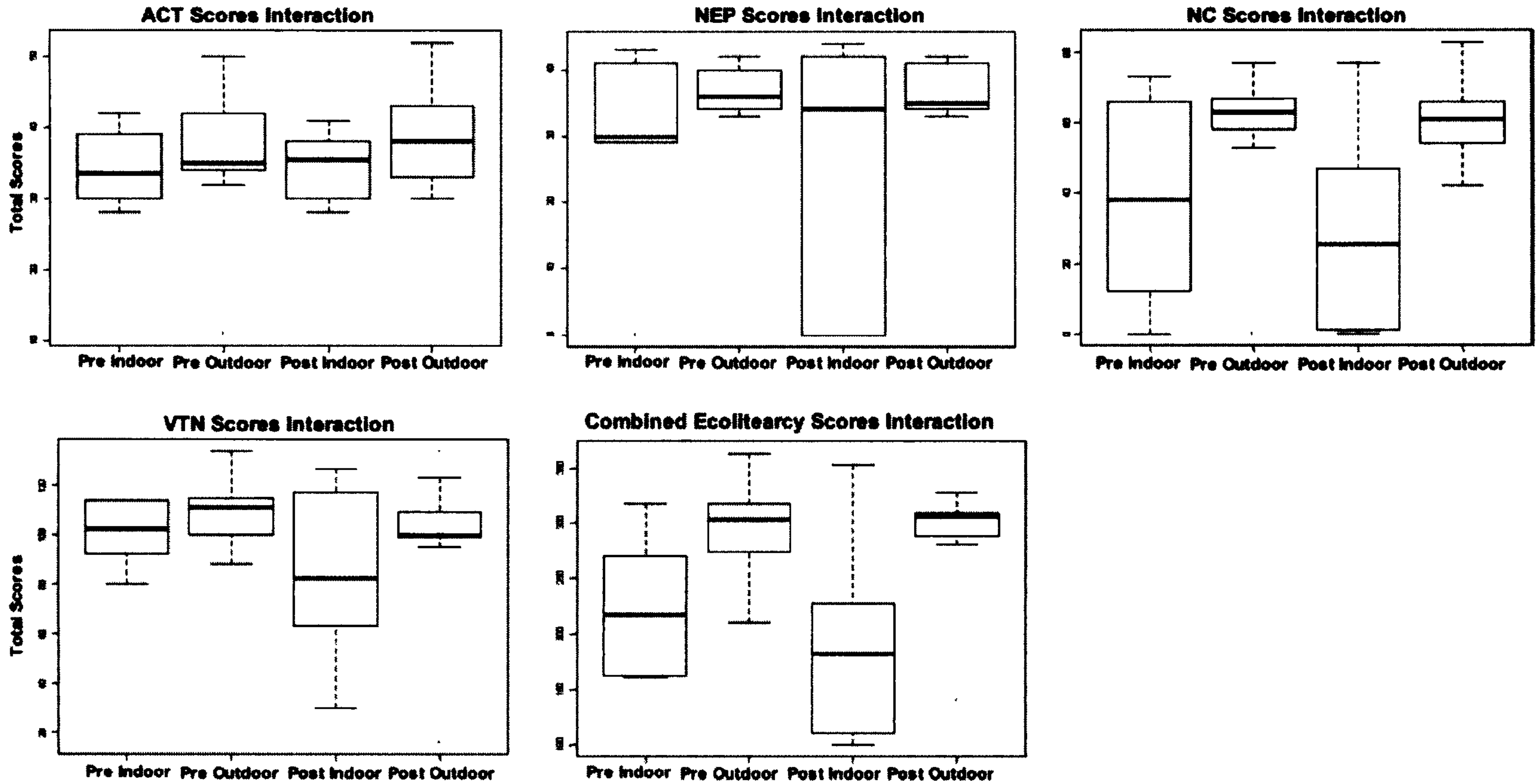


Figure 4. Box-plot displays of modular ecoliteracy scores; outdoor refers to the parkland group.

Table 12.

One-way ANOVA table for the different module scores.

Module	F	(num df,denom df)	p-value
ACT	0.05	(1,25.576)	0.833
NC	0.4698	(1,22.182)	0.500
VTN	0.89	(1,19.496)	0.357
Total Scores:	0.41	(1,20.692)	0.531

Table 13.

Repeated measures Type II ANOVA for the different modules with significant values bold and gray highlighted.

ACT	Sum Sq	Df	F Value	Pr (>F)
Treat	85.4	1	2.0343	0.1667
Gender	85.4	1	2.0343	0.1667
Treat:Gender	3.9	1	0.0934	0.7625
Residuals	1007.7	24		
NEP	**Sum Sq**	**Df**	**F Value**	**Pr (>F)**
Treat	41.7	1	0.6155	0.4404
Gender	99.5	1	1.4702	0.2371
Treat:Gender	18.5	1	0.2725	0.6064
Residuals	1625.1	24		
NC	**Sum Sq**	**Df**	**F Value**	**Pr (>F)**
Treat	485.0	1	1.8661	0.1857
Gender	2051.8	1	**7.8943**	**0.0102**
Treat:Gender	784.4	1	3.0178	0.0963
Residuals	5717.9	22		
VTN	**Sum Sq**	**Df**	**F Value**	**Pr (>F)**
Treat	1750.0	1	3.7417	0.0650
Gender	87.4	1	0.1868	0.6695
Treat:Gender	14.2	1	0.0303	0.8633
Residuals	11225.2	24		
All Scores	**Sum Sq**	**Df**	**F Value**	**Pr (>F)**
Treat	36611.0	1	**12.9669**	**0.0018**
Gender	1647.0	1	0.5834	0.4539
Treat:Gender	1.0	1	0.0004	0.9833
Residuals	56468.0	20		

Note: Significant at the $p<0.05$ level.

The pattern for endorsement in the ecological discounting (ED) module responses is shown in Figure 5. Only item 6 elicited a strong endorsement in this unit scenario, the remaining scenarios fluctuate closer to the 3 point neutral endorsement line (Figure 5b). All responses for items 12-16 were on the disagreeable end of the scale and generated an anomalous negative trend (Figure 5c). Unit D phrased scenarios around willingness to give up or pay, which was even less agreeable (Figure 5d) than responses in unit C (Figure 5c).

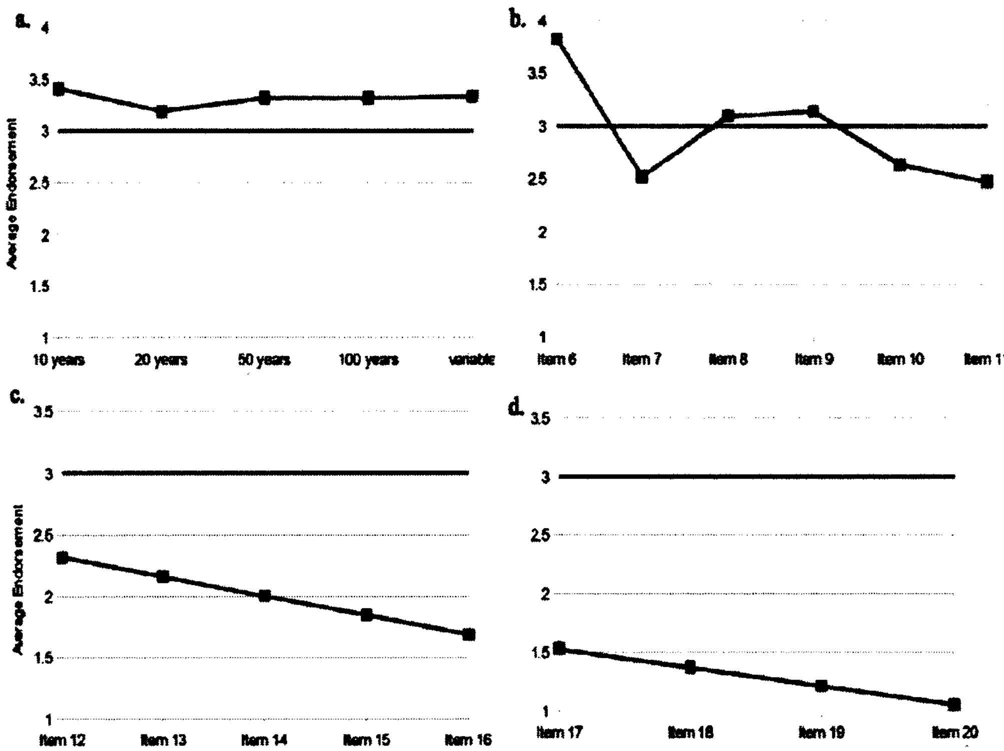


Figure 5.

Graphs illustrating average levels of endorsement in the ED module, unit A (Items 1-5, a), unit B (items 6-11, b), unit C (items 12-16, c), unit D (items 17-20. d).

CHAPTER V: DISCUSSION

Item analysis is traditionally used to identify items that are correlated in support of the existence of an underlying factor that the test is designed to measure. If items within a module, for example, are uncorrelated, then they may be eliminated because they may not be measuring the same kind of underlying theme. However, a measure of high internal consistency having Cronbach's alpha greater than 0.7 is typically used as an indication that a similar theme is being measured and all modules exceeded this value (Table 6). The heuristic process of using item analysis for the discrimination and elimination of items has been used extensively by educators and psychologists developing tests that are of minimum length while at the same time yielding scores that are reliable, valid, and correlated to the theme being studied (Nunnally & Bernstein, 1994; Rust & Golombok, 2009).

Contributions

My thesis study makes several contributions that give reason to continue on this path of research despite limitations that were known prior to piloting the curricula (Appendix B) and MEI (Appendix C). Psychometric instruments, educational assessments of attitude, or concept inventories can take multiple years to develop and refine before they prove effective for analysis and testing of outcomes (Leeming et al., 1993; Manoli, Johnson, & Dunlap, 2007). Klymkowsky and Garvin-Doxas (2008), for example, created the Ed's Tools program to assist researchers in the process of refinement of research-based conceptual assessment instruments. A refinement of the study design to include interviews, for example, would be required to refine sections of the MEI or even the curricula using Ed's Tools (Klymkowsky & Garvin-Doxas, 2008). A low sample size was used to pilot my study design to compensate for the first time use of the MEI, the curriculum, and prior knowledge of the amount of time that would be needed to create an effective test of ecoliteracy values.

At best, the MEI instrument may only provide insight into the cognitive aspects to the biophilia hypothesis. Furthermore, it is expected that the niche construction process, an underlying goal of the curricula, would take multiple generations to develop, which adds further limitations to the study design. However, the MEI, curriculum, and research methods that were applied in this thesis provide an informed foundation for their subsequent refinement. The curricula and MEI could be tailored to apply in other geographic locations beyond Prince George.

This thesis makes several original contributions. Examination of student perceptions of natural capital has yet to be explored in other studies. The development of the niche construction pedagogical theory is another original contribution that could improve on the ability of researchers to investigate and gain further insight into biophilia. It also provides a new direction for educators for getting students involved ecologically in a way that has the potential to address conservation related issues applicable to the Anthropocene mass extinction. Niche construction pedagogy identifies the means and a unique opportunity to access and create a diversity of ecological goods and services (Figure 1). There is opportunity to research this area further in relation to the ecological economics and sustainable education.

Convenience sampling. Prior to conducting an item analysis on the Activity Module (ACT), I arranged the different activities into three dimensions: a) *nature tech*, b) *tech*, and c) *nature rec*. These dimensions were identified by the sorted arrangement of the endorsement scores and the ANOVA revealed that the actual arrangement was significantly related to the themes I predicted. Cell phone usage was the only exception to the statistical pattern and my prediction. The fact that cell phones are used in social communication may have bearing on this surprising result. Otherwise, students that enrolled in the junior amphibian ecologists league would likely be biased toward traits for biophilia, at the very least their parents had enough interest and motivation in ecoliteracy-based education to enroll their children in the program. Even with this inherent bias of my convenience sampling design, however, these students' endorsed activity ratings indicated greater strengths of connection to technology relative to nature-based themes.

Statistical outcomes. All modules yielded statistically reliable responses, indicating honesty in the student responses, which means that the data provided useful information. Items with low correlation values are flagged using the discrimination index. Values $\leq .25$ for Pearson's r were used to discriminate items in the study (Tables 6-10) that may be flagged for elimination or close scrutiny for future development of the MEI. Several items within the activities module had low correlation scores. However, items within this module undoubtedly measure activities and despite the low correlation values, these items should be retained within this module. The process of ranking endorsement and predicting themes within the themes helped to identify different kinds of activity factors. If a particular student ranked technological or electronic types of activities more heavily than a student ranking nature-based activities, then there would be an expectation that the nature study intervention would affect the former student more than the student is already involved in nature. Students who were enrolled in my study, however, showed a high endorsement and reported involvement in nature-based activities.

The new ecological paradigm module. The New Ecological Paradigm (NEP) module is one of the most extensively used instruments to obtain measures of an ecological worldview among participants. The version utilized in this study was borrowed from Manoli, Johnson, & Dunlap (2007) after many heuristic rounds of discriminant item analysis, elimination of problematic items, and revision. The ≤ 0.25 correlation value was chosen because it approaches the lower values obtained in the NEP, which has received extensive study on its validity. Despite the extensive work that has been done on the NEP instrument, my study flagged item 10 (Table 8) as having a low correlation ($\leq .25$) in the pre-test, although the value was not as low in the post-test responses. This item also received the lowest level of endorsement in both the pre- and post-test. Item 8 was also flagged in the pre-test but yielded a high correlation in the post response measure. It is difficult to cross-compare these specific result with other studies, because the NEP has many different versions that are being used that could bias the interpretation. However, a review of the literature reporting on the relative endorsement for item 10 (or wording adapted thereof) revealed that it varies considerably across studies (for example, Hagenbuch, et al. 2009; Manoli, Johnson, & Dunlap, 2007; Wu, 2012). Of anecdotal significance, however, the two items most strongly endorsed in this study have similarly and consistently received top endorsement in other studies.

Manoli, Johnson, and Dunlap (2007) identified three dimensions in the NEP using factor analysis and a significant change in response from "slightly anthropocentric to a slightly ecocentric perspective" (p. 11). Hagenbuch et al. (2009) administered the NEP to post-secondary students in pre-posttest response following completion of a natural sciences-based course. They did not identify any significant shift in the responses. Hence, these previous studies identified only a minor shift in the NEP response following intervention. Chen, Peterson, Hull, Lu, Hong, and Liu (2013) used the NEP to study responses among groups who had experienced environmental harm. Their results using the NEP supported the general finding that higher scores tend to be significantly correlated with changes in environmental behaviour or intentions. Chen et al. (2013) found a significant link between high NEP scores and previous experience of environmental harm. Likewise, Pienaar, Lew, and Wallmo (2013) identified a significant change in context of presenting material on different species in conjunction with test administration. Kopnina (2012) reviewed some of the criticisms that have been launched against the NEP instrument, including Mayer and Frantz's (2004) conclusion that the NEP measures cognitive belief rather than affective experience. My study included students that were already nature-orientated individuals, as results from the ACT module suggested, and the curricula were more orientated toward affective experience. Moreover, an accumulating body of research has also indicted that there are different sub-scales contained within the NEP instrument (Pienaar, Lew, & Wallmo, 2013). Hence, these factors may have contributed to the lack of change in responses in my study.

The natural capital module. All items in the Natural Capital (NC) module had high internal correlation values in my study (Table 9). Although much discussion exists in the literature on natural capital (for example, Costanza, de Groot, Farber, Grasso, Hannon, et al., 1997; Farber, Costanza, Childers, Erickson, Gross, Grove, et al., 2006; Fenech, Foster, Hamilton, & Hansell, 2003; Rees, 2002) this is the first instrument, to the best of my knowledge, that has been designed to measure values on the topic of natural capital. Students gave the highest endorsement to the concept (item 1) that the economic cost of trying to conserve amphibians is necessary because they sustain forest ecosystems and wetlands. The second highest endorsement (item 2) supported the idea that amphibians are economically important. They did not agree with the idea that recycling of plastics, paper and metals was similar to the recycling processes in nature (item 16). The low endorsement scores for section D of this module seem to indicate a common conception that technology cannot replace, excel, or duplicate the processes of nature. It also shows a surprising contrast of nature conservation versus the instructional approach evident in green techno-environmentalism, such as recycling.

My analysis showed that the students generally held a high value for amphibians with what would be considered a pro-ecological viewpoint in both the pre- and the post-test responses (Table 9). Despite a relatively high number of blank or ambiguous responses (Table 4), the NC module was fully completed by the older students and the correlation analysis (Table 9) indicated that a consistent theme was measured. The item discrimination analysis performed in this study did not flag any problem items for elimination. While no treatment or pre-post effect was identified, there was a highly significant difference in response by gender.

The value typology Kellert module. Several items were flagged in the item analysis for the new Value Typology Kellert (VTK) module (Table 10). Although many of the items were flagged in the pre-test, the number and type of problematic items shifted in the post-test. This result may be a learned response to the instrument or there may be multiple themes or dimensions represented in the items. Other than the simplest ACT module, the lowest percentage of blank responses was given for this module (Table 3). Item 2 reflects the item developed by (Ballouard, Provost, Barré, & Bonnet, 2012) studying the affectivity toward organisms that are less favored (for example, "snakes are cute"). Further study, such as a more in-depth statistical factor analysis, is required to better understand the performance of this module. Items 6, 7, 9 produced the lowest overall correlations. Rather than elimination, their content could be simplified. Item 7 may be signaling a false effect because there was a grammatical error: "feel" appeared as "feels", and the error drawn to the students' attention during the test. Items 6 and 9, however, could be modified to the following:

From:

All wetlands can be restored, returned to a natural state, and populated by amphibians if foresters plant trees after a clear-cut timber harvest.

To:

Wetlands can be restored and populated by amphibians if foresters plant trees after a clear-cut timber harvest.

From:

The most important property of amphibians is that they serve an economic purpose by recycling soil nutrients, which is an essential service for forest industries.

To:

Amphibians help the economy by recycling soil nutrients, which is an essential service for forest industries.

The nature relatedness scale module. All items in the Value Typology Nisbet (VTN or Nature Relatedness Scale; Nisbet, Zelenski, & Murphy (2009)) module had high internal correlation values in this study (Table 10). The VTN was originally developed "to measure the affective, cognitive, and experiential aspects of individual connection with the natural world" (Nisbet, Zelenski, & Murphy, 2009, p. 735) but it also provides a hedonistic measure of happiness (Zelenski & Nisbet, 2012). The difficulty in comparing my results to other studies is that the endorsement scores have not been reported in the literature for comparison.

Comparative Analysis. Some of the item responses contrast sharply with similar items in other modules. Item 1 in the NEP module (Table 7), for example, focuses on equal rights for animals whereas items 2 and 8 in the VTN module are endorsed relatively strongly and would suggest that humans have more rights than animals. Some of the items with low endorsement also tend to have lower correlation and may be flagged for further consideration. Item 21, for example, places meaning into the question and may have less to do with the actual problem of species extinction. The low endorsement for item 20 suggests an optimism that is held by the respondents that their actions or behaviours can help to solve larger problems. The total score analysis suggests a significant treatment effect. The indoor group declined in their MEI score, whereas the outdoor group had a minor increase with a smaller variance in the post response (Figure 4).

Strengths and Limitations

It is notable that the top endorsement in the MEI was about enjoyment of the outdoors, which has a sharp bearing on the *outdoor parkland* versus the *indoor* treatment groups of my study. Nisbet and Zelenski (2011), however, concluded that "even natural spaces in urban settings can increase happiness; the grandeur of national parks is not required" (p. 1105). The results of my study may indicate that the urban setting that the indoor students were exposed to may have had a larger effect than anticipated and thus reduced the effectiveness of my study to measure an affect by means of exposure to nature.

Regardless of the statistical effectiveness of the MEI, the design and launching of the *Junior Amphibian Ecologist League curriculum* was a valuable outcome of this study. Teaching in the different environments in Prince George's Parklands helped to identify the ecological resources that are available for nature study. Numerous studies have identified the benefits of nature for health, happiness, and general well-being (for example, Zelenski & Nisbet, 2012). The curricular booklets that accompanied the program have also generated a resource that is being revised and shared widely with members of the Partners in Amphibian and Reptile Conservation (PARC). PARC is a not a funding organization but is an association described as "an inclusive partnership dedicated to the conservation of the herpetofauna – reptiles and amphibians – and their habitats" (PARC, 2013a). The mission statement of this organization, which is "to conserve amphibians, reptiles and their habitats as integral parts of our ecosystem and culture through proactive and coordinated public/private partnerships" (PARC, 2013b), is consistent with the original directive of NAMOS BC. Through my attendance at the Northwest PARC annual meeting on April 8th and 9th of 2013, I have formed partnerships within PARC to further develop these curricula and share the components of the MEI that appeared to work most effectively.

Observations of the behaviour of students expressing joy and enthusiasm during the administration of the Junior Amphibian Ecologists League, and especially upon the discovery of a live amphibian, suggested to me that the experience was significant. Ballouard, Provost, Barré and Bonnet (2012), for example, studied over 500 schoolchildren using a 47 closed and open item questionnaire showing a marked effect in children's attitude even after a single field trip. They reasoned that the direct handling of the snakes was largely responsible for this effect, which was rated by the students as the most preferred activity. However, these previous study results and my observations are not supported by the quantitative analysis of my study. Low sample size lead to an inconclusive statistical inference generated by the MEI, despite strong internal consistency.

My study design may not have offered a valid test of the learning or values that could have potentially developed during five days of nature study. Alternatively, or as a compounding factor, the MEI instrument may not have been effective in tracking affective, cognitive, and experiential changes that have been reported extensively in other studies involving nature-based education or outdoor-based interventions (for example, Nisbet, Zelenski, & Murphy, 2009). Strong internal consistency within the responses to the different module's plus the joining of tried and tested instruments from other studies, a common approach for this type of research (for example, Nisbet, Zelenski, & Murphy, 2009; 2011) suggested that the MEI was performing as intended.

My study design lacked an effective control group. Nisbet and Zelenski (2011), for example, identified increased levels of happiness through contact with nature; however, participants systematically underestimated the hedonic benefits of urban nature. Likewise, I may have underestimated the influence of urban nature on the indoor group during the Hudson's Slough field trip. Kossak and Bogner (2011) were able to identify a significant effect of individual connectedness to nature after a single day of intervention. Their control group consisted of students who were not enrolled in the program at all. The very act of teaching about nature and having even limited access to natural things likely had a greater influence on the experimental design than I had predicted or realized at the time. Many of the educational components in Kossak and Bogner's (2011) treatment group, for example, are similar to the components that were taught to my indoor group. Learning during the process of teaching the material would also suggest that I became more experienced by the time the final group was being taught, which could have furthered this effect and bias the treatment design, adding a further limitation or consideration when interpreting the final results. Hence, my study design would have required a strong effect from the parkland learning experience.

> In this study students were only asked (self-report) about their direct experiences with toads, therefore it cannot be treated as experimental. The possibility that some students who were more interested in toads (by unclear motivation) simply wanted to handle toads more than other children cannot be ruled out. (p. 261)

The limited sample size is another limitation in my quantitative study design. Although the smaller sample size may be a limitation quantitatively, it may have added strength to the qualitative component, adding practicable elements for implementing the curricula. A key indicator of the small sample size is noted in the pre-test responses in the MEI instrument. The two groups provided significantly different responses, indicating that they already held significantly different views, as would be expected with a smaller sample size. Clearly, however, an increased sample size after training through the gain of experience in teaching the curricula would provide a more robust data set for making conclusions and generalizing these to other studies.

Other limiting variables can be identified in my study. The post-administered MEI to group 3 was given on a cold and windy morning, for example, which may have made concentration more difficult for this group of students. Some students in the indoor group received thorns in their fingers and were annoyed by mosquitoes. Conversely, students in the indoor group seemed to lose focus and expressed boredom after spending too much time learning indoors when the weather was noticeably nice outside. A final limitation of studies of this kind is that they suffer from the general applicability of the results to other geographic regions and across cultures (Kopnina, 2012). Different types of ecosystems and cultural differences among participants that were not included in my analysis are likely variables of consideration in future applications of this study.

Considering Biodiversity and Niche Construction

> The frontiers of biodiversity and ecosystem functioning research are rapidly expanding as new approaches and technologies, and a rapidly growing database, allow researchers to address questions at levels of precision and scale not possible in 1992 when the field formally began. There is no question that we need new data, tools, and approaches to understand how growing biotic impoverishment and biotic homogenization will influence ecosystem functioning and the environmental and economic fates of nations... The central environmental message of biodiversity and ecosystem functioning research, to conserve biodiversity to improve human wellbeing, has historically been essentially utilitarian in its reasoning. This focus is sometimes understandably seen as contrary to widespread and urgent conservation efforts to save species and ecosystems from extinction for non-utilitarian, cultural reasons. (Naeem, Duffy, & Zavaleta, 2012, p. 1406)

The important thing about organisms (other than humans) in ecosystems is that they did not require international agreement or environmental awareness to organize a homeostatic and profitable global system that was sustained for billions of years. Salamanders, for example, are innately sustainable. Why has it become so important to teach fellow human beings what was once a part of our natural evolutionary condition? Is teaching environmental awareness or social marketing of environmental behaviour effective? The niche construction pedagogical perspective that I have developed in this thesis suggests an alternative approach that could be more successful and self-sustaining.

The niche construction pedagogical theory that was incorporated into my curricula and study addresses the very processes that modulate the resource base (for example, ecosystem goods and services, Figure 1). The approach involves students in the ecological engineering process by creating the conditions in which students have opportunities to design educational environments so that they can functionally self-invest in a homeostatic economy. My research on a biophilia effect as potentially measured by the MEI responses or by behavioural observation, contrasted the student-learning to environment relationships as though the study design created a closed system.

A critical component of the niche construction process is that it addresses the dimensional aspects of biodiversity that are not wholly covered in species-based approaches. This was addressed in the literature review, where it was revealed that biodiversity is more than species, which is only a measure of taxonomic diversity. Biodiversity also includes phylogenetic diversity (genealogical relations over time), genetic diversity, spatial or temporal diversity, landscape diversity, and functional diversity (Naeem, Duffy, & Zavaleta, 2012). The niche construction process not only stimulates the singular dimension of species diversity but it is a process that ecologically engineers the multiple dimensions to biodiversity that functionally sustain and regenerate ecosystem goods and services (Figure 1) that the curricula (Appendix B) were designed to access. Likewise, biophilia may also be expanded to include behavioural motivation or desire to value not only species but a broader spectrum of biodiversity that the niche construction approach can access.

> Indeed, species targeted for conservation, reserves, and protected areas represent a tiny fraction of the biosphere and are therefore not likely to strongly influence biogeochemically derived ecosystem services such as carbon sequestration and food production. Yet the cultural values of biological diversity can themselves be construed as ecosystem services, and their preservation is fully coherent with nonutilitarian conservation efforts and arguably no less important. Nothing in biodiversity and ecosystem functioning research should dissuade conservation from its efforts to bring our age of extinction to a halt. (Naeem, Duffy, & Zavaleta, 2012, p. 1406)

In comparison to the niche construction pedagogy, the *Emulated Natural Disturbance* approach to forest management (Kreutzweiser, Sibley, Richardson & Gordon, 2012) and the theory behind it aim to emulate or mimic processes of natural disturbance, such as matching the spatial patterns of fire in a harvest. The process lets foresters and industrial investors engineer and incorporate a managed disturbance into their plans.

Sections of my literature review consider traditional environmental educational initiatives that focus on recycling, energy efficiency, and a long list of "Earth friendly" strategies aimed to get everyone involved, to pitch in, and do their part. However, in contrast to an ecosystem engineering approach these strategies seem highly ineffective in the longer-term because they are largely disconnected from the ecological processes and represent an ecological dysfunction that may be the root cause of pollution, climate change, and the extinction of life.

Niche construction pedagogy is an ecological approach to deal with these issues in a direct way. Rather than focusing on teaching environmental awareness, my proposal for niche construction pedagogy concentrates on getting students involved directly in the kinds of ecological activities that have the potential to generate natural capital. Students linked into the inertia of a niche-constructed economy can enable a natural metabolism for producing and sustaining a steady supply ecological goods and services (Figure 1). According to the theory, the general well-being in society would be increased for a greater number of individuals as the activities and their choices modify their own niche and other's that become linked collectively, directly, and freely into the commonwealth that is created out of the niche construction process.

Niche construction pedagogical theory and practice may suffer educational and social prejudice because nature study is not accepted as a current instructional approach. Yet, my reading and experience as an ecologist have compelled me to believe that nature study is the most vital means to exercise and advance sustainable scientific knowledge in a way that is healthy. A broad analysis on research into direct engagement and learning outdoors broadly supports the premise that educators and students "have a greater sense of satisfaction in their lives" (Blanchet-Cohen & Elliot, 2011, p. 759). There are more opportunities for development of the learning environment, the educator and the student through increased access to natural spaces.

During the outdoor teaching program in this study, students were actively engaged in physical activities, excavating logs, digging through dirt, sifting through soil, and wading through wetlands. Children learned peripatetically because the curricula spanned three environments, including a forested park with wetlands, urban ecosystems with forests and wetlands, and indoors at the Exploration Place museum. The indoor group differed from the urban ecology and outdoor group through the exclusion of direct niche constructing activities. Outdoor learning presented students with opportunities to directly engage and manipulate soils and organisms in local ecosystems. The two outdoor student groups bioturbated soils, foraged on wild berries, and added disturbance to the sites where they learned. In short, the curricula enabled and encouraged ecological engineering from the students, although the experiment was short-term relative to the broader implications of the primary research questions entailing niche construction theory.

CHAPTER VI: SUMMARY AND CONCLUSIONS

The concept of the Junior Amphibian Ecologist League was part of an educational initiative for the non-profit conservation charity that I initiated in 2003. The curricula that I delivered and evaluated in this study were part of this conservation leadership initiative. A paper by Manolis et al. (2008) identifying the importance of building on leadership theory and practice in conservation science inspired me to link this study to my leadership position within NAMOS BC (Northern Amphibian Monitoring Outpost Society). As the director for this conservation-orientated charity, my goals were to develop an effective and practical conservation initiative. Specifically to develop curricula that could encourage learning practices that would sow the seeds of ecoliteracy for youth in the Prince George area.

Outcomes of the Ecoliteracy Research

Moving a step beyond the biophilia hypotheses, I inferred that longer-term outcomes for conservation behaviour could be further enhanced by building on the principles and insights that have grown out of niche construction theory in the past decade (Odling-Smee, Erwin, Palkovacs, Feldman, & Laland, 2013). Therefore, a further goal that went into the development of my curricula was to engage learners in activities that would also mimic the natural process of ecosystem engineering, where students could modify their learning environments that could potentially, in turn, modify their learning experience as niche construction theory would predict. The peripatetic approach also allowed students the opportunity to engage experientially with the natural habitats adjacent to urban areas. This approach avails access and the opportunity for students to create wealth in their learning community via ecological goods and services (Figure 1).

Curricular environments. I developed nature study curricula on amphibian ecology and conservation that transected different areas of Prince George, including rural parkland, urban parkland, and the Exploration Place Museum, which are all nature-orientated centers and places where families can visit. In the process of delivering the curricula, I also considered the educational and ecological resources that are available in the city for executing this type of curricula.

I did not expect that an amphibian would be encountered in Moore's Meadow as occurred in my urban parkland group. My repeated annual searches within that park area have only resulted in a single observation of a long-toed salamander in 2006. The locations of amphibian habitats within the urban perimeter are not well known. This kind of information is important for the future development of nature-orientated programs and outdoor learning activities within the city. Nature study is becoming identified as an important component in the educational system of an increasingly urban world (Ardoin, Clark, & Kelsey, 2013). My study and further research that has been conducted by NAMOS BC has provided an early glimpse into the spatial arrangement of amphibian habitats within the Prince George area in relation to schoolyards and other places that might be of interest to an urban planner or to school educators organizing field trips.

Study limitations. The MEI was distributed and completed by students using a pretest-posttest study design. However, the two groups provided significantly different responses in the pretest prior to the educational intervention. This indicates that the initial conditions were not ideal to study the effect of the treatment. A larger sample size is more likely to provide an overall representation of children within Prince George. A larger sample size would also add to the robustness of the quantitative analysis to highly polar viewpoints.

Furthermore, a strong control group consisting of students that had never taken part in any form of nature study intervention could have improved on the study design.

The identified limitation of the quantitative component to my study design means that a statistical inference could not achieve validity in reference to my hypotheses **[1]**, in its abductive form:

[1] *Rule:* Students with increasing direct experience in nature study (that is, rural parkland), correspondingly respond more favorably to the MEI ecological values and students without direct experience in nature study (that is, urban parkland and indoor) will remain indifferent (no effect).

Result: Students in group 1 exhibit higher endorsement of MEI ecological values.

∴ *Case:* Students in group 1 are significantly affected in favor of and by the nature-study experience.

However, the item analysis shows significant internal consistency, which means that the responses had a high degree of reliability. Although the treatments could not be tested quantitatively with confident validity, the overall responses and item analysis provides insight into the way that students might respond generally to the values that the items were designed to study. Moreover, the item analysis also offers guidance for future refinement of the MEI instrument and modular approach. The study was also limited by the very nature of the biophilia hypothesis and its connections to niche construction pedagogy, which would require methodological development and experimental treatment beyond short-term feedback from a written response based instrument.

Contributions of the Study

Conservation educators or teachers may be inspired by my description of the activities of the Junior Amphibian Conservation League to adopt a niche construction pedagogical approach for designing nature study lessons. Although the quantitative analysis in this study did not provide an effective test of the hypothesis [1], the item analysis, the experiences gained by myself and the students, and the information obtained about the ecological resources in Prince George for nature study programs may be seen as worthwhile contributions. This study into the practicability of launching a biophilic, niche construction-based curricula revealed that valuable places remain within Prince George's urban ecology where educators may be able to provide and enhance nature study programs or outdoor learning opportunities.

This study also revealed how the niche construction capabilities of children within city limits are limited by the distance required for travel from one ecosystem to another. There are also legislative hurdles in involving people in a participatory approach to education. Ballouard, Provost, Barré and Bonnet (2012), for example, identified handling of snakes as the most preferred activity. Handling and direct contact with wildlife is identified as a critical component in the biophila experience but the Wildlife Act of BC requires a permit for the handling of wildlife, including amphibians. Further work is needed to bridge the divide between the legislative concern for harm to wildlife and conservation educators noting the psychological benefits for direct experiential values that develop in school children.

Few amphibians inhabit the urban periphery of Prince George where breeding wet lands and migratory networks have been built over. Promoting the participatory nature of niche constructing activities in a learning environment is a novel approach that may face some hurdles.

The theory of niche construction pedagogy describes the combined means by which knowledge, experience and practice of ecosystem management are captured, stored, revived and transmitted over time (Colding & Barthel, 2013, p 160). I selected the topic of amphibians because rate of global decline that has been measured in this group of animals has become a pressing concern for conservation biologists. This makes it all the more important to understand how people are valuing and understanding the issue of amphibian declines. Other educators may agree that a valid and reliable instrument is needed to evaluate the effectiveness of nature study lessons and help to develop an instrument that provides decision makers with compelling reasons to improve on community-based outdoor learning opportunities for children. Other educators may improve on my instrument design more generally and in specific relation to the modules that were adopted from other studies. The NC module looks promising as a first of its kind to investigate the economic worth of nature. The VTK was my attempt to develop a module focused specifically on amphibians. At the time this study was designed, published modules were unavailable to address the herpetological side of ecological values.

Closing Remarks

Other scientists may be inspired by my efforts to communicate with the non-scientific community, especially with those young people who will inherit a new world with fewer amphibians lacking more natural spaces. Recent studies into the biophilic or nature-based values of school children, even specific research into herpetofauna (Ballouard, Provost, Barré and Bonnet ,2012; Tomazic, 2011) points the value of my research and curricular objective to integrate learning with ecological processes so that students and educators can become agents of biophilic design in their learning environments. The potential benefit of increased biophilia and niche construction opportunities continue to inspire me to persist in grappling with the problems posed here, having learned from the specified limitations and experiences described. It is my intent to utilize a revised version of the MEI in future studies that would involve an external control group not involved in the lesson plans and sampled from a more general educational setting, such as public schools. It is also my goal to use these data and the knowledge gained from my research and teaching experience to improve on the curricula and share the lessons learned to a wider community of leaders invested in the conservation of nature and education.

REFERENCES

Anderson, D. L., Fisher, K. M., & Norman, G. J. (2002). Development of the conceptual inventory of natural selection. *Journal of Research in Science Teaching, 39,* 952-978.

Ardoin, N. M., Clark, C., & Kelsey (2013). An exploration of future trends in environmental education research. *Environmental Education Research, 19(4),* 499-520.

Bacon, F. (1990). *Novum Organum.* (P. Urbach & J. Gibson, Trans.) Peru, Illinois: Carus. (Original work published in 1620)

Ballouard, J. M. Brischoux F, Bonnet X (2011) Children prioritize virtual exotic biodiversity over local biodiversity. *PLoS ONE 6(8):* e23152.

Ballouard, J.-M., Provost, G., Barré, D., & Bonnet, X. (2012). Influence of a field trip on the attitude of schoolchildren toward unpopular organisms: An experience with snakes. *Journal of Herpetology, 46*(3), 423–428.

Barnett, M., Lord, C., Strauss, E., Rosca, C., Langford, H., Chavez, D., & Deni, L. (2006). Using the urban environment to engage youths in urban ecology fieldnstudies. *The Journal of Environmental Education, 37(2),* 3-11.

Barnosky, A. D., Hadly, E. A., Bascompte, J., Berlow, E. L., Brown, J. H., Fortelius, M., Smith, A. B. (2012). Approaching a state shift in Earth/'s biosphere. *Nature, 486*(7401), 52–58.

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O. U., Swartz, B., Quental, T. B., Ferrer, E. A. (2011). Has the Earth/'s sixth mass extinction already arrived? *Nature, 471(7336),* 51–57.

Blanchet-Cohen, N. & Elliot, E. (2011). Young children and educators engagement and learning outdoors: A basis for rights-based programming. *Early Education and Development, 22(5),* 757–777.

Burton, T.M., & Likens, G. E. (1975a). Energy flow and nutrient cycling in salamander populations in the Hubbard Brook experimental forest, New Hampshire. *Ecology, 56(5),* 1068-1080.

Burton, T. M., & Likens, G. E. (1975b). Salamander populations and biomass in the Hubbard Brook experimental forest, New Hampshire. *Copeia, 1975(3),* 541-546.

Cachelin, A., Paisley, K., & Blanchard, A. (2009). Using the significant life experience framework to inform program evaluation: The nature conservancy's wings & water wetlands education program. *The Journal of Environmental Education*, 40(2), 2-14.

Carl, G. C. (1966). *The Amphibians of British Columbia.* Victoria, BC: British Columbia Provincial Museum, Department of Recreation and Conservation. Handbook No. 2.

Carrier Sekani Tribal Council (2007). A CSTC background. Retrieved from http://www.cstc.bc.ca/downloads/CSTC%20Background%20-%20Feb%202007.pdf

Cashins, S. D., Alford, R. A., & Skerratt, L. F. (2008) Lethal effect of latex, nitrile, and vinyl gloves on tadpoles. *Herpetological Review, 39 (3),* 298-301.

Ceballos, G., & Erlich, P. R. (2002). Mammal population losses and the extinction crisis. *Science, 296,* 904-907.

Chemers, M. (1995). *Contemperorary leadership theory.* In J. Wren (Ed.) The Leader's Companion: Insights on leadership through the ages (pp. 83-99). New York: The Free Press.

Chen, X., Peterson, M.N., Hull, V., Chuntian, L., Hong, D., Liu, J. (2013). How perceived exposure to environmental harm influences environmental behavoiur in urban China. AMBIO, 42(1), 52-60.

Chiesura, A., & de Groot, R. (2003). Critical natural capital: a socio-cultural perspective. *Ecological Economics, 44(2-3),* 219-231.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* (2nd ed.). Hillsdale, NJ: Erlbaum

Colding, J., & Barthel, S. (2013). The potential of 'Urban Green Commons' in the resilience building of cities. *Ecological Economics, 83,* 156-166.

Colon-Gaud, C., Whiles, M. R., Kilham, S. S., Lips, K. R., Pringle, C. M., Connelly, S., & Peterson, S. D. (2009). Assessing ecological responses to catastrophic amphibian declines: Patterns of macroinvertebrate production and food web structure in upland Panamanian streams. *Limnology and Oceanography, 54(1),* 2009, 331–343.

Collins, J. P., & Crump, M. L. (2008). *Extinction in our times: Global amphibian decline.* Oxford University Press: New York.

Costanza, R. d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387,* 253-260.

Cowling, R. M., Knight, A. T., Faith, D. P., Ferrier, S., Lombard, A. T., Driver, A., et al. (2004). Nature conservation requires more than a passion for species. *Conservation Biology, 18(6),* 1674-1676.

Coulter, S. (1905). Part I. In Coulter, S., Fairbanks, H. W., & Bigelow, M. A. *Symposium On Educational Values and Aims of Nature-Study* (pp. 49-52). *Nature Study Review, 1(2),* 49-57.

Crocker, L.M., & Algina, J. (1986). *Introduction to classical and modern test theory.* New York: CBS College Publishing.

Darwin, C. (1882). *The formation of vegetable mould, through the action of worms with observations on their habits: Seventh thousand (corr.).* London: J. Murray.

de Groot, R. S., Wilson, M. A., & Boumans, R. M. J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics, 41,* 393-408.

Downing, E. R. (Ed.). (1912). *The Washington Meeting. Nature Study Review, 8(1),* 1-7.

Dunlap, R. E., & Van Liere, K. D. (1978). A proposed measuring instrument and preliminary results: The 'new environmental paradigm'. *Journal of Environmental Education, 9,* 10-19.

Dunlap, R. E., & Van Liere, K. D. (1984). Commitment to the dominant social paradigm and concern for environmental quality. *Social Science Quarterly, 65,* 1013-1028.

Ehlrich, P. R., Kareiva, P. M., & Daily, G. C. (2012). Securing natural capital and expanding equity to rescale civilization. *Nature, 486,* 68-73.

Ehlrich, P. R., & Pringle, R. M. (2008). Where does biodiversity go from here? A grim business-as-usual forecast and a hopeful portfolio of partial solutions. *Proceedings of the National Academy of Sciences, 105(1),* 11579-11586.

Fairbanks, H. W. (1905). Part II. In Coulter, S., Fairbanks, H. W., & Bigelow, M. A. Symposium on educational values and aims of nature-study. *Nature Study Review, 1(2),* 49-57.

Fairbanks, H. W., Hodge, C. F., MacBride, T. H., Stevens, F. L., & Bigelow, M. A. (1905). Nature-study and its relation to natural science. *Nature Study Review, 1(1),* 2-18.

Farber, S., Costanza, R., Childers, D. L., Erickson, J., Gross, K., Grove, M., Hopkinson, C. S., Kahn, J., Pincetl, S., Troy, A., Warren, P., & Wilson, M. (2006). Linking ecology and economics for ecosystem management. *BioScience, 56(2),* 121-133.

Farmer, J., Knapp, D., & Benton, G. M. (2007). An elementary school environmental education field trip: Long-term effects on ecological and environmental knowledge and attitude development. *The Journal of Environmental Education, 38(3),* 33 - 42.

Fenech, A., Foster, J., Hamilton, K., & Hansell, R. (2003). Natural capital in ecology and economics: An overview. *Environmental Monitoring and Assessment, 86(1),* 3-17.

Ferraro, P. J., & Pattanayak, S. K. (2006). Money for nothing? A call for empirical evaluation of biodiversity conservation investments. *PLoS Biology, 4(4),* 0482-0488.

Fitzhugh, K. (2005). The inferential basis of species hypotheses: The solution to defining the term 'species'. *Marine Ecology, 26,* 155–165.

Fitzhugh, K. (2006). The abduction of phylogenetic hypotheses. *Zootaxa, 1145,* 1-110.

Fitzhugh, K. (2013). Defining 'species,' 'biodiversity,' and 'conservation' by their transitive relations. In I. Y. Pavlinov (Ed.) The species problem: Ongoing issues. (93-130). Rijeka, Croatia: InTech.

Flynn, E. G., Laland, K. N., Kendal, R. L., & Kendal, J. R. (2013). Target article with commentaries: Developmental niche construction. *Developmental Science, 16*(2), 296–313.

Friborg, O., Martinussen, M., Rosenvinge, J. H. (2006). Likert-based vs. semantic differential-based scorings of positive psychological constructs: A psychometric comparison of two versions of a scale measuring resilience. *Personality and Individual Differencies, 40,* 873-884.

Friendly, M. (n. d.) Power analysis for ANOVA designs. Retrieved January 2nd, 2013, from http://www.datavis.ca/online/power/index.html

Fullan, M. (2007). *The new meaning of educational change (4th ed.).* New York: Teachers College Press.

Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K. J. (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters, 3(4),* 390-394.

Gardner, G. T. & Stern, P. C. (2002). *Environmental Problems and Human Behaviour*. 2nd Ed. Pearson Custom Publishing.

Gaston, K. J. (2010). Valuing common species. *Science, 327(5962),* 154-155

Gill, D. E. (1978). The metapopulation ecology of the Red-Spotted Newt, *Notophthalmus viridescens* (Rafinesque). *Ecological Monographs, 48(2),* 145-166.

Gould, S. J. (1991). Enchanted evening. *Natural History, 100(9),* 4-14.

Gould, S. J. (2000). Deconstructing the 'science wars' by reconstructing an old mold. *Science, 287(5451),* 253-261.

Gratwicke, B., Lovejoy, T.E., & Wildt, D.E. (2012). Will Amphibians Croak under the Endangered Species Act? *BioScience, 62(2),* 197-202.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. *Science, 319(5864),* 756-760.

Hacking, I. (1988). The Participant Irrealist at Large in the Laboratory. *The British Journal for the Philosophy of Science*, *39*(3), 277–294.

Haberl, H., Erb, K. H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., et al. (2007). Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. *Proceedings of the National Academy of Sciences*, *104*(31), 12942–12947.

Hagenbuch, B. E., Bynum, N., Sterling, E., Bower, A. H., Cigliano, J. A., Abraham, B. J., et al. (2009). Evaluating a multi-component assessment framework for biodiversity education. Teaching Issues and Experiments in Ecology, 6. Retrieved from http://tiee.ecoed.net/vol/v6/research/hagenbuch/article.html

Hanski, I. (2005). Landscape fragmentation, biodiversity loss and the societal response. *EMBO reports, 6(5),* 388-392.

Hanski, I. (2008). The world that became ruined. *EMBO reports 9,* S34-S36.

Hardin, G. (1968). The tragedy of the commons. *Science, 162,* 1243-1248.

Hardisty, D. J., & Weber, E. U. (2009). Discounting future green: Money versus the environment. *Journal of Experimental Psychology, 138(3),* 329-340.

Hargreaves, A., & Fink, D. (2005). *Sustainable Leadership.* John Wiley & Sons, Inc.

Hastings, A., Byers, J.E., Crooks, J.A., Cuddington, K., Jones, C.G., Lambrinos, J.G., et al. (2007). Ecosystem engineering in space and time. *Ecology Letters, 10(2),* 153–164.

Hayden-Smith, R. (2007). Soldiers of the soil: A historical review of the United States School Garden Army. Applied Environmental Education & Communication, 6(1), 19-29.

Hoffmann, M. (1999). Problems with Pierce's concept of abduction. *Foundations of Science, 4,* 271-305.

Hooper, D. U., Adair, E. C., Cardinale, B. J., Byrnes, J. E. K., Hungate, B. A., Matulich, K. L., O'Connor, M. I. (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature*, *486*(7401), 105–108.

Hurlburt, R. T. (2006). *Comprehending behavioral statistics* (4th ed.). Belmont, CA: Wadsworth.

Jackson, J. B. (2008). Ecological extinction and evolution in the brave new ocean. *Proceedings of the National Academy of Sciences, 105(1),* 11458-11465.

Jackson, S. T., & Hobbs, R. J. (2009). Ecological restoration in the light of ecological history. *Science, 325(5940),* 567-569.

Jones, A. L. (1909). *Logic inductive and deductive: An introduction to scientific method.* New York: Henry Holt and Company.

Jones, C.G., Lawton, J.H., & Shachak, M. 1994. Organisms as ecosystem engineers. *Oikos, 69,* 373-386.

Karpicke, J. D., & Blunt, J. R. (2011). Retrieval practice produces more learning than studying with concept mapping. *Science, 331*(6018), 772-775.

Kellert, S. R. (1999) Ecological challenge, human values of nature, and sustainability in the built environment. In C. J. Kibert, & A. Wilson (Eds.), *Reshaping the built environment: Ecology, ethics and economics.* (pp. 39-53). Washington, DC: Island press.

Kellert, S. R. (2002). Experiencing nature: Affective, cognitive, and evaluative development in children. In P. H. Kahn, P. H. & S. R. Kellert (Eds.), *Children and Nature: Psychological, Sociocultural, and evolutionary investigations.* (pp. 117-151). The MIT Press.

Kellert, S. R., & Wilson, E. O. (Eds.). (1993). *The biophilia hypothesis.* Washington, D.C.: Island Press.

Kendal, J., Tehrani, J.J., & Odling-Smee, J. (2011). Human niche construction in interdisciplinary focus. *Philosophical Transactions of the Royal Society, Biological Sciences, 366(1566),* 785-792.

Kenny, D.A. (1975). A quasi-experimental approach to assessing treatment effects in the nonequivalent control group design. *Psychological Bulletin, 82(3)*, 345-362.

Kimmerer, R. W. (2002). Weaving traditional ecological knowledge into biological education. *BioScience, 52(5),* 432-438.

Klymkowsky, M. W., & Garvin-Doxas, K. (2008). Recognizing student misconceptions through Ed's Tool and the biology concept inventory. *PLoS Biology, 6(e3),* 1-14.

Knapp, A. K., & D'Avanzo, C. (2010). Teaching with principals: Toward a more effective pedagogy in ecology. *Ecosphere, 1(6),* 1-10.

Kohlstedt, G. (2005). Nature, not books : Scientists and the origins of the nature-study movement in the 1890s. *Isis, 96(3),* 324-52.

Kollmuss, A., & Agyeman, J. (2002). Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research, 8*(3), 239 - 260.

Kopnina, H. (2012). Education for sustainable development (ESD): the turn away from 'environment' in environmental education? *Environmental Education Research, 18(5),* 699-717.

Kossak, A. & Bogner, F. X. (2012). How does a one-day environmental education programme support individual connectedness with nature? *Journal of Biological Education, 46(3),* 180-187.

Kreutzweiser, D.P., Sibley, P.K., Richardson, J.S., & Gordon, A.M.(2012) Introduction and a theoretical basis for using disturbance by forest management activities to sustain aquatic ecosystems. *Freshwater Science, 31(1),* 224-231.

Krupa, J. J. (2000). The importance of naturalists as teachers & the use of natural history as a teaching tool. *The American Biology Teacher, 62(8),* 553-558.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by.* Chicago: The University of Chicago Press.

Laland, K. N. & O'Brian, M. J. (2011). Cultural niche construction: An introduction. *Biological Theory, 6,* 191-202.

Laland, K. N., Odling-Smee, J., & Feldman, M. W. (2001). Niche construction, biological evolution, and cultural change. *Behavioural and Brain Sciences, 23,* 131-175.

Laland, K. N., Kendal, J. R., & Brown, G. R. (2007). The niche construction perspective: Implications for evolution and human behaviour. *Journal of Evolutionary Psychology, 5,* 51-66.

Laland, K. N., Odling-Smee, J., Feldman, M. W., & Kendal, J. (2009). Conceptual barriers to progress within evolutionary biology. *Foundations of Science, 14(3),* 195-216.

Lankester, R. (1913). *Science from an easy chair. A second series.* New York: Henry Hold and Company.

Latour, B., & Woolgar, S. (1979). *Laboratory Life: The Construction of Scientific Facts.* Princeton University Press.

Laudan, L. (1971). William Whewell on the consilience of inductions. *The Monist, 55*(3), 368–391.

Leeming, F. C., Dwyer, W. O., Porter, B. E., & Cobern, M. K. (1993). Outcome research in environmental education: A critical review. *Journal of Environmental Education, 24(4),* 8-21.

Levin, S. A. (1999). *Fragile Dominion: Complexity and the Commons.* Massachusetts: Perseus Books.

Levin, S. A. (2005). Self-organization and the emergence of complexity in ecological systems. *BioScience, 55(12),* 1075-1079.

Lewontin, R.C. 1983. *Gene, organism, and environment.* In: D.S. Bendall (ed) Evolution from Molecules to Men. (273–285)Cambridge University Press.

Mahner, M., & Bunge, M. (1997). *Foundations of Biophilosophy.* New York: Springer.

Manoli, C. C., Johnson, B., & Dunlap, R. E. (2007). Assessing children's environmental worldviews: Modifying and validating the new ecological paradigm scale for use with children. *The Journal of Environmental Education, 38*(4), 3-13.

Manolis, J. C., Chan, K. M., Finkelstein, M.E., Stephens, S., Nelson, C. R., Grant, J. B., & Dombeck, M. P. (2008). Leadership: A new frontier in conservation science. *Conservation Biology, 23(4),* 879-886.

Mayer, F.S., Frantz, C.M. 2004. The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology, 24(4),* 503–515.

McCallum, M. L. (2007). Amphibian decline or extinction? Current declines dwarf background extinction rate. *Journal of Herpetology, 41(3),* 483-491.

McElwain, J. C., & Punyasena, S. W. (2007). Mass extinction events and the plant fossil record. *TREE, 22(10),* 548-557.

Meyer, J.P. (2013). jMetrik version 3.01 [computer software]. Retrieved from www.ItemAnalysis.com.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Biodiversity synthesis.* World Resources Institute, Washington, DC.

Miller, J. R. (2005). Biodiversity conservation and the extinction of experience. *Trends in Ecology and Evolution, 20(8),* 430-434.

Minteer, B.A., & Collins, J.P. (2005). Why we need an "ecological ethics". *Frontiers in Ecology and the Environment, 3,* 332–337.

Mitchell, C., & Sackney, L. (2008). *Sustainable Improvement.* Sense Publishers: Rotterdam The Netherlands.

Mitchell, J. C., & Brown, R. E. J. (2008). Urban herpetology: Global overview, synthesis and future directions. In J. C. Mitchell, R. E. J. Brown, & B. Bartholomew (Eds.), *Urban Herpetology* (pp. 1-30). Herpetological Conservation, V. 3, Society for the Study of Amphibians and Reptiles.

Mitchell, J. C., Brown, R. E. J. & Bartholomew, B. (Eds.) (2008). *Urban Herpetology. Herpetological Conservation,* V. 3, Society for the Study of Amphibians and Reptiles.

Mitchell, D. B., & Mueller, M. P. (2011). A philosophical analysis of David Orr's theory of ecological literacy: biophilia, ecojustice and moral education in school learning communities. *Cultural Studies of Science Education, 6,* 193-221.

Molnar, J., Marvier, M., & Kareiva, P. (2004). The sum is greater than the parts. *Conservation Biology, 18(6),* 1670-1671.

Moore, R. C., & Marcus, C. C. (2008). Healthy planet, healthy children: Designing nature into the daily spaces of childhood. In S. R. Kellert, J. Heerwagen, & M. Mador (Eds.), *Biophilic design: The theory, science and practice of bringing buildings to life.* (21-25). Hoboken, New Jersey: John Wiley and Sons.

Naeem, S., Duffy, J. E., Zavaleta, E. (2012). The functions of biological diversity in an age of extinction. *Science, 336,* 1401-1406.

Nisbet, E. K., Zelenski, J. M. & Murphy, S. A. (2009). The nature relatedness scale: Linking individuals' connection with nature to environmental concern and behavior. *Environment and Behavior,* 41: 715-740.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory.* (3rd Ed.). New York, NY: McGraw-Hill Inc.

Odling-Smee, J., Erwin, D., Palkovacs, E., Feldman, M., & Laland, K. (2013). Niche construction theory: a practical guide for ecologists. *The Quarterly review of biology, 88*(1), 4–28.

Olsson, U., Drasgow, F., & Dorans, N. J. (1982). The polyserial correlation coefficient. *Psychometrika, 47(3),* 337-346.

Ostrom, E. (2009). A general framework for analyzing sustainability of social ecological systems. *Science, 235,* 419-422.

Ovaska, K., & Govindarajulu, P. (2010*). A guide to amphibians: Frogs, toads, salamanders of British Columbia North of 50^{0}*. BC Ministry of Environment.

Partners in Amphibian and Reptile Conservation (2013a, July 14). About PARC. Retrieved from http://www.parcplace.org/about-parc.html

Partners in Amphibian and Reptile Conservation (2013b, July 14). Mission. Retrieved from http://www.parcplace.org/about-parc/mission.html

Papworth, S.K., Rist, J., Coad, L., Milner-Gulland, E.J. (2009). Evidence for shifting baseline syndrome in conservation. *Conservation Letters, 2(2),* 93–100.

Peirce, C. S. (1891). The architecture of theories. *The Monist, 1(2),* 161–176.

Peirce, C. S. (1994). *Collected papers of Charles Sanders Peirce.* Vols. 1-6. C. Hartshorne, W., P. Weiss, (Eds.). (1931). Vols. 7-8. A. W. Burks, (Ed.). (1958) Cambridge: Harvard University Press (Original dates 1867-1914). Electronic edition accessed through UNBC collections.

Persha, L., Agrawal, A., & Chhatre, A. (2011). Social and ecological synergy: Local rulemaking, forest livelihoods, and biodiversity conservation. *Science, 332,* 1606-1608.

Pienaar, E. F., Lew, D.K., & Wallmo, K. (2013). Are environmental attitudes influenced by survey context An investigation of the context dependency of the New Ecological Paradigm (NEP) Scale. *Social Science Research, 42,* 1542–1554

Pinker, S. (2010). The cognitive niche: Coevolution of intelligence, sociality, and language. *Proceedings of the National Academy of Science, 107(S2),* 8993-8999.

Prokop, P. & Fančovičová, J. (2013). Does colour matter? The influence of animal warning coloration on human emotions and willingness to protect them. *Animal Conservation, 16(4),* 458–466.

Puppim de Oliveira, J. A., Balaban, O., Doll, C. N. H., Moreno-Peñaranda, R., Gasparatos, A., Iossifova, D., & Suwa, A. (2011). Cities and biodiversity: Perspectives and governance challenges for implementing the convention on biological diversity (CBD) at the city level. *Biological Conservation, 144*(5), 1302–1313.

R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Randler, C., Ilg, A., & Kern, J. (2005). Cognitive and emotional evaluation of an amphibian conservation program for elementary school students. *The Journal of Environmental Education, 37(1),* 43-52.

Rands, M. R. W., Adams, W. M., Bennun, L., Butchart, S. H. M., Clements, A., Coomes, D., Entwistle, A., et al. (2010). Biodiversity conservation: Challenges beyond 2010. *Science, 329*(5997), 1298-1303.

Rees, W. (2002). An ecological economics perspective on sustainability and prospects for ending poverty. *Population and Environment, 24(1),* 15-46.

Rees, W. (2009). The ecological crisis and self-delusion: implications for the building sector. *Building Research and Information, 37(3),* 300-311.

Regester, K. J., & Whiles, M. R. (2006). Decomposition rates of salamander (*Ambystoma maculatum*) life stages and associated energy and nutrient fluxes in ponds and adjacent forest in southern Illinois. *Copeia, 2006(4),* 640-649.

Remmers, H. H. (1938). Propaganda in the schools: Do the effects last? *The Public Opinion Quarterly, April,* 197-210.

Rendell, L., Fogary, L., & Laland, K. (2011). Runaway cultural niche construction. *Philosophical Transactions of the Royal Society B, 366(1566),* 823-835.

Robert, J.S., Hall, B.K., Olson, W.M. (2001). Bridging the gap between developmental systems theory and evolutionary developmental biology. *BioEssays, 23(10),* 954–962.

Rockstrom, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E. F., Lenton, T. M., et al. (2009). A safe operating space for humanity. *Nature, 461(7263),* 472–475.

Rossiter, D. G. (2007). Classification of urban and industrial soils in the World Reference Base for Soil Resources. *Journal of Soils and Sediments, 7(2),* 96-100.

Rowley-Conwy, P., & Layton, R. (2011). Foraging and farming as niche construction: stable and unstable adaptations. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366*(1566), 849–862.

Rull, V. (2011). Sustainability, capitalism and evolution: Nature conservation is not a matter of maintaining human development and welfare in a healthy environment. *EMBO reports, 12,* 103-106.

Rust, J., & Golombok, S. (2009). *Modern psychometrics: The science of psychological assessment.* (3rd Ed.) New York, NY: Routledge.

Saunders, C. D. (2003). The emerging field of conservation psychology. *Human Ecology Review, 10(2),* 137-149.

Shennan, S. (2011). Property and wealth inequality as cultural niche construction. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366*(1566), 918–926.

Shepherd, S., & Kay, A. C. (2012). On the perpetuation of ignorance: System dependence, system justification, and the motivated avoidance of sociopolitical information. *Journal of Personality and Social Psychology, 102(2),* 264-280.

Shufeldt, R. W. (1922). Conservation and nature-studies in the public schools of Washington, D. C. *Nature Study Review, 18(7),* 259-262.

Silvertown, J., Tallowin, J., Stevens, C., Power, S. A., Morgan, V., Emmett, B., Hester, A., et al. (2010). Environmental myopia: a diagnosis and a remedy. *Trends in Ecology & Evolution, 25*(10), 556–561.

Smith, T. B., Bruford, M. W., & Wayne, R. K. (1993). The preservation of process: The missing element of conservation programs. *Biodiversity Letters, 1(6),* 164-167.

Smith-Sebasto, N. J., & Cavern, L. (2006). Effects of pre- and posttrip activities associated with a residential environmental education experience on students' attitudes toward the environment. *The Journal of Environmental Education, 37,* 3–17.

Snaddon, J. L., Turner, E. C., & Foster, W. A. (2008). Children's perceptions of rainforest biodiversity: Which animals have the lion's share of environmental awareness? *PLoS ONE, 3(7),* e2579.

Sneider, C. I., & Ohadi, M. M. (1998). Unraveling students' misconceptions about the Earth's shape and gravity. Science Education, 82(2), 265-284.

Southam, T., & Curran, E. A. (Eds.) (1996). J. R. The wetlandkeepers handbook: A practical guide to wetland care. B. C. Wildlife Federation, Surrey, B. C. and Environment Canada, Delta, B. C.

Stern, M.J., R.B. Powell, & N.M. Ardoin 2008. What difference does it make? Assessing outcomes from participation in a residential environmental education program. *Journal of Environmental Education, 39(4),* 31-43.

Stork, N. E. (2010). Re-assessing current extinction rates. *Biodiversity and Conservation, 19(2),* 357-371.

Termorshuizen, J. W., Opdam, P., & van den Brink, A. (2007). Incorporating ecological sustainability into landscape planning. *Landscape and Urban Planning, 79,* 374-384.

Thanos, C. A. (1994). Aristotle and Theophrastus on plant-animal interactions. In M. Arianoutsou, R. H. Groves, (Eds.), Plant-animal interactions in the Mediterranean type ecosystems (3–11). Dordrecht, Neth.: Kluwer Acad.

Thompson, M. D. (2010). Book review, Extinction in our times: Global amphibian decline. *Herpetological Review, 41(1),* 116–118.

Thorndike, L. (1940). Elementary and secondary education in the middle ages. *Speculum, 15(4),* 400-408.

Trafton, G. H. (1913). Children's interests in nature materials. *Nature Study Review, 9(6),*150-160.

Turner, N.J., & Cocksedge, W. (2001). Aboriginal use of non-timber forest products in Northwestern North America. *Journal of Sustainable Forestry, 13, (3-4),* 31-58.

Turner, N. J., Davidson-Hunt, I. J., O'Flaherty, M. (2003). Living on the edge: Ecological and cultural edges as sources of diversity for social-ecological resilience. *Human Ecology, 31(3),* 439-461.

Turner, N. J., Ignace, M. B., & Ignace, R. (2000). Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. *Ecological Applications*, *10*(5), 1275-1287.

Voivontas, D., Assimacopoulos, D., & Koukios, E. G. (2001). Assessment of biomass potential for power production: A GIS based method, *Biomass and Bioenergy, 20(2),* 101-112.

Wagler, R. (2011). The Anthropocene mass extinction: An emerging curriculum theme for science educators. *The American Biology Teacher, 73 (2),* 78-83

Wake, D. B., & Vredenburg, V. T. (2008). Are we in the midst of the sixth mass extinction? A view from the world of amphibians. *Proceedings of the National Academy of Sciences,105(S1),* 11466-11473.

Waldick, R. (1997). Effects of forestry practices on amphibian populations in Eastern North America. *Herpetological Conservation, 1,* 191-205.

Weaver, R. L. (1947). The teaching of ecology: From the nature study viewpoint. *The American Biology Teacher, 9(6),* 162-164.

Whewell, W. (1860). *On the philosophy of discovery: Chapters historical and critical.* London: John W. Parker and Son, West Strand.

Whiles, M. R., Lips, K. R., Pringle, C. M., Kilham, S. S., Bixby, R. J., Brenes, R., et al. (2006). The effects of amphibian population declines on the structure and function of

Neotropical stream ecosystems. *Frontiers in Ecology and the Environment, 4(1),* 27-34.

Wilkinson, M. T., Richards, P. J., & Humphreys, G. S. (2009). Breaking ground: Pedological, geological, and ecological implications of soil bioturbation. *Earth Science Reviews, 97*(1–4), 257–272.

Williamson, A. C., & Remmers, H. H. (1940). Persistence of attitudes concerning conservation issues. *Journal of Experimental Education, 8(3),* 354-361.

Wilson, D. S., O'Brien, D. T., & Sesma, A. (2009). Human prosociality from an evolutionary perspective: Variation and correlations on a city-wide scale. *Evolution and Human Behavior, 30,* 190-200.

Wilson, E. O. (1984). *Biophilia: The human bond with other species.* Presidents and Fellows of Harvard College.

Wilson, E.O. (1992). *The diversity of life.* Cambridge, Massachusetts: The Beknap Press of Harvard University Press.

Wilson, E. O. (1993). Biophilia and the conservation ethic. In S. R. Kellert, & E. O. Wilson (Eds.). (31-41). *The biophilia hypothesis.* Washington, D.C.: Island Press.

Wilson, E. O. (1998). *Consilience: The unity of knowledge.* New York: Alfred A. Knopf, Inc.

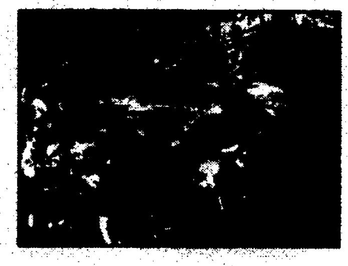
Wood, C. C., & Gross, M. R. (2008). Elemental conservation units: Communicating extinction risk without dictating targets. *Conservation Biology, 22(1),* 36–47

Wyman, R. L. (1998). Experimental assessment of salamanders as predators of detrital food webs: effects on invertebrates, decomposition and the carbon cycle. *Biodiversity and Conservation, 7(5),* 641-650.

Zak, K. M., & Munson, B. H. (2008). An exploratory study of elementary preservice teachers' understanding of ecology using concept maps. *The Journal of Environmental Education, 39(3),* 32-46.

Zelenski, J.M. & Nisbet, E.K. Happiness and feeling connected: The distinct role of nature relatedness. *Environment and Behavior,* 1-21.10.1177/003916512451901

APPENDIX A JUNIOR AMPHIBIAN ECOLOGIST LEAGUE ANNOUNCEMENT POSTER.



NAMOS BC

JUNIOR AMPHIBIAN ECOLOGIST LEAGUE

FREE Outdoor Science Program for Children!!

- Participate in a UNBC Graduate Study - Masters of Education Program.
- Completely FREE - free books, free supervision, and lots of fun activities!
- Please e-mail to register your spot today! Three Groups - five children per group, Ages 10-14.
- Parents and guardians are welcome to join us to learn about the amphibians of Prince George!

Group 1	Group 2	Group 3
Thursday August 25, 2011 8:30am-4:30pm	Tuesday August 30th, 2011 9am-4:30pm	Friday September 9, 2011 6pm-8:30pm
Friday August 26, 2011 8:30am-4:30pm	Wednesday August 31st, 2011 9am-4:30pm	Saturday September 10, 2011 9am-4:30pm
Saturday August 27, 2011 8:30am-Noon	Friday September 2nd, 2011 9am-Noon	Sunday September 11, 2011 9am-4:30pm
Sunday August 28, 2011 8:30am-4:30pm	Saturday September 3rd, 2011 9am:4:30pm	Saturday September 17, 2011 9am-4:30pm
Monday August 29, 2011 8:30am-4:30pm	Sunday September 4th, 2011 9am:4:30pm	Sunday September 18, 2011 9am-4:30pm

Contact: Mark D. Thompson
E-mail: ecology@namos.ca

APPENDIX B. CURRICULUM BOOKLETS.

A Guide to

Frogs, Toads, Salamanders

of British Columbia of 50°

HOW TO USE THIS GUIDE

This brochure provides a quick and easy identification key to adult amphibians in northern B.C., with separate keys for salamanders and for frogs and toads.

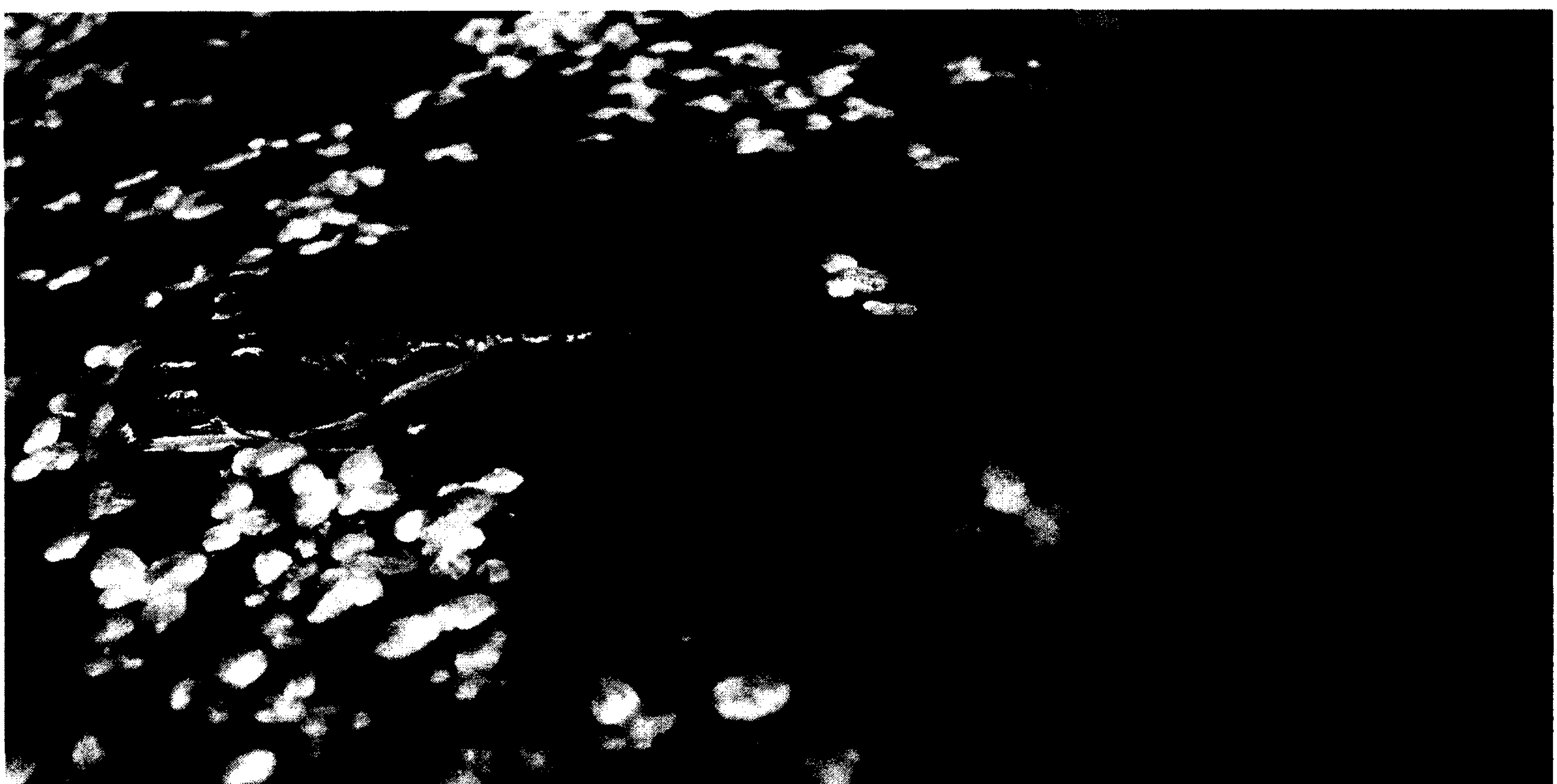
- Read the statements in the boxes at the top of the page as questions.
- If your answer to all questions is yes, proceed to read down the page to learn more about the species.
- If the answer is no, proceed to the next page and onwards, until you reach a box where you answer yes to all the questions.
- Refrain from handling amphibians unless absolutely necessary. Amphibian skin is very sensitive to contaminants, such as sunscreen or insect repellent on our hands.
- If in doubt, take photographs and confirm with BC Frogwatch contact.

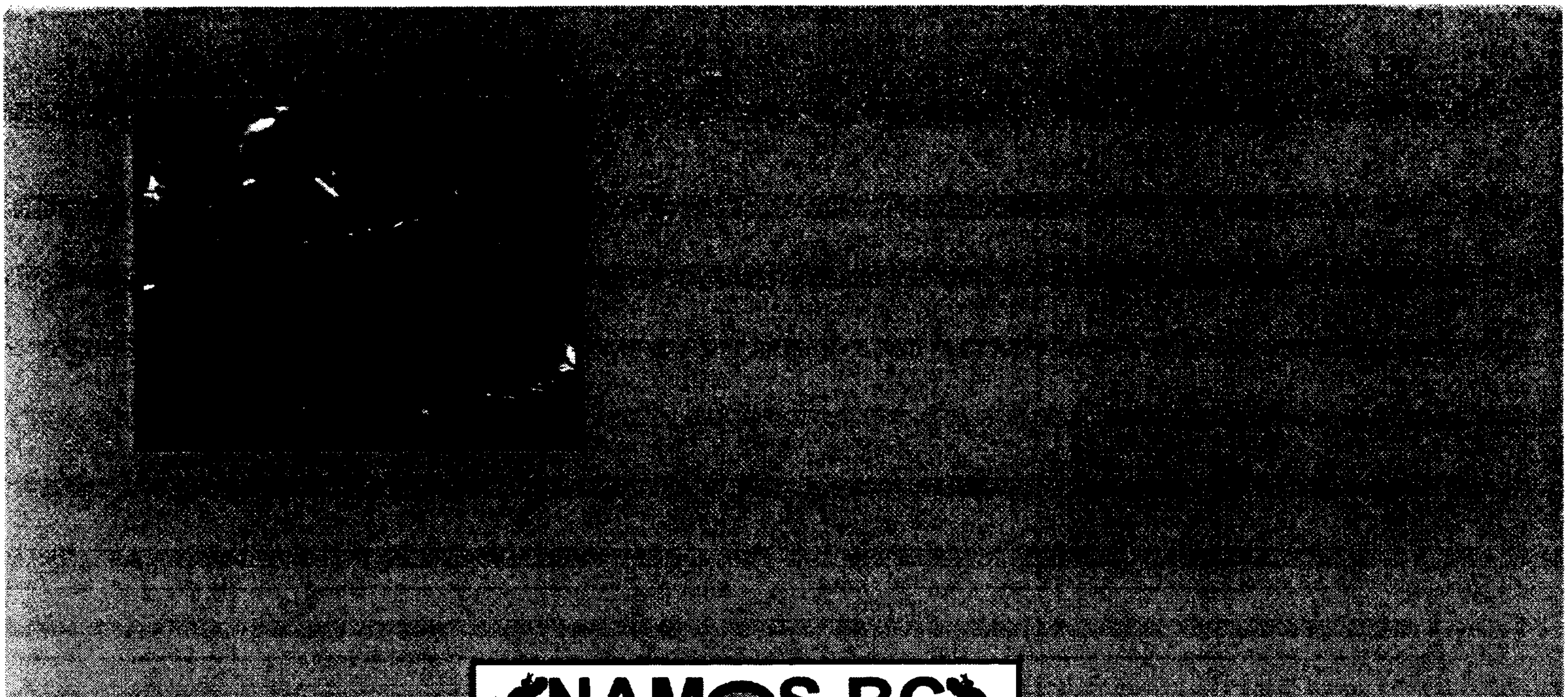
Nearly one third (32%) of the approximately 5,750 amphibian species are at risk worldwide. The situation in British Columbia is equally bleak: 30% of the salamanders and 64% of the frogs and toads are listed as species of concern either federally, provincially, or both. Even common and widespread species such as the Western Toad and Columbia Spotted Frog are showing signs of decline in parts of the province.

Northern B.C. is especially important for the conservation of amphibians as it is not under the same development pressures as southern regions. Northern areas may form strongholds for amphibians that are declining farther south. This role is expected to increase in importance in the face of climate change, as warmer and drier conditions in the south may result in northward range shifts for many amphibians. We need improved monitoring of amphibians of northern B.C. both for management and for conservation planning.

NAMOS BC

JUNIOR AMPHIBIAN ECOLOGIST LEAGUE





NAMOS BC

Members of the Junior Amphibian Ecologist league will learn about local amphibians and their ecological functions that sustain the soils, wetlands and communities of the Central Interior of British Columbia

A NAMOS BC (Northern Amphibian Monitoring Outpost Society) publication.

By: Mark D. Thompson - BSc, MSc

NAMOS BC

NAMOS BC
c/o UNBC
3333 University Way
Prince George BC
V2N 4Z9

Web: http://www.namos.ca/
Contact:ecology@namos.ca

Learning contents

Activity 1:
Materials, Handouts, & an Introduction to the Terminology

Learning Objectives. In this first activity we will introduce ourselves to everyone and to the science of amphibian ecology. Your instructor will run through the handouts and materials that will be used in your training as a junior amphibian ecologist. We will go over and learn the activity terms as we gather to discuss the nature of the junior amphibian ecologist program.

Activity Terms. *Ecology, Environment, Nature, Amphibian, Metamorphosis, Habitat, Algae, Photosynthesis, Energy, Matter, Symbiosis*

Introduction to the Ecology of Amphibians

In the early days of civilization, children and natural historians devoted a great amount of time observing, collecting, and planting natural things. The modern ecologist has inherited a great legacy of knowledge that has been past down over the generations. In their quest to understand and probe the most complex riddles of life, ecologists continue to take part in the tradition of natural history. Ecologists observe nature as they collect data, hypothesize, test, and then report on the intricate wonders and inner workings of the natural world. The junior amphibian ecologist league will teach some of the methods that ecologist have developed to effectively study and learn about amphibians.

Nature encompasses all living things from the tiniest bacteria to the largest animal on Earth, the blue whale. Nature also embodies non-living things, including physical matter, the sun, moon, rocks, minerals, water, energy, and the chemistry of the surrounding environment. Nature is relentlessly on the move, spinning, ticking, flowing, chirping, and crawling about. Some parts move slowly, like a snail across a leaf, yet its tiny nerves send signals at 1/3 the speed of sound! Some parts are large and rapid like a volcanic eruption, or slow as a continent drifting apart. There are creatures in the various domains of life that have big effects on our lives that cannot be seen by the naked eye, such as viruses and *'bacteria-like'* archaeans. These smaller creatures contribute importantly to the ecology of life on this planet, but this booklet will focus mainly on plants, animals, fungi, and bacteria in relation to amphibian ecology.

Amphibians include frogs, toads, salamanders, and limbless caecilians (Figure 1). Frogs start life as a tadpole (Figure 2). Tadpoles graze on sediments to feed on tiny photosynthetic plants called algae (Figure 3). Hence, frogs are connected to plants in a web of feeding relations. There are many kinds of ecological connections that bind communities together. Eggs, for example, are attached to sticks or blades grass (Figure 4). Frogs hide, swim, and hop among lily pads and duck weed (Figure 2). Salamanders burrow into decomposing logs and eat bugs that eat plants (Figure 2). Salamander eggs also provide habitat for photosynthetic algae (Figure 4) and in some cases symbiotic algae even live in salamander cells! These linkages create ecological highways and opportunities for exchange of biological or physical matter and energy. In the same way that an exchange takes place every time you buy lettuce, carrots, or broccoli at the grocery store, ecology has been described as the economy of nature.

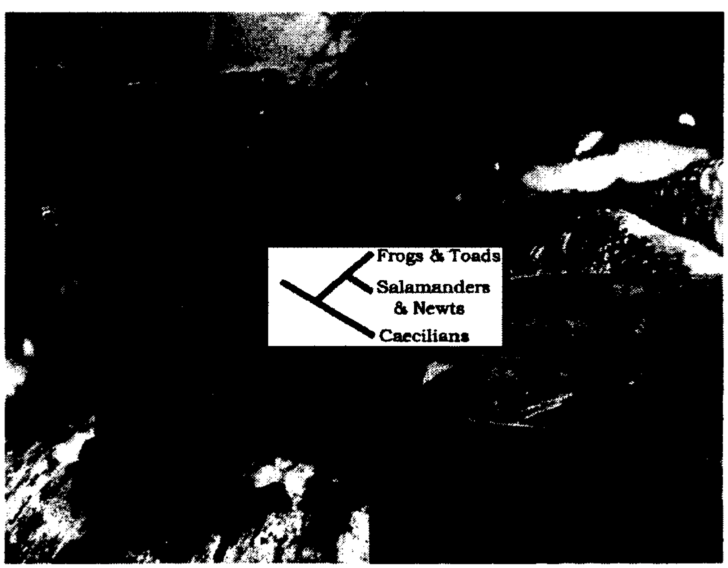


Figure 1. Photographs of the different kinds of amphibians (a-d) and a family tree showing how they are related to each other (inset). The panels include: a) wood frog, b) caecilian, c) western toad, d) long-toed salamander. Only a, c, & d live in British Columbia's habitats; the caecilians live in tropical regions of the planet.

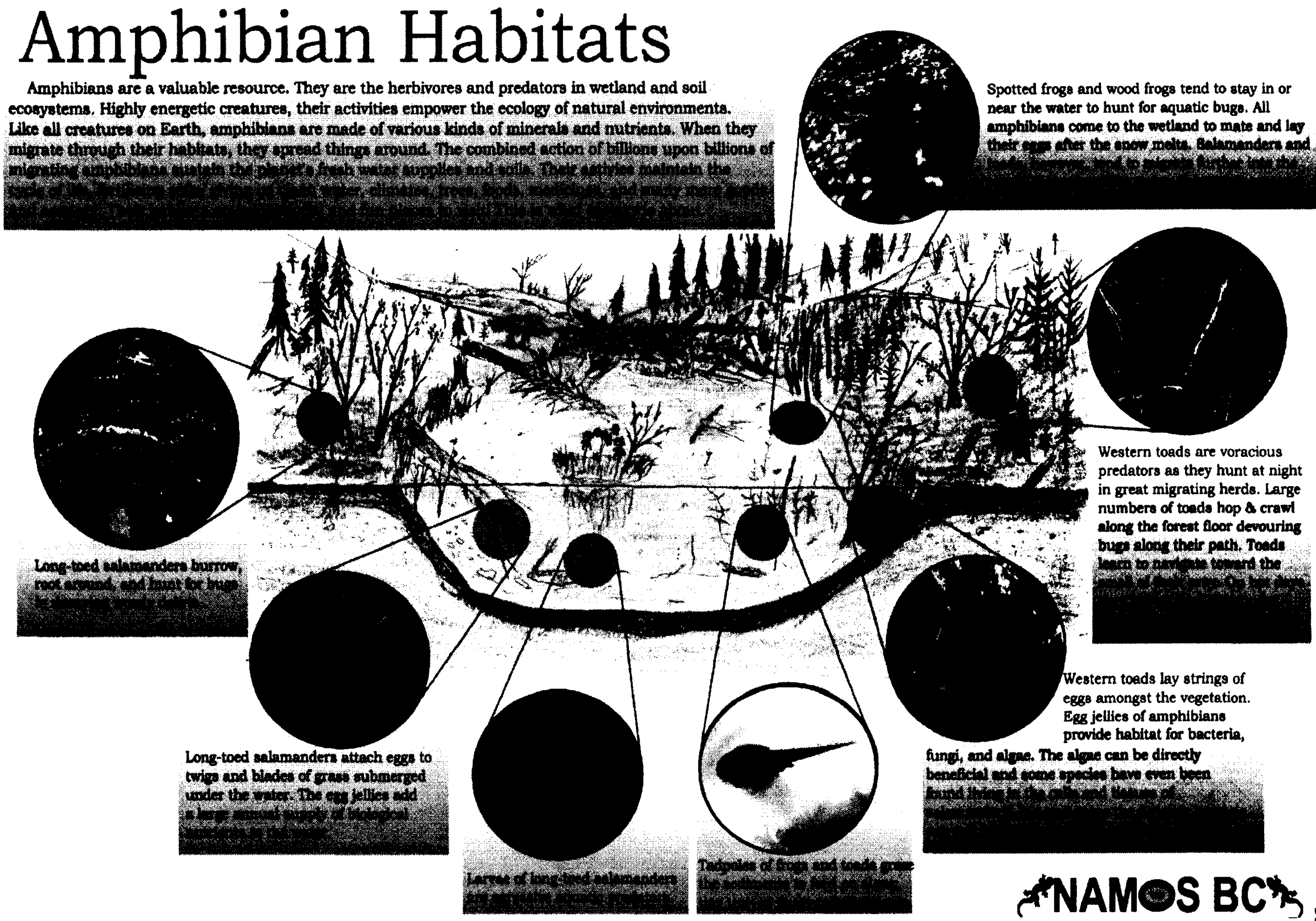


Figure 2. An illustration of amphibian habitats.

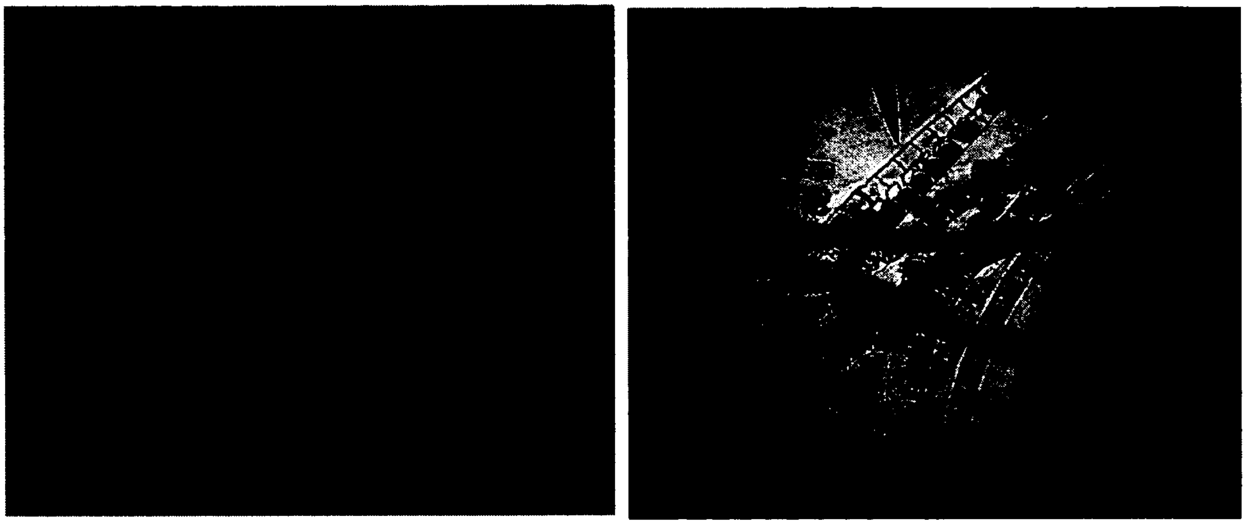


Figure 3. Tiny green algae cells photographed and magnified under a microscope.

Figure 4. Photographs of larval long-toed salamanders preparing to hatch from their eggs. The green coloration is caused by tiny algae in the eggs. Some eggs do not survive. Can you locate the dead egg?

Activity 2: Decomposing logs

Learning objectives:

- To collect, classify, and measure facts about decomposing logs
- To understand decomposition and soil biodiversity
- To piece together the niche of the salamander
- To learn how to navigate and read the history of the land

Activity Terms. *Landscape, Decomposition, Minerals, Nutrients, Biomass, Biodiversity, Species, Invertebrates, Bugs, Fungi, Lichen, Plot*

As trees fall, they open gaps in the forest. These small bits of disturbance add complexity to the landscape. New patterns emerge as different species and seedlings establish themselves in the sun filled gaps. Fallen logs create new habitats and start to decompose. Decomposing logs leave behind a recorded history of stages of ecological succession in these gaps, from a pioneer to a climax community. In this activity, we will measure and classify decomposing logs, which is the primary hunting grounds and habitat of the long-toed salamander.

Methods: Four terrestrial sites and two aquatic sites that will be visited are mapped (Figure 5). It is asked that you have a parent or guardian drop you off at the main parking lots for each site. Once the class meets and gets organized, the instructor will show you how to use a compass and GPS to navigate toward our precise destinations:

- Day 1: Moores Meadow Park - meet at parking lot off Foothills. Site A: 10U, 512543, 5976510
- Day 2: Cottonwood Island Park - meet at PG railway and forestry museum parking lot. Site B: 10U, 517970, 5974983

- Day 3: College Heights Greenbelt - meet and park at College Heights Secondary. Site C: 10U, 516080, 5968259
- Day 4: Hudson's Bay Slough - park at Exploration Place. Site D: 10U, 517236, 5972461
- Day 5: Forests for the World - meet at Shane Lake. Site E:10U, 510889, 5971061, Site F=10U, 510370, 5970804

The class will first sample and study the terrestrial life of amphibians by looking at decomposing logs. Your instructor will demonstrate how to do a circular plot at Site A (Figure 5). Within the plot, your instructor will go over the classification of decomposing logs as shown in Figures 6 & 7. The class will collectively identify and classify logs in each circular plot that will be completed at sites A and B (figure 5). Toads or salamanders that we capture will be examined, weighed, measured, and photographed as we discuss their natural history biology. The depth of the soil organic horizon and litter layer will be measured. We will examine and study each log in detail using a dissecting microscope and guide books to learn about and identify the various living and non-living components. Everyone will have an opportunity for hands on experience.

Assignment: You will notice that our sampling sites are predominantly contained within the urban perimeter of Prince George (Figure 5). We are going to learn about the urban ecology of amphibians. How do you think this will affect your chances of catching or seeing an amphibian? How might this change the type and amount of logs we encounter? We will review and discuss these questions as a class.

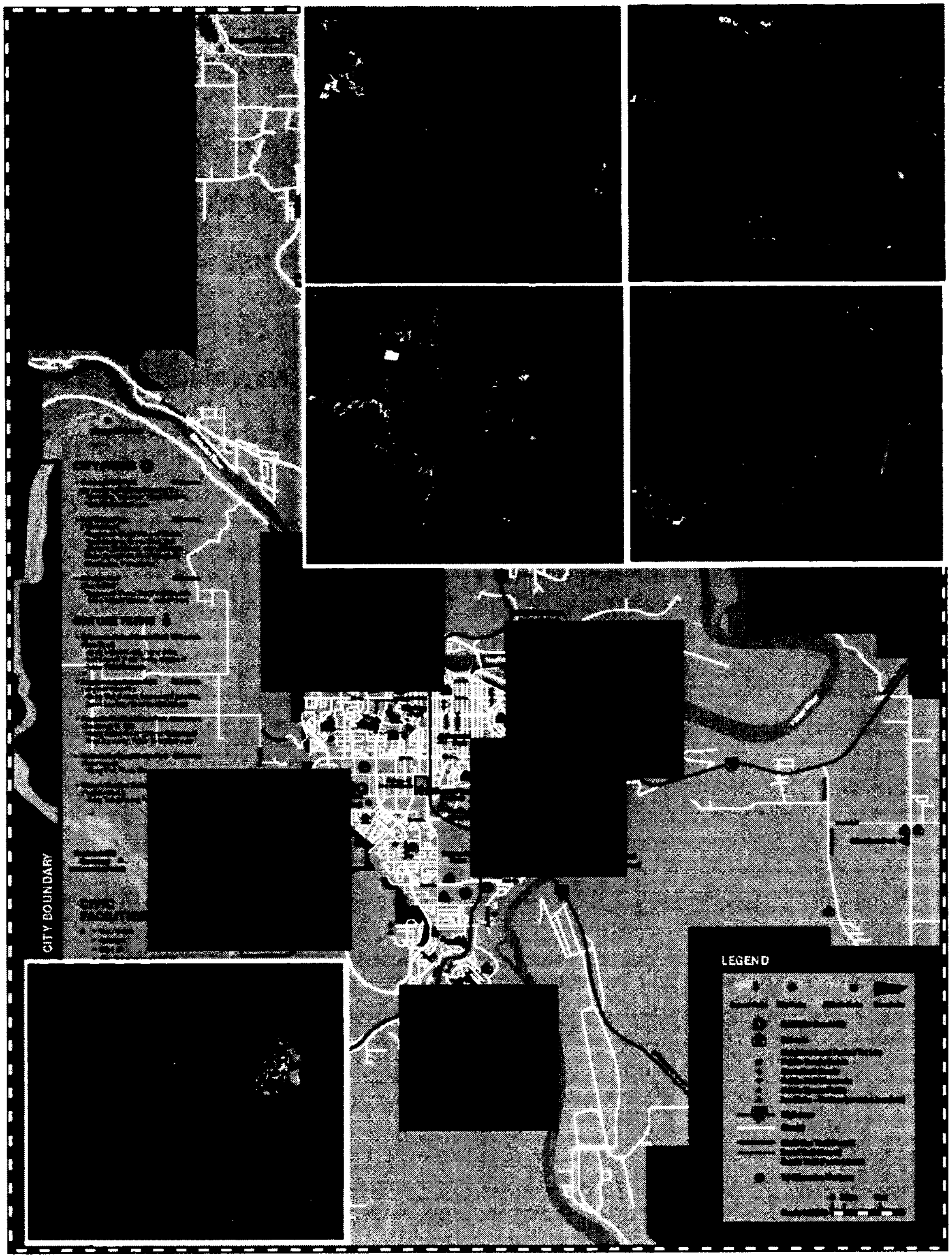
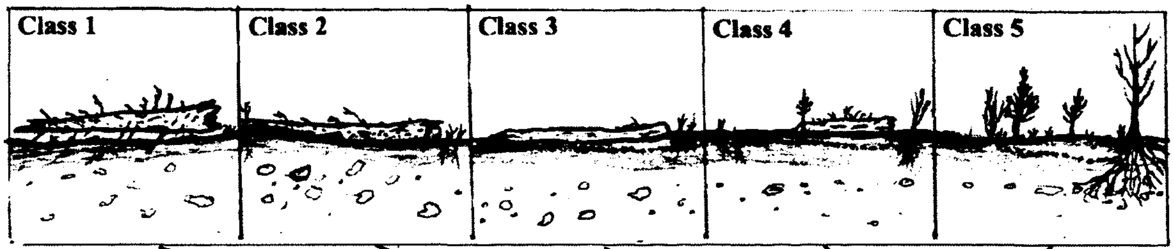


Figure 5. An image of a Prince George city map with five (A-E) GoogleEarth insets showing the locations that will be visited.



	Class 1	Class 2	Class 3	Class 4	Class 5
Wood Texture	Intact, hard	Rot outside, hard inside, thumbnail penetrates	Hard (spongy if wet), large pieces	Small, blocky pieces crumble in hand (mushy when wet)	Soft, small pieces crumble in hand
Portion on Ground	Elevated by support branches	Elevated and sagging slightly	Sagging near ground, or broken	Entire log settled on ground, sinking	Entire log sunken
Branches	Present – hard with twigs	Present, but soft few twigs	Stubs <3 cm	Absent	Absent
Bark	Intact	Intact but loose	Trace amounts	Absent	Absent
Invading roots	None	None	In outer sapwood and fungi present	Throughout and fungi present	Throughout and fungi present
Approximate age (years)	0-4	3-14	13-35	30-150	>35

Figure 6. Classification of decomposing logs at different stages of development.

Main Function	Types of Decomposing Logs	Main Vertebrate Users
Hibernation, Reproduction, Resting, Escape, Thermoregulation (Temperature) Hygroregulation (Moisture)	Type 1: Large Concealed Spaces	Cats, mustelids, grouse, Snowshoe Hare, Bushy-tailed Woodrat, Porcupine, canids, Black Bear
	Type 2: Small Concealed Spaces (or Soft Substrate Allowing Excavation of Such Spaces) at or below Ground Level beneath Hard Material	Amphibians, snakes, shrews, voles, squirrels, Deer Mouse, jumping mice, weasels
	Type 3: Small Concealed Spaces above Ground Level	Winter Wren, Townsend's Solitaire, Northern Waterthrush, Pacific Treefrog, flycatchers, other passerines, Deer Mouse
Concealed Travel runways	Type 4: Long Concealed Spaces (or Soft Substrate Allowing Construction of Runways)	Long-toed Salamander, voles, Rubber Boa, shrews, Deer Mouse, squirrels, weasels
Travel lanes	Type 5: Large or Elevated, Long Material Clear of Dense Vegetation, Exposed & Raised	Squirrels, Marten
Foraging & Feeding Substrates	Type 6: Invertebrates in Wood, under Bark or Moss Cover, or in Litter/Humus	Amphibians, woodpeckers, Winter Wren, shrews, Deer Mouse, Striped Skunk, bears

Figure 7. Classification of the functional types of decomposing logs.

Activity 3: Terrestrial Amphibian Survey - Line Transect

Learning objectives:

- To learn how to sample populations using quadrat, plots, or transects
- To search of amphibians and classify decomposing logs in their habitat

Activity Terms. *Niche, Landscape, Population, Community, Succession, Transect, Fact, Data,Taxonomy, Bacteria*

Scientists work with different units of measurement to characterize ecological habitats. This activity will introduce you to the transect, which is one method used to measure ecological attributes. We will use a transect scaled to sample the decomposing logs. A decomposing log sitting on top of soil is the most advanced recycling system on the planet. Soil is like a big stomach for plants that slowly digests fallen logs to release the minerals and nutrients that plants need. Amphibians are the keystone predator that prowl through decomposing logs. Their predatory actions help to directly regulate the invertebrate community that bores, digs, and feeds on and in the decomposing logs. In this way, amphibians contribute significantly to the rates and process of decomposition in the recycling of logs into soil and back into plants.

Materials & Methods: On day 2, the class will meet at the PG railway and forestry museum parking lot near site B (Figure 5). As a class exercise, we will run a transect 20 meters in length to record data on decomposing logs (Figure 8). A stake will be used to mark a starting point. A 20 meter string will be tied to the stake and run through a section of the forest. Your instructor will walk out in a straight line using a compass while carrying the string to mark out the transect line. One student will be in charge of recording the data. Two students will be in charge of measuring the width and length of each log that the string intersects (Figure 8, right panel). The remaining students will determine how the log should be classified while also looking for amphibians. Two transects will be run, one at site B (Figure 5) and the class will decide after lunch where we will run the second transect.

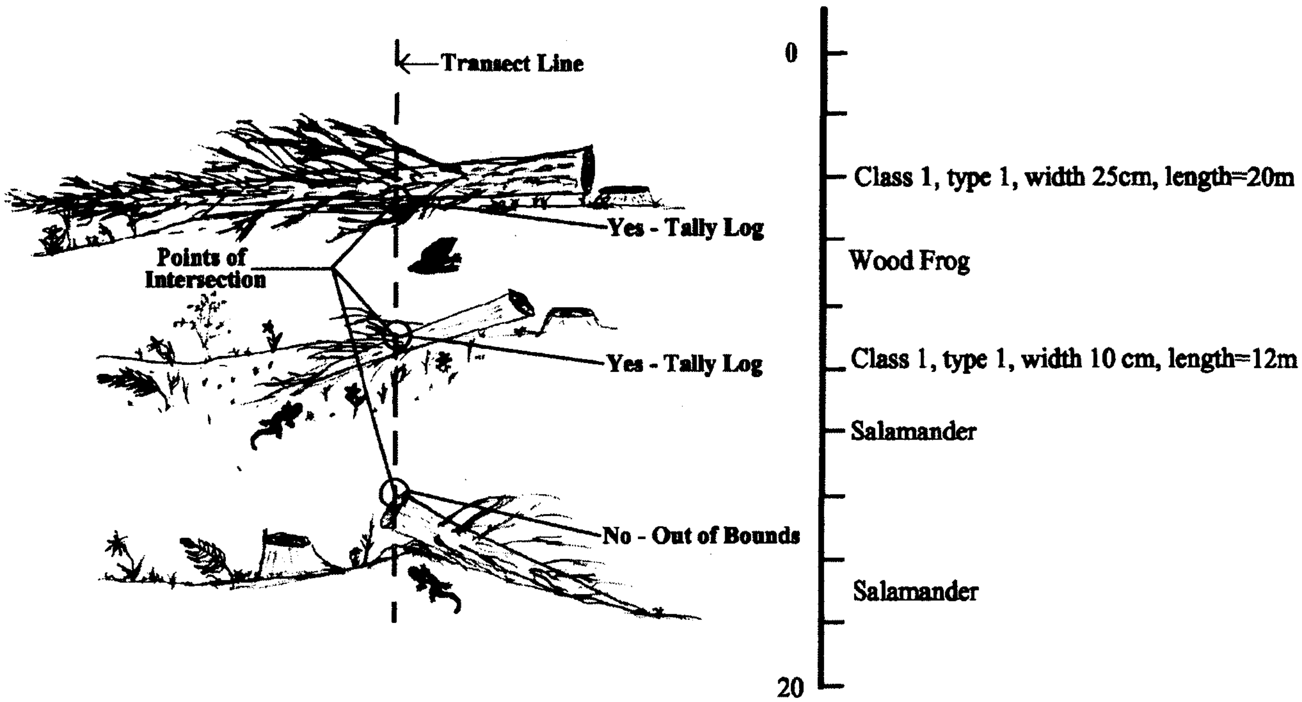


Figure 8. An illustration of a 20 meter transect with data on decomposing logs and amphibians. The left side shows how a decomposing log must run through the transect in order to be tallied into the notebook. The right side shows how the transect data can be recorded in a field notebook.

Assignment: After running the transects, we will discuss as a class the activity terms and how they relate to the data gathered. The class will be shown how these transects can be used to estimate how many salamanders are likely to exist in a defined and measurable area. The following questions will be discussed:

- How many transects would be needed to accurately describe a salamander's habitat?
- Do you think your results would be different if the transect was run during the nighttime?

Activity 4: Terrestrial Amphibian Survey - Biomass

Learning objectives:

- To count populations and estimate biomass
- To estimate the biomass of materials in a decomposing log

Activity Terms. *Quadrat, Burlese Funnel, Biomass, Detritus*

Plants are completely dependent upon the bacteria, fungi, and all the digestive systems of all the other soil critters, including amphibians. The collective action of these creatures decompose logs, leaves, and other litter into digested and then usable nutritive material for plants. For example, the older logs that are in an advanced stage of decomposition (Class 3-5, Figure 4), become nurse logs. These nurse logs supply mineral nutrients and the physical foundations that facilitate the growth of new seedlings. Biomass is a short way of biological mass. The weight of things or the amount of energy stored in living things is a measure of their biomass.

Methods & Materials: Continuing from site B (Figure 5) on day 2, the class will deconstruct a decomposing log (class 4 to 5, and type 6). Materials include: weight scale, calipers, collection vials, tweezers, digital camera with super macro lens, and microscope. A 10 cm X 10 cm quadrat will be used to take five measured sections of a log and surrounding soil. Populations of shrubs, moss, lichens, seeds, leaves, needles, fungi, salamanders, frogs, toads, beetles, ants, harmless wasps, worms, and cute little spiders will be sorted, counted, and weighed. The leaf litter (or detritus) samples will left overnight in a Berlese funnel (Figure 9).

Assignment: Each student will take one Berlese funnel home. In the morning pour the vegetable oil and bugs into a small container and bring this to Activity 5.

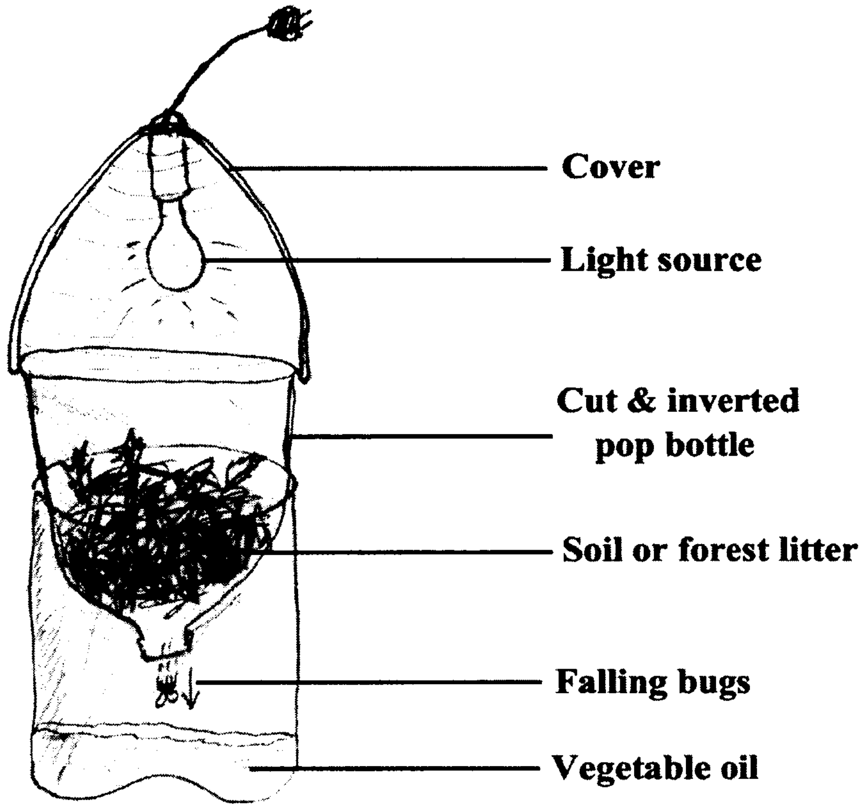


Figure 9. A Berlese funnel for collecting bugs out of soil or forest litter.

Activity 5: Amphibian Ecology - Trophic Pyramids and Food-Webs

Learning objectives:

- To classify and study bugs from the Burlese funnels
- To organize the trophic organization, energyflow, biomass assimilation, and food webs of places visited

Activity Terms. *Producer, Consumer, Trophic Species, Predator, Energy, Ectotherm, Endotherm, Herbivore, Omnivore, Detrivore, Food Web, Heterotroph, Autotroph, Metabolism, Assimilation*

Organisms are linked into communities. The feeding habits of organisms provide important linkages in food webs. What and who an organism feeds on determines where the energy and nutrients are being transported and exchanged. Interesting patterns emerge when ecologists group different organisms into different feeding categories called trophic species. The number and biomass of different species and how they link to plants and then to each other as sources of energy and nutrients creates what is called a trophic pyramid (Figure 10). All ecosystems can be split into two very broad trophic layers: 1) the autotrophic self-nourishing organisms, and 2) the heterotrophic organisms that consume others for nourishment (Figure 10a).

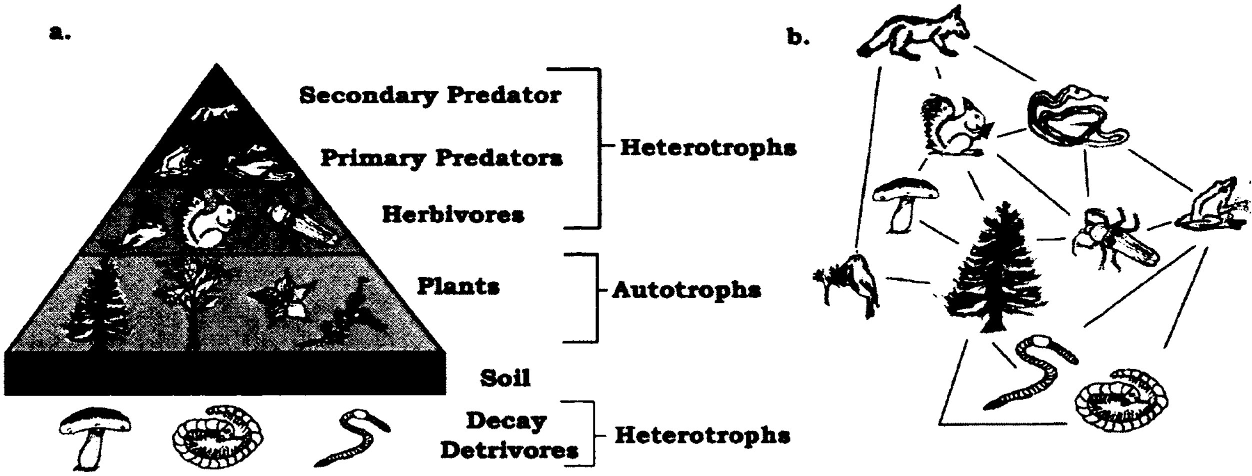


Figure 10. Organisms that capture nourishment of feed in a like manner are arranged into trophic layers. A trophic pyramid (a) is a common emergent pattern in forested ecosystems. Organisms are layered according to their biomass, which decreases in concentration up the trophic pyramid. Predators hold the least amount of biomass in most ecosystems. Plants support the base and hold the greatest amount of biomass. Ecologists study the transfer of energy and nutrients through the various feeding relationships that link communities into a food web structure (b).

Plants are autotrophic primary producers (Figure 10a) and obtain their energy from the sun directly. They make their own food by absorbing nutrients through their roots and by converting the sun's energy, carbon dioxide, and water into sugars and other organic compounds along their stems and leaves. As plants grow, they assimilate the sun's energy and store it into the biochemical bonds of carbon based molecules. The photosynthetic conversion of energy and the metabolic assimilation of nutrients into biomass is called primary production.

Plants use less metabolic energy than heterotrophic consumers, such as amphibians. Heterotrophs include herbivores (plant eaters), predators (animal hunters), omnivores (will eat plant or animal), and detrivores (eats detritus). Heterotrophs consume others to metabolize and assimilate matter and energy into biomass. They run at a higher metabolic rate than plants to fuel the diverse kinds of activities of they perform, including migration, foraging, hunting, reproducing, and regulating body temperatures. The metabolic digestion of food adding to body biomass in heterotrophs collectively adds to levels of secondary production in a trophic pyramid.

Feeding relationships in an ecological community link together into a food web (Figure 10b). At the base of the food web, dead creatures, leaves, pollen, and seeds accumulate on the ground or in the water. This mixture of organic waste is called detritus and is broken apart, eaten, and digested by detrivores. The detrivores usually include worms, bugs, fungi, and bacteria. Detritus is a very important part of food-webs, because it contains a lot of energy. The process of decomposition transforms detritus into nourishing soil that feeds into the roots of plants.

The density and size of amphibian populations can have a significant impact on rates of decomposition as they feed on many of the detrivorous bugs and they disturb and dig tunnels through the soil. The very presence of amphibians actually changes the way that the habitat looks. Amphibians regulate the ecology of soil formation and primary production of plants through various food-web linkages (Figure 10b). They are busily employed in their ecological activities (such as bioturbation or ingestion) that either helps or depletes other creatures. The ecological community is adapted to the modifications that amphibians engineer into their environments.

Materials & Methods: The class will meet at the Exploration Place (near site D, Figure 5) where we will gather around and pour the bug collections from our Burlese funnels (Figure 9) into trays to tally and sort them into the following trophic groups: predator, herbivore, omnivore, or detrivore. Your instructor will assist in the identification of bugs as we learn about their diets. Using data collected from our plots, transects, and quadrats, we will obtain estimates of biomass densities of each functional trophic group (including estimates for plants and detritus).

Assignment: As a group we will estimate the biomass of each trophic group. These estimates will be stacked to see if we have found a trophic pyramid (Figure 10a). The class will discuss the outcome of the patterns we see.

Your assignment is to draw a food web that looks like the one illustrated in Figure 10b, but draw the creatures (including plants) you saw in the decomposing logs. The class will use the information we have learned about trophic feeding in our collections to build a food web using Marsh Market exercise (http://www.wetland.org/downloads/Marsh%20Market.pdf) created by *WOW! The Wonders of Wetlands*.

Activity 6: The Aquatic Transition - The Riparian Zone

Learning objectives:

- To study the linkage between terrestrial forests and wetlands
- To learn the basics of wetland classification
- To learn about the ecology of the water cycle

Activity Terms. *Wetland (Marsh, Bog, Swamp, Pond), Riparian, Hydrology, Water Cycle, Evaporation, Migration, Dispersal, Cohort, Home Range*

A riparian zone is a transitional area wedged between terrestrial and aquatic ecosystems. The boundary of a riparian zone extends from the waters edge to upland areas that have been influenced by the ecological transition (Figure 11). There is a very complex exchange of energy and nutrients that runs through riparian zones. We will learn about these exchanges by learning about the life cycle of amphibians and the seasonal rhythm or clockwork of events that take place and define the nature of their habitats.

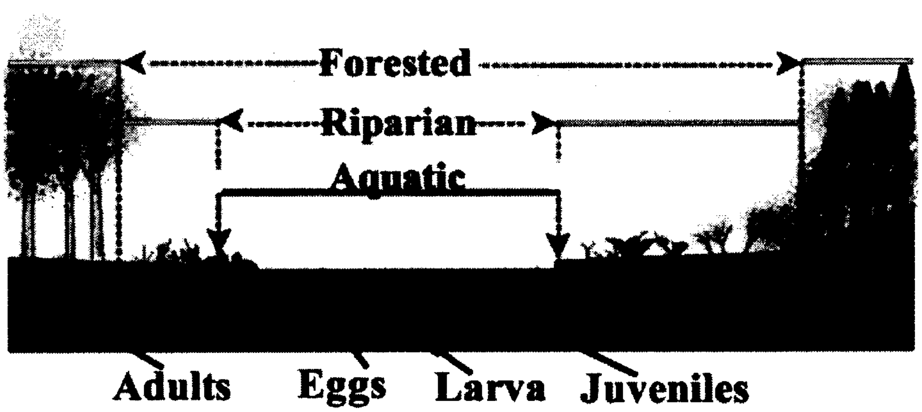


Figure 11. An illustration showing the transition from a terrestrial zone (forested in this example), a riparian zone, and the aquatic zone. The life cycle of a salamander is also illustrated into the different zones.

The term riparian stems from a Latin word that means "of or belonging to the bank of a river". However, the modern meaning refers to the transitional area between a terrestrial and aquatic zone, which can also include lakes and ponds. Riparian zones are also part of a dynamic seasonal change that begins with a spring, summer drought, rainy fall, and freezing winters. Many small wetlands start out as streams but puddle into ponds or even dry out as water supplies dwindle.

There is a seasonal rhythm in natural landscapes (Figure 12a). Sizes of wetlands fluctuate seasonally as the sun's energy drives the water cycle. Evaporation accumulates water in the atmosphere and precipitates as rain and snow. The timing, permanence, and distribution of wetlands impact the migratory linkages and survival of amphibian populations (Figure 12b). The changing status of a wetland impacts water concentrations in the adjacent soils where adults like to hunt and rest.

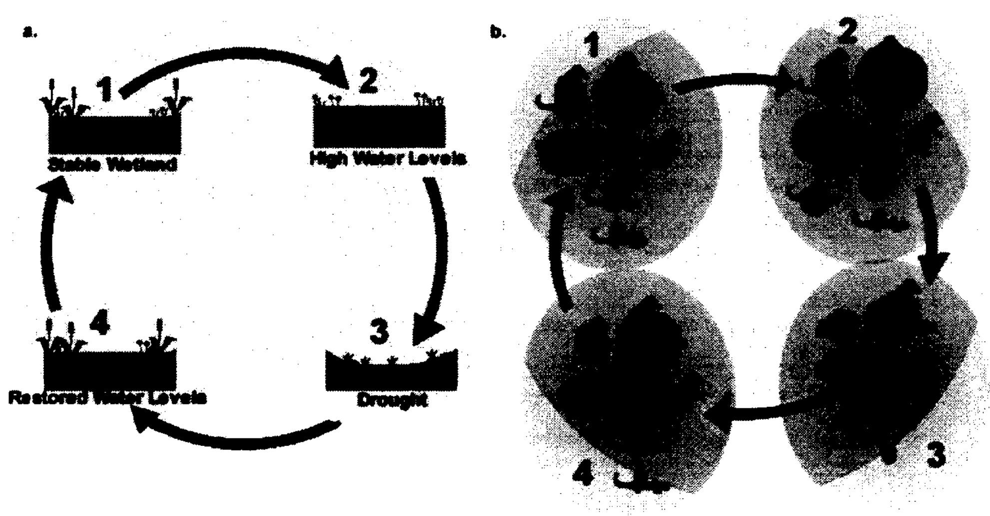


Figure 12. An illustration of a dynamically evolving wetland (a). Water levels change over seasons (1-4) and this effects amphibian migratory networks and pathways (b) as they populate habitats across the landscape.

Frogs tend to forage closer to wetlands, whereas toads and salamanders migrate away from wetlands and hunt deeper into the forest. Different age cohorts, size ranges, and species of amphibians may occur in the riparian zone (Figure 11). Western toads and long-toed salamanders migrate annually from terrestrial hunting grounds to breed in wetlands. They migrate through their home range, which is usually less than several kilometers in size. Juveniles are more likely to disperse into other areas, but many amphibians like to stay at home and return to their place of birth to lay eggs of their own.

Materials & Methods. The class will navigate to site C (Figure 5), our first wetland area. Students will walk the trail edge along the Hudson's Bay slough. This area is a Ducks Unlimited Wetland restoration site. The class will flip debris at the waters edge and visually search for amphibians in the water. Decomposing logs will be flipped and searched for frogs, toads, and salamanders. As the class moves along the trail, each student will write a log in their journal about the sorts of creatures you find, what the habitat looks like, and any other notes that may be relevant to an urban ecologist.

Assignment. The class will return to exploration place to will work on a GoogleEarth mapping exercise. We will measure the forested land area available to amphibians at sites A-E. The class will supplied with data that was collected on leaf litter and amphibians from a wetland in Forests for the World.

Using the data, the class will organize the amphibians into two groups, 1) adults from the riparian zone and 2) adults from the terrestrial forest. As a class we will discuss and answer the following questions:

- Are the adults in the terrestrial forest larger than those in the riparian zone?
- Do you think the length of the animal is an indication of its age?
- Do you think there is sufficient habitat for amphibians to live in sites A-D (Figure 5)?
- How might you test your answer to the previous question?

Share your thoughts and answers in the class discussion. The class will also review the Duck's Unlimited wetland classification scheme showing illustrations of a bog, fen, marsh, and pond (=shallow open water).

Activity 7: Aquatic and Wetland Ecology of Amphibians

Learning objectives:

- To sample aquatic bugs, tadpoles and salamander larvae in wetlands
- To learn about aquatic plants
- To learn how to classify wetland ecosystems

Activity Terms. *Development, Anaerobic Bacteria, Littoral, Limnetic, Profundal, Benthic, Fossil Fuels*

When amphibians hatch out of an egg, they essentially find themselves floating in a nutritious aquatic soup. A food web (Figure 10b) is an effective way to illustrate and understand connectivity in ecosystems. Real ecosystems are often more complex than can be illustrated, because not every organism is a strict herbivore or a strict predator. Amphibians are ecologically complex creatures, because their diets change as they grow and metamorphose into adults.

Salamander babies are called larvae. Frog and toad babies are called tadpoles. Tadpoles can have teeth, beaks, and other adaptations that lets them digest pollen, leaves, and a small amount of invertebrates. This means that different species can eat combinations of both plant and animal materials. Various species of tadpoles have been classified as detrivores, herbivores, omnivores, and even predators. Some species even specialize on eating the eggs of other amphibians!

Salamander larvae instinctively prey on tiny aquatic bugs while incidentally ingesting small amounts of bacteria and plant materials. Almost every amphibian metamorphoses into a predatory adult. A few species of frog feed on plants, but no strictly herbivorous adult amphibian has ever been discovered.

The burrowing activities of amphibians and other creatures creates tunnels in the soil which mixes nutrients. These tunnels also opens passageways where oxygen and other gases can flow where other creatures can breath and seek refuge. In wetlands, the physical properties of water slows the rate of diffusion of oxygen and carbon dioxide across the surface. There is a lower concentration of gases in water than in the air we breath. Salamanders and tadpoles use their gills, which are adapted to the watery environment. Gills can absorb oxygen and release carbon dioxide or 'breath' under water. Many aquatic invertebrates also have gills. Aquatic plants have other kinds of adaptions, such as having stems that act like straws to reach above the waters surface into the air.

We have learned about the carbon element in its gaseous form in the atmosphere -- *carbon* dioxide. We also learned about it in its solid form as carbon molecules link together into the physical parts of life, such as twigs, leaves, and the foods organisms eat. In this way, wetlands provide many essential services in the way that they regulate both carbon and water cycles, which translates into climates. In an indirect yet significant way, amphibians are linked to the climates of planet Earth.

The size, shape, abiotic, and biotic properties of wetlands provides important information about the way the habitat is structured. A convenient way to understand wetlands is to structure them into stratified habitat zones (Figure 13). Amphibians in northern BC tend to breed in shallow ponds, but also visit and breed in streams, rivers, and lakes. A shallow pond can be divided into five habitat zones that share common properties of temperature, light, and chemistry. Populations of different

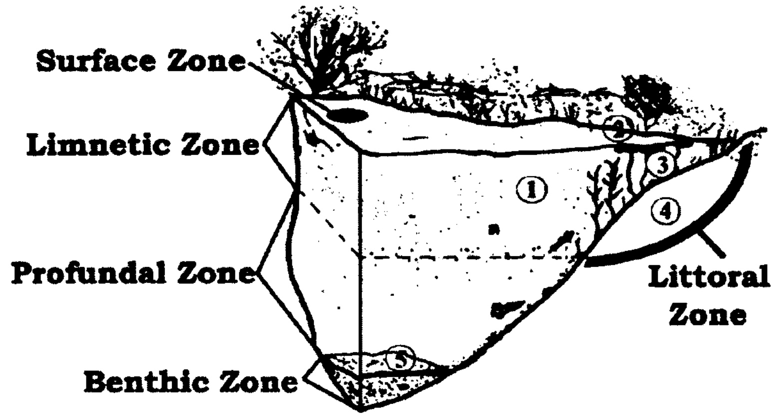


Figure 13. Five different zones are illustrated for a typical amphibian pond. Five locations that will be studied in this activity are numbered in circles. The littoral zone is populated with aquatic rooted plants that have access to sunlight. It also has higher oxygen concentrations while providing forage, cover, and substrates for attaching eggs. Water striders, spiders, and pollen float and move aalong the surface zone. Floating aquatic plants and algae populate the limnetic and surface zones. The profundal zone receives less light and usually has lower concentrations of oxygen. Oxygen levels are lowest in the benthic zone where sedimentary detritus accumulates and is slowly decomposed by anaerobic bacteria.

species migrate and then aggregate into habitat zones and communities to which they are adapted.

On a landscape scale, there is a wide range of ecological imbalance in the exchange of biomass and energy. In the previous activity, we noted how the depth of organic detritus in soil litter varied amongst sampled sites. Aquatic ecosystems often exhibit an even more pronounced change in the soils. Much of the organic matter is dissolved or floating in the water column, which is also populated by small algae and aquatic plants that hold less biomass than trees and other terrestrial plants.

While amphibians are not as energy efficient as plants are, they are much more efficient than most creatures. Plants, fish, amphibians, reptiles, and most invertebrates are *cold-blooded creatures*, otherwise known as ecotherms. These creatures obtain heat from the environment. Birds, mammals, and some invertebrates are *warm-blooded creatures*, otherwise known as endotherms. These creatures metabolize energy to produce internal body heat.

Ectothermic organisms are more energy efficient at growing and accumulating biomass than endothermic organisms are. Amphibians, for example, assimilate more than fifty percent of the energy they ingest into body biomass! Most endotherms (like us) are very energy inefficient because we assimilate less than one percent of ingested material into body biomass and use the rest to maintain an elevated body temperature.

Amphibians must feed and then assimilate the energy and nutrients from the food supplies that are available to them in the habitats they occupy. Growth rates can vary across landscapes as production levels adjust to the ecological conditions. Some wetlands are more nutritious than others. When nutrients become limited or conditions become overcrowded, some salamander larvae and tadpoles can change into cannibals by growing bigger heads that lets them feed on their brothers, cousins, and sisters. Amphibians grow at different rates according to the kind of food they eat and the quality of the detritus that feeds the wetland trophic system. Different kinds of trees and shrubs produce different kinds of detritus with varying levels of energy content, different organic chemistry, and some pieces are more difficult to metabolically digest than others.

The size that an amphibian attains by the time it metamorphoses is a general predictor of how large they will be as adults. Smaller tadpoles or salamander larvae will grow into smaller adults or take longer to mature. It may take several years for an adult to accumulate enough biomass to reach its full reproductive growth potential. Productive wetlands with lots of resources give the young amphibians a head-start in life. Fully grown males tend to be more attractive and larger females can lay more eggs. Many invertebrates go through the same cycle and move about as amphibians do, starting from an egg to an aquatic larvae that metamorphoses into a terrestrial adult. The ecological principals you have learned can apply to many different kinds of creatures and their habitats.

Materials & Methods. This exercise is a field trip to Forests for the World Site E-F (Figure 5). The class will sample in five wetland locations at site E (Figure 13) using a fine net and jars to gather sediments. An amphibian dip net will be used to capture larvae and tadpoles that will be placed into a bucket. Each larvae and tadpole will be weighed, measured in length with calipers, placed into a small water bath (1.5 cm width X 5 cm length X 2 cm depth) carved into a piece of paraffin wax. A glass cover slip is placed over the water bath and the amphibian is digitally photographed. This process will be repeated at site F (Figure 6).

Assignment. The class will look at the aquatic bugs, results from the measurements, and discuss the ecological implications. Average weights and measurements of the tadpoles and larvae will be compared from the different sites and the results will be discussed as a group.

Glossary.

Abiotic - The non-living, dead, and physical components of the Earth and universe, such as air, sunlight, temperature, water, rocks, gravity, fire, nutrients, and fossil fuels.

Adaptation - Parts of organisms that are shaped, developed, and passed on from parent to child because they give them the functional capabilities to acquire the resources they need to survive and reproduce in their habitats. Amphibian tadpoles have gills, fins, teeth, beaks, and other body parts that are adapted to life in an aquatic environment. Adults have hands, feet, lungs, toxic glands in their skin, and other body parts that are adapted to life on land and water.

Algae - Photosynthetic organisms that are closely related to photosynthetic land plants, such as moss, ferns, grass, shrubs, and trees. Algae live primarily in aquatic habitats, mostly as microscopic forms floating in wetlands, but they also include the large kelp and seaweed in oceans and those species that live symbiotically with fungi in lichens. Algae have the same kinds of cellular structures and organelles typically found in plants, but they lack flowers, woody stems, and are lack many of the adaptations for living on land. They range in size from single-celled forms to larger filamentous or colonial forms. Some species have symbiotic relations with amphibians.

Amphibian - Vertebrate animals including frogs, toads, salamanders, limbless caecilians, and several fossil lineages that went extinct. Amphibians have semi-permeable skin with glands and lack scales, feather, and hair. Their eggs have permeable jelly membranes instead of a hard outer shell, although some species give birth to live young. Amphibians undergo a metamorphic transformation from an aquatic larvae or tadpole to a terrestrial form, but not every amphibian leaves the water and some species have no aquatic stages in their life history. Amphibians are defined by unique skeletal features with an internal anatomy that is intermediate between fish and reptiles.

Anaerobic bacteria - Bacteria species that live and metabolize in habitats lacking oxygen, such as the bottom of a swamp.

Assimilation - Metabolism that converts nutrients and energy into growth and production of living matter. Autotrophs (e.g., plants) *assimilate* the suns energy, carbon dioxide, and soil nutrients during photosynthesis. Heterotrophs (e.g., animals) *assimilate* biomass by eating and digesting the assimilated biomass of autotrophs or other heterotrophs.

Atom - The smallest fundamental unit of matter that is held together by electrons, protons, and neutrons. Different kinds of atoms are called elements. If atoms are the smallest units that make up elements, then elements combine into molecules. The scale of things continues to grow as the smaller units combine into bigger units. Molecules composed of elements combine to form compounds, that combine to form minerals or proteins and so on. This process of scaling can start from atoms all the way up to the entire universe.

Autotroph - Creatures, such as plants, that produce their own food supplies internally.

Bacteria - Single celled creatures that lack a nucleus and evolved into the little organelles that live in animal cells.

Benthic - Bottom or lowermost zone where detritus accumulates in an aquatic ecosystem.

Biodiversity - Is the variety of life that evolves dynamically within the genes of species, in the physical attributes of species, and in the differences among species. Biodiversity creates complex ecosystems, processes, and functions that has sustained life on this planet for billions of years.

Benthic - Bottom or lowermost zone where detritus accumulates in an aquatic ecosystem.

Biodiversity - Is the variety of life that evolves dynamically within the genes of species, in the physical attributes of species, and in the differences among species. Biodiversity creates complex ecosystems, processes, and functions that has sustained life on this planet for billions of years.

Biomass - The weight or amount of living matter contained in a measurable area or volume.

Biotic - The living components of an ecosystem.

Bioturbation - The active movement, mixing, and reworking of soils and their sediments by plants, fungi, microbes, and burrowing animals. Amphibians and worms are very active bioturbators as they digest their food, enhance the dispersal of nutrient particles, and aerate the soil as they tunnel along.

Bug - There are two definitions for bugs. To a biologist a bug is a specific lineage of insects that have sucking mouth parts. Biologists classify these 'true bugs' into the order known as Hemiptera. However, to the common person and the way it is used in this book a bug refers to any kind of crawling or creeping invertebrate, including insects, spiders, centipedes, millipedes, scorpions and sometimes even slugs, snails, and worms.

Berlese funnel - A devise that holds a light source over soils and leaf litter in a funnel that is suspended over collection jar. As the light dries and heats the top, the bugs scurry downward and fall into a collection reservoir where they can be studied in detail.

Carbon cycle - Carbon is a common element in the molecular building blocks of life. It cycles through ecological food webs, through the atmosphere, oceans, and even into the depths of the planets core. Carbon can cycle through ecosystems, through photosynthetic plants that are eaten by herbivores, that die, that decompose into soil, and then become absorbed through the roots of other plants. Across the planet there are carbon sources that flow into carbon sinks in both the living and non-living parts. The carbon cycle describes the pathways that this important element travels.

Cohort - A population of related individuals of the same age. Cohorts of amphibians in British Columbia generally follow the yearly cycle of the seasons. Each new cohort starts with the eggs being deposited in the early spring.

Community - Populations of different species that associate and overlap in their geographic distribution. A community is connected by food webs and ecological behaviours that modify the surrounding environment. Amphibians modify their local environment by tunneling through soil. Their tunnels loosens the soils for plant roots and creates habitat for other species in the community, including bacteria, mushrooms, and other animals.

Complexity - Describes the state of something that has too many parts for the human mind to comprehend or to predict what those parts will do when they come together. Things that have many interacting parts are complex. In ecology, there are many layers or levels of complexity as elements organize into molecules, molecules into proteins, proteins into cells, cells into organisms, and so on, ecologists study the way each level of organization functions as a whole. Smaller parts combine to form larger things that exhibit very different physical, structural, and behavioural properties that do not exist when the smaller parts are studied in isolation.

Consumer - Organisms that get their nutrients and energy by eating other organisms.

Data - Measurements, weights, numbers, and other factual pieces of information that is accurately recorded into a notebook.

Decomposition - A combination of biotic and abiotic actions (such as fire) that breaks, decays, and digests larger pieces of organic matter into smaller pieces. Decomposition is vital to life as it creates different kinds of soils and adds to their nutrient contents.

Detritus - Dead and decomposing organic matter that gravitates toward and accumulates on the ground, water surfaces, and at the bottom of wetlands and oceans. Detritus is a mixture of leaves, seeds, pollen, dead creatures, sand, minerals, microorganisms, and animal waste.

Detrivore - Any creature that feeds on and receives nourishment from detritus.

Development - Changes in body form, shape, and structure as creatures grow and age.

Dispersal - The migration of an individual from one population to another. Amphibians often return to the wetland where they originally hatched. Some individuals migrate further than normal and disperse into other wetlands where they may live and reproduce.

Ecology - The study of life and the way that organisms behave, migrate, function, regulate, distribute, interact, and evolve across the surface of the planet, over time, in relation to the environment, and in relation to each other. More broadly, ecology is the study of the economy and politics of nature, including the many ways that biodiversity and environments sustain the health, wealth, well-being, organization, and functions of human civilization.

Ecosystem - An environment that is occupied by a community of organisms that interact and affect each other and the abiotic components of their habitat. Ecosystems do not have strict and clearly definable boundaries because everything is interconnected on the planet, either by food webs or in the exchange of matter and energy into a common global environment. Ecologists usually describe, organize, and name ecosystems according to a whole functional pattern. A wetland ecosystem, for example, is defined by a perimeter of water. There is an abrupt physical difference between the wetland and the surrounding terrestrial ecosystems that changes how these different ecosystems function.

Ectotherm - Any creature that obtains bodily heat from its environment. Amphibians have to migrate to different parts of their environment to adjust their body temperature. Plants are also ectotherms.

Element - The building blocks of all matter consist of atoms that bond together. The different kinds of atoms are known as elements. Scientists organize the different kinds of atoms into the periodic table of elements. The most common elements found in ecosystems is carbon. Carbon elements link together into different kinds of molecules.

Endotherm - Any creature that metabolizes energy to generate internal body heat. Humans and bees are examples of endotherms. Bees shiver and crowd together to generate heat in their bodies and in their hive.

Energy - The ability of one physical or biological system to do work on another physical or biological system. Energy has a physical interaction with mass that adheres to strict laws that are forever consistent and create predictable rules of behaviour. Energy can be stored in the chemical bonds of nutrients and molecules and it also flows through living systems, such as food webs, as it fuels the metabolic activities of life. Energy can be found in different forms, such as light, heat, radiation, electricity, chemicals, and sound. There are different units of potential energy, such as calories, joules, or kilowatt-hour. Energy flow through salamander populations, for example, contributes to metabolic levels of production that can equal 11,000 kilo calories per hectare over the course of one year.

Environment - Anything, living or non-living, that is external to and surrounding an object or creature. Environments place certain restrictions and constraints on life. Organisms are both the product and modifiers of their environments. The relationship between organisms and their environments creates feedback and they influence the evolution, design, and development of the other. Amphibians have a significant influence on the nature of our local forested and wetland environments.

Evaporation - The physical loss of heat lifting off the surface of a liquid as the molecules transition into a gas. The evaporation of water away from the permeable skin of an amphibian cools its body down. This evaporation, however, also makes amphibians susceptible to dehydration if left away from a water source for too long.

Fact - Pieces of reliable information and larger compilations of scientific ideas that have been recorded as evidence that can be independently checked, observed, measured, verified, tested, and mathematically proven. Facts are a part of science. Facts are not universally accepted as true. Scientists regularly check their facts. They loosely hold onto those that have not been examined in great detail and they reject those that fail to predict logical consequences or outcomes should they indeed be true. It is a fact that amphibians add to rates of productivity in our local forested and wetland ecosystems.

Food web - An illustration that links organisms together according to their feeding relations in a community. The food web helps to visualize and study the directions and flow of energy and nutrients through ecosystems.

Fossil fuels - Coal, oil, and gas that originates from detritus that becomes trapped in sedimentation for millions of years. Many freshwater wetlands during the age of the dinosaurs and earlier, where amphibians played a major ecological role accumulated into the fossil fuels that are used today. Fossil fuels contain energy.

Fungi - A lineage in the tree of life that you might commonly know as a mushroom. The mushroom is actually the fruiting body of a kind of fungi. Molds, yeasts, and other similar kinds of organisms are classified as fungi. Many species of fungi are microscopic and they come in all sorts of shapes, colours, and sizes. In terms of biomass, fungi closely match bacteria as the primary decomposers in most ecosystems. Fungi are heterotrophs.

Habitat - The place where an organism lives and the resources in that environment that allow it to survive.

Herbivore - Any creature that eats and obtains all of its energy and nutrients from plants.

Heterotroph - Any creature that must eat another to obtain energy and nourishment.

Home range - The distribution and area where an organism may migrate through the seasons.

Hydrology - The study of water including its chemistry, movement, and distribution across the planet. Evaporation is an important factor in the hydrological cycle.

Hydrological cycle - The movement of water as it evaporates, flows, accumulates, precipitates, and percolates through ecosystems and throughout the environment. Amphibians are part of the hydrological cycle through their ecological activities in wetlands and due to the water that is absorbed into and evaporates away from their bodies.

Invertebrate - A diverse and most abundant group of animals that do not have an internal skeleton with vertebrae along the spine. Invertebrates can have different kinds of skeletons, such as the hard outer exoskeletons of insects, crabs, or scorpions, or they can have soft inner hydrostatic skeletons, like worms or slugs. Frogs and salamanders are vertebrate animals that regularly prey and feast on invertebrates.

Landscape - A piece of land that gives a unique character or quality to a region by virtue of its geographic and ecological configuration. A landscape is perceived around us without looking too closely at the small details to allow the bigger image of interacting ecosystems blend and drape over the undulating topography of the Earth surface.

Lichen - A symbiotic organism composed of a fungus and a photosynthetic partner, usually a green algae or a cyanobacterium.

Limnetic zone - The well-lit open surface waters that stretch beyond the littoral zone of a wetland. Traditionally the limnetic zone refers to the open deep waters in a lake that is populated by zooplankton (tiny invertebrate microorganisms), but the classification of this zone gets more complicated as the size of the habitat becomes smaller and seasonally ephemeral. The limnetic zone is provides unique environmental qualities that is populated by different kinds of aquatic plants and microorganisms that are adapted to the conditions.

Littoral zone - The shoreline waters of wetlands where aquatic plants take root.

Mass - The amount of something usually measured by its weight. Mass is a physical property of matter, but energy can also have mass.

Matter - Any physical substance that has a mass and occupies a physical space. Matter can exist in multiple forms, such as liquid, solid, and gas.

Metabolism - The physical and chemical processes within organisms that are fueled by energy and material resources to maintain life functions, such as growth, movement, and reproduction.

Metamorphosis - An abrupt developmental transition from an early larval form into a adult form having different adaptations. All amphibians go through metamorphosis. Frogs metamorphose from a tadpole having no limbs, gills, and tails for swimming to an adult form with limbs, lungs, and no tail.

Migration - The seasonal movement of an organism across its home range as it travels to find resources for survival and reproduction. Amphibians generally migrate within 1-2 kilometers of the wetlands they hatch from.

Mineral - Any solid is a potential mineral if it has a unique chemical composition and an organized molecular structure. Minerals are sources of nutrition. Minerals aggregate into larger solid things, such as rocks, sand, silt, and clay in soil mixtures. The ecological activities of organisms, digging, feeding, digesting, assimilating matter into biomass, and migrating, contributes to the release, formation, and transportation of minerals in a global mineral cycle.

Molecule - Tiny particles that have at least two atoms that are stuck or chemically bonded together to form a larger unit of matter.

Nature - Our complete physical and living surroundings, including wild nature that has not been subjected to human development and urban nature that has been extensively modified by human actions. Nature also includes the sun, moon, stars, universe, and their observable properties. Nature study was the early precursor to modern science.

Niche - The set of environmental conditions in which a species is able to live and sustain populations. The niche is similar to the habitat of an organism, but instead of describing where an organism lives the niche describes the features of the habitat that allows the organism to survive and persist.

Nutrient - A molecule, such as an element, mineral or protein, that is needed to fuel the metabolic functions of organisms. Nutrients are the molecules that are metabolically assimilated into biomass. The movement of nutrients by the ecological actions of organisms and other environmental factors generates and powers a global nutrient cycle.

Omnivore - A heterotrophic organism that eats a combination of autotrophs and heterotrophs.

Photosynthesis - A complex metabolic process in plants that captures energy from sunlight by breaking the chemical bonds in water

Plot - A unit or measured sample of a piece of land. Plots are used by ecologists when conducting research or surveys to characterize and measure the attributes of ecosystems.

Population - A group of individuals. In ecology a population refers to a group of individuals from a species that belong to the same community.

Profundal zone - A layer below the pelagic zone where the amount of light and oxygen is diminished to an extend that primary production ceases. There is also a distinct temperature difference between the pelagic and profundal zones.

Protein - A kind of molecule in organisms that is created within cells and has an organization and structure that is adapted to perform specific metabolic functions. The physical parts of organisms that we can see are primarily composed of proteins.

Quadrat - A measured square frame or perimeter that is used to sample habitats. Ecologists use quadrats to sample and then estimate the density of species or other environmental factors in the habitat. Multiple quadrat samples are generally needed to obtain enough information about the average quality or density of things in the habitat.

Recycling - The process of moving materials back into use after they have served a utility and outlived their purpose. Recycling has feedback loops that use energy in the process of putting material resources back into use. Ecosystems employ many species in the food webs that recycle natural materials. Salamanders, for example, are one link in an ecological web that recycles nutrients through soils back into plant biomass. Human beings do not employ ecological food webs to recycle technological waste back into different kinds of marketable pieces of technology.

Riparian - An ecological transition that is wedged between any terrestrial ecosystem and a wetland. Riparian areas traditionally referred to the banks of rivers, but ecologists now include the shore, bank, or edge of any wetland under the definition. Small ephemeral ponds, for example, are seasonally occupied by different age classes and densities of amphibians. Male salamanders migrate toward and cluster in riparian zones in the early spring before the females arrive on the scene.

Soil - The uppermost layer of the Earth's surface that contains mixtures of detritus, minerals, nutrients, and ecological communities that actively decompose and recycle natural materials into constituents that can support plant growth. Modern soils also contain technological artifacts that disrupt or modify natural cycles.

Species - Populations of individuals that interbreed to produce fertile offspring that have similar appearances and similar ecological behaviours by virtue of their common ancestry.

Succession - Changes that occur in ecosystems as they age and go through different developmental stages after a disturbance, such as a fire. The process starts with pioneering species that help to assemble ecological webs as other species begin to inhabit the site.

Symbiosis - A reciprocally beneficial relationship between two species that exchange energy and nutrients and live in close contact.

Taxonomy - The scientific method that is used to classify species into groups that are organized according to their naturally evolved patterns of relationship. Taxonomists (people who practice taxonomy) gather facts on the anatomy, ecology, and genetics of living and fossil organisms. Taxonomic groups nest into levels starting with Kingdoms progressing downward through Phylum, Class, Order, Family, Genus, and ending with Species.

Transect - A measured line or path that runs through an area. Ecologists run transects to count things, such as salamanders under logs. Transects are used to sample habitats and the counts are used to estimate how many things, such as salamanders, live in the area.

Trophic level - An ecological position that organisms occupy when classified according to the way that they feed or acquire their nourishment. Many organisms, such as amphibians, are difficult to classify into a strict trophic category, such as herbivore or carnivore. Many amphibians are classified as omnivores, because organisms they feed on a variety plants, animals, and microorganisms. Some amphibian larvae have even been classified as detrivores.

Water cycle - Continuous recycled movement of water through Earth systems. The suns energy evaporates water into the atmosphere. Water molecules precipitate into fog, rain, hail, or snow and returns to the surface. Ecosystems regulate the water cycle as water is absorbed into organisms, held by cellular membranes, transported, and then channeled about until it is evaporated once again.

Wetland - An ecosystem that is saturated with water to such an extent that the organisms living in this kind of habitat are adapted to the unique physical conditions that an aquatic environment creates. Oxygen and carbon dioxide, for example, diffuse more slowly and are are less concentrated in water than in air. This means that the physical nature of water creates a unique kind of habitat where different creatures, such as anaerobic bacteria, can survive. The physical presence of different aquatic species also changes the nature of the wetland environment. Aquatic plants and other wetland creatures have many different kinds of adaptations to obtain and transport oxygen and carbon dioxide that lets them live under the water. Some aquatic plants have leaves that float and long stems that act like straws to bring air down to the roots. Amphibians have feathery gills that gives them a large surface area to exchange oxygen and carbon dioxide into and out of their bodies. Marshes, bogs, swamps, fens, and ponds are different kinds of wetlands that are frequently populated by amphibians. Rivers and streams are also wetlands, but the water needs to flow slow enough for most species of amphibian eggs to remain stuck to the twigs or grass where their parents thought best to put them. The tailed frog of British Columbia, however, is an exception and is adapted to lay its eggs in stream habitats. Each kind of wetland is distinguished by differences in: 1) soil nutrient levels (bog's are very poor, marshes are very rich); 2) the amount of moisture they retain (bog's are very moist, fens and marshes are very wet); and 3) and the amount of seasonal water movement (marshes are very dynamic, bogs, fens, and ponds can be stagnant or sluggish).

APPENDIX C MODULAR ECOLITERACY INSTRUMENT.

Item
1 Age
2 Gender (m / f)
3 Cultural background / ethnicity

I participate in the following activities:

Item	Never	?		Often	
		1	2	3	4
4	Camping in a tent				
5	Internet				
6	Mountain biking				
7	Video-games				
8	X-country skiing				
9	Canoeing				
10	Motorcycling				
11	Motor boating				
12	Water skiing				
13	Quading				
14	Skidooing				
15	Nature watching				
16	Television				
17	Movies				
18	Hunting or Fishing				
19	Cell phone				
20	Watching nature programs				

		Disagree strongly	Disagree a little	Neither agree or disagree	Agree a little	Agree strongly
		1	2	3	4	5
1	People are supposed to rule over the rest of nature.	[redacted]				
2	Plants and animals have as much right as people to live.					
3	People must still obey the laws of nature.					
4	If things don't change, we will have a big disaster in the environment soon.	[redacted]				
5	There are too many (or almost too many) people on Earth.					
6	People are treating nature badly.					
7	When people mess with nature it has bad results.					
8	People are clever enough to keep from ruining the Earth.	[redacted]				
9	Nature is strong enough to handle the bad effects of our modern lifestyle.					
10	People will someday know enough about how nature works to be able to control it.					

	Disagree strongly	Disagree a little	Neither agree or disagree	Agree a little	Agree strongly
	1	2	3	4	5

A. The economic cost of trying to conserve amphibians:

1 Is too high and would reduce economic benefits, such as jobs.
2 Is necessary because amphibians sustain forest ecosystems and wetlands.
3 Is mainly important if there are endangered or threatened species involved.
4 Is not as important as conserving fish, bears or other large animals.

[redacted]

B. Wide strips of vegetation should be left along the margins of every amphibian wetland when clear cutting a forest:

5 Wetlands need to be large enough to justify the cost of preserving them. Otherwise, companies will loose money as they are forced to reduce the harvest size by leaving so many trees around every small pond.
6 Only if fish are also present.
7 Only where, when, and if it is economically feasible to do so.
8 Even if it reduces timber harvest supply in the short term as this measure is necessary for the conservation of amphibian biodiversity.
9 Only within protected areas, like Jasper or Banff National Park, otherwise this practice would reduce forestry yields, industry profit, and threaten job markets.
10 Would sustain the long-term economic situation for foresters because this would help enhance biodiversity functions, such as nutrient flow.

[redacted]

C. Having ponds with amphibians in cities, like Prince George or Vancouver is:

11 As important as having ponds with amphibians in a forest.
12 Should be drained to prevent mosquitoes from breeding.
13 Is a great idea.

[redacted]

D. Recycling plastics, paper and metals:

14 Is very similar to the recycling process in nature, such as a decaying log.
15 Is energy efficient and directly beneficial for amphibian ecosystems.
16 Is more green, sustainable, and creates more jobs than investing in conservation programs for amphibians.

[redacted]

E. Amphibians:

17 Are not as complex as computers or other technological devises that humans can create.
18 Are economically important.
19 Have important roles to play in our health care system. For example, glands in their skin may contain potential medicinal properties and cures for disease.
20 Not as economically valuable as fish, because there is an huge fishing industry and very little to no industry that relies on amphibians.

[redacted]

#	Item	Disagree strongly 1	Disagree a little 2	Neither agree or disagree 3	Agree a little 4	Agree strongly 5
	A. In forestry, reduce the total amount of area that is usually harvested in the province by 50% and leave the rest alone to let amphibian ecosystems and migration routes return to normal.					
1	This sounds like a wise economic policy for the next ten years.					
2	This sounds like a wise economic policy for the next twenty years.					
3	This sounds like a wise economic policy for the next fifty years.					
4	This sounds like a wise economic policy for the next one-hundred years.					
5	This sounds like a wise economic policy for the next ______________ years. Give an answer of zero years if your answer is never.					
	B. It is better to:					
6	Put all our efforts toward conserving amphibians now to prevent further losses in the future.					
7	To conserve fewer large wetlands instead of many small wetlands.					
8	Spend more on the conservation of the few species of amphibians that live in Prince George and less to conserve amphibians that live in Vancouver where more species exist.					
9	Spend more on the conservation of the few species of amphibians that live in Prince George and less to conserve amphibians that live in the Amazonian rainforests where there are many more species.					
10	Spend more on the conservation of places that are remote, wild, and distant from human cities instead of places that are near settlements with roads.					
11	Spend more on the conservation of threatened or endangered species than the more abundant local species.					
	C. The economics of government, industry, and society would improve greatly if everyone decided it was best to spend money on:					
12	Sustaining global ecosystems and the amphibian species that live there.					
13	Sustaining local ecosystems and the amphibian species that live there.					
14	Sustaining the worlds amphibians in the present.					
15	Sustaining the worlds amphibians into the distant future.					
16	Investing in the conservation of amphibians as much as any other species, such as fish, bears, and even mosquitoes.					
	D. I would be willing too:					
17	Give up internet, movies, cell phones, and video games if this meant that all local amphibians (in Prince George) would never go extinct.					
18	Give up internet, movies, cell phones, and video games if this meant that all the worlds amphibians would never go completely extinct.					
19	Pay taxes to conserve local amphibians in Prince George.					
20	Pay taxes to conserve amphibians in tropical rainforests.					

		Disagree strongly	Disagree a little	Neither agree or disagree	Agree a little	Agree strongly
		1	2	3	4	5
1	Salamanders are cute.					
2	Wetlands can be restored and populated by amphibians if foresters plant trees after a clear-cut timber harvest.					
3	A frog does not feels pain the same way that I do.					
4	It is important to be kind to amphibians. I feel empathy for the toads and salamanders that get squished on roads by cars.					
5	Amphibians are fascinating and mysterious creatures. I hope to see and then learn more about them.					
6	The thought of a salamander or frog touching my cheek frightens me or grosses me out.					
7	Amphibians are an important scientific resource for medicine and education.					
8	Amphibians are a source of inspiration for artists and storytellers.					
9	Amphibians help the economy by recycling soil nutrients, which is an essential service for forest industries.					
10	Snakes are cute.					
		Disagree strongly	Disagree a little	Neither agree or disagree	Agree a little	Agree strongly

		Disagree strongly	Disagree a little	Neither agree or disagree	Agree a little	Agree strongly
		1	2	3	4	5
1	I enjoy being outdoors, even in unpleasant weather.					
2	Some species are just meant to die out or become extinct.					
3	Humans have the right to use natural resources any way we want.					
4	My ideal vacation spot would be a remote, wilderness area.					
5	I always think about how my actions affect the environment.					
6	I enjoy digging in the earth and getting dirt on my hands.					
7	My connection to nature and the environment is a part of my spirituality.					
8	I am very aware of environmental issues.					
9	I take notice of wildlife wherever I am.					
10	I don't often go out in nature.					
11	Nothing I do will change problems in other places on the planet.					
12	I am not separate from nature, but a part of nature.					
13	The thought of being deep in the woods, away from civilization, is frightening.					
14	My feelings about nature do not affect how I live my life.					
15	Animals, birds and plants should have fewer rights than humans.					
16	Even in the middle of the city, I notice nature around me.					
17	My relationship to nature is an important part of who I am.					
18	Conservation is unnecessary because nature is strong enough to recover from any human impact.					
19	The state of non-human species is an indicator of the future for humans.					
20	I think a lot about the suffering of animals.					
21	I feel very connected to all living things and the earth.					
		Disagree strongly	Disagree a little	Neither agree or disagree	Agree a little	Agree strongly
		1	2	3	4	5

1 I am afraid of toads.
2 I would like to study toads in nature.
3 I would like to hold a toad in my hands.
4 I wouldn't like to hunt toads.
5 Cars kill to many toads each year
6 Toads are disgusting animals.
7 Toads are very important in nature.
8 It would be for the best if all toads were killed.
9 Hunting toads for fun is cruel.
10 When I am walking through the woods, I do not have a special wish to meet a toad.
11 I would rather see a model of a toad than a live one.
12 I get bored when biologists are talking about toads
13 I would rather see a movie about toads than watch them in nature.
14 Toads are of value as they eat mosquitoes and other bugs.
15 I like to read about toads.
16 I would like to learn about different species of toads.
17 I would like to know how toads eat, smell and hear.
18 Toads need to have rights too.
19 Keeping toads in captivity is cruel.
20 I could observe toads for a long time.
21 I would like to have a toad at home.
22 I would like to learn about environments where toads live.
23 We don't need to protect rain forests, because toads living there will move elsewhere.
24 I would like to know how toads developed.
25 Toads are ugly.

[redacted]