Traditional Knowledge and Genetic Discrimination of Lake Nipigon Lake Trout Stocks

By

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Submitted in partial fulfillment of the requirements for the degree of Master of Natural Resources Management

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TRADITIONAL KNOWLEDGE AND GENETIC DISCRIMINATION OF LAKE NIPIGON LAKE TROUT STOCKS

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree

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MASTER OF NATURAL RESOURCES MANAGEMENT

ABSTRACT

Lake trout (*Salvelinus namaycush*) stocks in Lake Nipigon were characterized by exploring the knowledge of Biinjitiwaabik Zaaging Anishinaabek (Rocky Bay First Nation) fishers and examining sequence variation in regions of the cytochrome-b and d-loop genes of mitochondrial DNA (mtDNA). Fishers directed sampling efforts by choosing four locations and predicted how many morphologically different stocks should be detected at each sampling site. Each sample was assigned to morphological category based upon fishers' descriptions. Haplotype frequency distribution would be examined among morphological categories to examine whether particular haplotypes were specific to a morphotype, and among sampling sites to determine to what extent stock structure could be inferred. The fishers' knowledge and the genetic results were compared to examine whether they were complementary.

Traditional knowledge was shared through interviews and direct participation as an apprenticing deckhand on commercial boats. Lake Nipigon fishers made a distinction among four sexually isolated stocks of lake trout. The stocks were morphologically different and were named 'blacks', 'browns', 'silvers' and 'deep-water'. The 'blacks' were predominant in northern areas of Lake Nipigon while the remaining stocks were concentrated in southern regions of the lake. Fishers described fishing according to lunar phases, the depth distribution of lake trout throughout the year and ethics in regards to fishing. Knowledge was communicated in Anishinaabek context and an attempt was made to acquire knowledge in accordance to protocols set by fishers. My experience of working as a deckhand on boats, and the development of social relationships, and shifting

preconceived perceptions of worldview fostered a greater appreciation of traditional knowledge.

A total of 590 base pairs from the 5' end of the cytochrome-b and d-loop regions of mtDNA were sequenced from 186 samples. A total of nine nucleotide positions were polymorphic, and these defined six haplotypes. Phylogenetic analysis resolved three major phylogenetic groups. Three mitochondrial DNA lineages were resolved when Lake Nipigon haplotypes were compared to out-groups. Each haplotype was associated with refugia of the previous glacial period.

Evidence for genetic differences among lake trout morphotypes was observed. The frequency distribution of four haplotypes, associated with three glacial refugia and different morphotypes, among sampling sites displayed significant differences indicative of genetic segregation and the presence of three stocks. The frequency of a haplotype associated with a fourth refugium was too low to elucidate the potential presence of a stock.

Fishers' predictions and genetic results were complementary. The fishers anticipated three morphologically different stocks would be detected in Lake Nipigon based on the timing of the sampling. Results concluded there was evidence of three morphologically distinct stocks present in Lake Nipigon. Complementing fishers' knowledge and genetic results promoted a thorough and collaborative approach towards examining Lake Nipigon lake trout stocks.

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I wish to thank the people of Biinjitiwaabik Zaaging Anishinaabek (Rocky Bay First Nation) for their friendship and acceptance. I met so many people who did not hesitate to welcome me into their homes and share coffee, stories and laughter; Chi' Megwetch! I wish to acknowledge Tash, Kim, Churchill, Ashley, Dave, Monique and Sherry for making my time in the community much more fun. I am forever grateful to Harold and Agnes Michon. I thank Harold not only for the food and lodging, but also for his patience, guidance and teachings. A special thanks is extended to Dennis Lesperance and family for their hospitality. Dennis and Harold provided an amazing learning environment and shared their knowledge through training me as a deckhand that provided life experiences that I will never forget. I also thank Frank Goodman and family for their kind hospitality and taking time to accommodate my visits. I also wish to acknowledge Moses and Abraham Kowtiash and James Hardy for taking the time to share knowledge.

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CHAPTER I: INTRODUCTION

Knowledge held by commercial fishers who harvest the waters of Lake Nipigon (Fig.1), Ontario, can provide important insights to fishery managers in regards to fish stocks. An understanding of stock structure of Lake Nipigon lake trout (*Salvelinus namaycush* (Walbaum)) can be derived from the knowledge of commercial fishers and from analysis through molecular genetics. Complementing fishers' traditional knowledge with the pattern of molecular sequence variation from lake trout deoxyribonucleic acid (DNA) will provide a comprehensive understanding of lake trout stocks.

Lake trout constitute the second most abundant catch for Lake Nipigon commercial fishers (24,727 kilograms round weight) and are the primary interest of most sport fishing on Lake Nipigon. Protecting an economically important species to communities surrounding Lake Nipigon requires implementing quotas and population monitoring studies by the Ontario Ministry of Natural Resources (OMNR) and the Anishinabek/Ontario Fisheries Resource Centre (A/OFRC). Gaining an understanding of the population ecology of any species includes determining life history and ultimately an understanding of the genetic population structure.

The incorporation of stock structure knowledge into lake trout population studies will enable researchers to not only understanding the ecology of a single species but also to understand the ecology of the individual populations. The measurement of population parameters of a species while ignoring the stock structure may overlook differences among populations. Incorporating stock structure into population monitoring will help ensure the sustainability of commercially important species (Hilborn and Walters 1992).

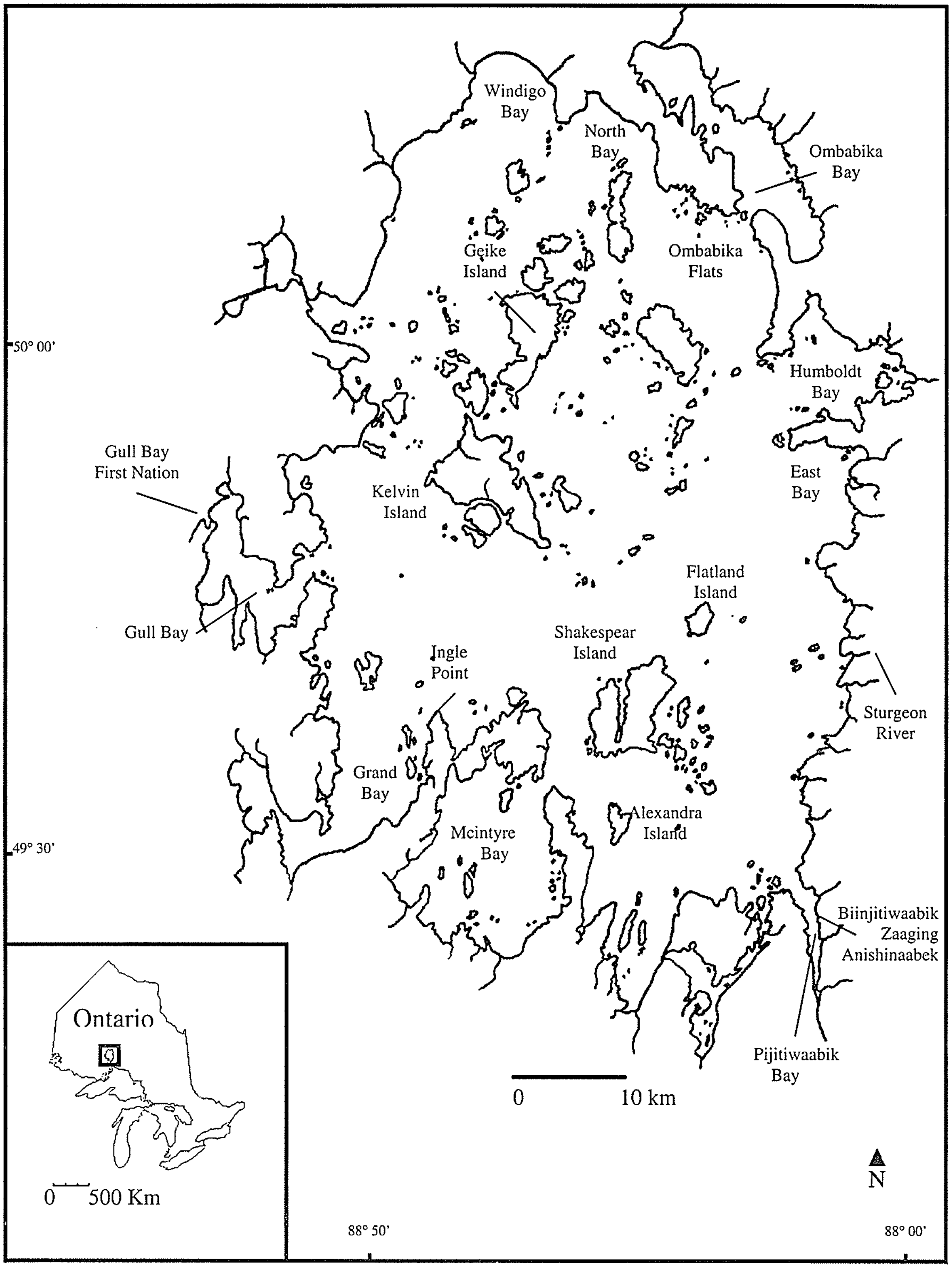


Figure1. Lake Nipigon, Ontario, with insert of the Province of Ontario.

Fisheries management without consideration of population structure may result in under-harvesting of some stocks and over-harvesting of others. Differential rates of harvest of populations can result in the complete elimination of vulnerable stocks and subsequent loss of genetic variability within the population in general (Larkin 1972).

The stock concept has two central tenets: that fish species are subdivided into local populations, and that there are genetic differences between local populations which are adaptive (Maclean and Evans 1981). Allendorf and Phelps (1981) characterize the goal of genetic investigation as describing the pattern of genetic exchange and isolation among geographical units. If managers are to consider stock structure, the first basic step is to gather genetic information to help determine the number of populations in a lake.

Other sources of information for Lake Nipigon management include local knowledge. Some fishers may possess knowledge in regards to stocks that will help identify the structure and segregation pattern of populations. Incorporating all sources of information will ensure a thorough approach on the question of stocks.

Biologists and managers consider that no data exist to scientifically support the claims made by aboriginal commercial fishers to OMNR officials about the presence of multiple stocks of lake trout in Lake Nipigon (Salmon 2000, pers. comm.; Chudobiak 2000, pers. comm.). However, some evidence for the presence of multiple stocks of lake trout are found in the publication of a four-year study of Lake Nipigon, conducted between 1921 and 1924, by J.R. Dymond (1926, 67):

> Many specimens… being merely grayish and varying from light gray to very dark; others are distinctly brownish, and have the lower fins tipped with salmon or orange.
>
> The question of the existence of varieties or races of trout has received little attention. It is said that there exists in Lake Nipigon a sort of lake

> trout known locally as "black trout," which ascends some of the rivers, notably the Sturgeon river, at spawning time. This form is described as being very dark in colour and of medium size, seldom attaining more than four or five pounds in weight. They have not been recognized in the lake during the summer, which suggests that their dark colour may be assumed on entering the dark river water. It is a fact, however, that very dark trout, all of medium size, do enter the Sturgeon river at spawning time in large numbers. They also spawn earlier than the trout which spawn in the lake, usually beginning about September 20.
>
> The fishermen recognize a third [an error in the text because the author only refers to a second] variety, which they call "deep water trout," and which are said not to come into water of less than 20 fathoms. They are believed to spawn between October 20 and November 10 at depths of 20 to 30 fathoms (Dymond 1926, 68).

The traditional knowledge of aboriginal fishers can provide a source of information for ecological processes. Traditional knowledge can help decrease the uncertainty in fisheries science, and such knowledge can help in gaining a better understanding of the functioning of ecosystems (Freeman 1992).

Exploring the realm of Indigenous knowledge in relation to fisheries sciences has historically been ignored due to the quantitatively based decision-making framework employed by fishery managers. Complementing scientific data with traditional knowledge is becoming more prevalent with the acceptance of alternative (i.e., non-scientific/postpositivistic) forms of "knowing" (Berkes 1999, Johnson 1992, Wolfe et al. 1992).

Interactions between traditional knowledge and science have been fraught with appropriation of knowledge and compartmentalization, distillation and misinterpretation of information from the scientific perspective (Nadasday 1999). Inevitably such interactions occur due to the interpretation of one form of knowledge through the epistemology of another. Working together and learning from one another to promote a collective 'knowledge' for a better understanding of not only the environment, but also both cultures, should be the primary idea behind applying aboriginal knowledge and Western science. Integrating aboriginal knowledge into scientific research can permit scholarly exchange and growth, and empower a community in the scientific arena (Colorado 1988). The word "integration", according to Colorado (1988), needs to reflect a blending of research efforts and not the domination or extension of ideological control by one over the other.

This thesis will be an attempt to learn from both ways of knowing, Western science and Indigenous knowledge, about stocks of Lake Nipigon lake trout. The purpose of the thesis is not to "prove", using science, the validity of traditional knowledge held by an aboriginal community. Traditional knowledge held by fishers is valid in its own right. Genetic results may or may not scientifically substantiate traditional knowledge. Regardless of what scientific results are produced in relation to fishers' knowledge of lake trout, science cannot change the epistemological 'truth' of the knowledge gained through personal observations passed down through oral history. One reason for exploring traditional knowledge is to use it to formulate a hypothesis for science in regards to lake trout stocks. Traditional knowledge can also help locate the stocks, thus increasing the efficiency of sampling. Other, more personal, intentions of pursuing a project with a traditional knowledge component was to gain an appreciation of a culture, and obtain a greater respect for and better understanding of traditional knowledge through first hand experience. By respectfully learning about the knowledge held by aboriginal fishers of Biinjitiwaabik Zaaging Anishinaabek (Rocky Bay First Nation), and complementing that knowledge with scientific research, better recommendations for management decisions may be achieved, improving the management and sustainability of Lake Nipigon lake trout.

1 Issue statement

Resource managers have historically ignored local aboriginal knowledge, relying solely on Western science. A greater realization of the complexity of the natural environment has forced scientists and managers to become more accepting of alternative ways of viewing the environment. Learning from traditional knowledge, describing how science can build cooperative bridges toward aboriginal knowledge, and communicating scientific results will promote the community's participation in fisheries and resource management.

Fishers recognize four separate stocks of lake trout in Lake Nipigon. Can direct sequencing of mitochondrial DNA (mtDNA) provide the resolution to discriminate between stocks of lake trout?

Examining and learning from the unique knowledge of local fishers and through molecular genetics will provide two important sources of knowledge for a better understanding of lake trout stocks. Comparing the results, without attempts towards validation of one source of knowledge over the other, and examining whether either sources of knowledge are complementary will provide information important for the management of lake trout.

2 Objectives

- The first objective is to learn traditional knowledge regarding stocks of Lake Nipigon lake trout.
- The second objective is to examine the genetic population structure from samples collected during spawning.

The first objective is to integrate into the community of Biinjitiwaabik Zaaging Anishinaabek and learn about traditional knowledge from the perspective of the community. Working with elders and knowledgeable people (teachers) including fishers will provide direct learning in regards to the different stocks and will provide experiences to better appreciate the holistic nature of traditional knowledge. Knowledge in relation to stocks of lake trout in Lake Nipigon such as the number, distribution, spawning location and time of each stock and other population parameters will be requested. Cultural aspects of lake trout or other subjects pertinent to appropriately represent, as much as possible, the unique knowledge fishers possess will also be requested.

The second objective is to have knowledgeable fishers direct the timing and location for the sampling of stocks of lake trout for genetic analysis. Fishers will predict the number and 'kind' of stock that should be spawning. While sampling, samples will be labeled with a particular morphological label ('kind') based upon the description provided by fishers. Direct sequencing of portions of the mitochondrial DNA may detect variation indicative of stocks of lake trout. Whether genetic differences exist among the morphologically different lake trout, as described by fishers, will be preliminarily examined by determining whether a morphological category is consistent with particular patterns of genetic variation. The results from both traditional knowledge and genetic analysis will be compared for a collective understanding of Lake Nipigon lake trout stocks.

3 Partnership

The study was carried out in cooperation and partnership with the Anishinabek/Ontario Fisheries Resource Centre (A/OFRC). Established in 1995, the

A/OFRC serves as an independent source of information on fisheries conservation and management in traditional harvesting areas in the Anishinabek territory. A/OFRC is a partnership between the Union of Ontario Indians the Ontario Ministry of Natural Resources. The A/OFRC is a non profit corporation whose roles are to report on stock status, evaluate stresses on fish populations and habitats, promote the use of state of the art science and technology, and provide a forum for information sharing and participation with stakeholders (A/OFRC 2000).

The Centre's studies utilize Western science and traditional ecological knowledge for management recommendations. The A/OFRC strengths lie in designing and carrying out field fisheries assessment studies, analyzing and interpreting the results and communicating this information to First Nation communities and other interested stakeholders.

CHAPTER II: TRADITIONAL KNOWLEDGE

1 Introduction

Beginning in the early eighties, a great deal of attention was placed on examining and incorporating the knowledge of aboriginal peoples, known as Indigenous knowledge, traditional ecological knowledge (TEK) or traditional knowledge, by non-aboriginal people in order to obtain a greater understanding of the environment (Berkes 1999). Traditional knowledge in Canada has become more popular with the emergence of native political power and has become a manner of participating in the decision-making regarding natural resources.

Aboriginal knowledge has been important for natural resource management (Berkes 1999, Freeman and Carbyn 1988), environmental impact assessment (Sadler and Boothroyd 1994), and environmental ethics (Cajete 1994). Traditional knowledge rests with people in a community, passed orally onto future generations and is rooted in spirituality. Some aboriginal authors have voiced concerns over the use of traditional knowledge by Western science (Goodstriker 1996, Deloria 1995, Stevenson 2001). Some make the argument traditional knowledge cannot be interpreted from a scientific viewpoint. Aboriginal knowledge uses a different epistemology from Western science. Science perceives and categorizes information from a Eurocentric viewpoint. Science has used local knowledge outside of its cultural context, producing a skewed view of aboriginal people's knowledge (Simpson 1999).

Even with such problems, scientists and community members will need to foster understanding and cooperation, not only for the sake of attaining the 'truth', but to decrease the cultural divide. Non-aboriginals cannot ignore traditional knowledge because First Nations argue the importance of traditional knowledge as pertinent to the community and its lands. Traditional knowledge, along with education, training and planning, is key to an aboriginal community's economic, cultural and social sustainable future (Brascoupé 2000).

2 Literature review

2.1 Western and aboriginal paradigms coming together

When exploring both 'ways of knowing', having an appreciation of the basic understanding of the epistemology of each is fundamental. Reality is relative based upon the epistemological origins of a person because paradigms, whether scientific or aboriginal, has a particular basis of generating knowledge. Understanding and acknowledging aboriginal epistemologies by non-aboriginal people is difficult due to a lack of understanding certain elements not necessarily present in Western science such as spirituality. Johnson (1992) mentions the importance for scientists and managers to recognize messages in the spiritual explanations of traditional knowledge because stories or teachings conceal relevant and appropriate conservation strategies, which do not detract from the reality of a situation. Science does have many solutions in regards to environmental dilemmas and the methodology involved in furthering understanding has improved the sustainability of the environment. Although, Knudson and Suzuki (1992) mention traditional ecological knowledge and the spirituality of Native people can offer great hope for the resolution of environmental and social problems than all scientific knowledge combined.

Typically, scientists have only taken the information making sense to themselves and have integrated the knowledge into resource management decisions in a manner where the information has been conveniently assimilated into Western scientific models as tidbits (McGregor 1999, Nadasdy 1999). Traditional knowledge, in many instances, is compartmentalized and distilled in order for the scientific community to understand the information (Nadasdy 1999). Indigenous knowledge does not use similar methods of data collection, storage, analysis and interpretation as Western science. Scientists therefore have difficulty in acknowledging the validity of data generated in unfamiliar ways. Scientists removing the context of the tid-bits of information weaken and destroy the traditional knowledge (McGregor 1999). Learning about traditional knowledge is not necessarily about dealing with "knowledge", as defined by academics, and interpreting the information gathered. In order to comprehend what has been shared, understanding the context, world-view and culture is important. Traditional knowledge cannot be measured by the scientific yard-stick (Simpson 1999).

In order for the two kinds of knowledge to work together more successfully, both cultures need to not only learn from one another, but to appreciate how knowledge, from both cultures, is generated. Developing genuine relationships of reciprocity between community and researcher/institution is required to foster trust. Colorado (1988) claims a bi-cultural research model needs to strengthen aboriginal knowledge, be valid and reliable and improve communication between both sides. A focus on relationships between the community and the researcher needs to be fostered. Scientists need to learn of traditional knowledge from the community's perspective. The methodology of anyone doing a project on traditional knowledge needs to be reassessed not only to accommodate the community but also to better understand the holistic and encompassing concept of traditional knowledge:

> This means challenging Eurocentric researchers, their methodologies, and their investigators' skills. Often this interrogation causes discomfort. Grasping the holistic structure and processes of Indigenous knowledge requires an investigator's assumptions and perspective to stretch and develop. The researcher will have to explore uncharted territory without a conventional map (Battiste and Youngblood Henderson 2000, 33).

Community members involved in a project want to be part of a team where the knowledge is shared, or attained, in a collaborative manner. Acknowledging what cannot be wholly placed into a document such as spirituality should be made as much as possible to promote the underpinnings of aboriginal culture. Any research model incorporating traditional knowledge and science together should foster a cultural collective understanding of the environment.

2.2 Ways of knowing

Understanding the world is based upon an individual's cultural upbringing. Epistemological differences between Western and aboriginal realities lead to political, philosophical and moral conflicts when decisions regarding natural resources are made (Bielawski 1993). Gaining an appreciation in worldview differences provides a starting point to examine, understand and potentially resolve cultural conflicts pertinent to natural resource management. Understanding the differences implies adopting the opposite worldview and moving away from assumptions about ones' reality and how phenomena are interpreted towards one that is more "aboriginal" or specifically relevant to a community of teachers and elders.

Western culture is premised on a belief that the scientific method is the basis of knowledge. Western science is guided by a mechanistic, reductionist view of the universe, and considers, depending upon the discipline, all living and non-living phenomena as separate parts working together as a system. The framework is positivistic whereby nothing is considered to be true until a hypothesis is tested by statistical standards. Events must be observed objectively, values cannot be incorporated, and measured in a quantitative manner. Reductionism leads to compartmentalization and a mechanistic understanding of the environment where reality is either animate or inanimate. Understanding the linear process of cause and effect has been the premise of Western scientific thought (Freeman 1992). Phenomena are explained in terms of a set of laws, which are continually tested over time through the accumulation of more quantifiable data. The result is a reality measured by corrective measurable methods transcending all cultures.

The aboriginal paradigm, as opposed to the scientific approach, does not separate people from nature, from their kin, from the spirit world and spirituality, and from health and wholeness (Bielawski 1993). Little Bear (2000) while discussing aboriginal philosophy writes about energy and how existence consists of energy and how all objects are animate, imbued with spirit and in constant motion. Worldview is based upon life as being continually in a state of flux (Youngblood Henderson 2000); continually moving and changing. Understanding the Universe is based on relationships between humans, nature and spirits. Knowledge is embedded in the context of stories, legends, myths, histories, song and experience. Reality is not divided into animate or inanimate; everything is alive having spirit and knowledge. Language reflects the animate and flux worldview of aboriginal people with verb-rich languages describing happenings rather than objects (Little Bear 2000). Spiritual, ecological, human and social experiences are melded together into one holistic understanding of Native peoples' place in the universe.

A "science", used as a general term, can relate to a way of understanding. Every paradigm, whether European, aboriginal, or others, have methods, or ways of knowing (Collins and Colorado 1987) that are culturally constructed. Cajete (2000) writes of Native science as:

> ...a metaphor for a wide range of tribal processes of perceiving, thinking, acting, and "coming to know" that have evolved through human experience with the natural world. Native science is born of a lived and storied participation with the natural landscape. To gain a sense of Native science one must *participate* with the natural world. To understand the foundations of Native science one must become open to the roles of sensation, perception, imagination, emotion, symbols, and spirit as well as that of concept, logic, and rational empiricism.
>
> (p.2)

> Native science is a broad term that can include metaphysics and philosophy; art and architecture; practical technologies and agriculture; and ritual and ceremony practiced by Indigenous peoples both past and present. More specifically, Native science encompasses areas such as astronomy, farming, plant domestication, plant medicine, animal husbandry, hunting, fishing, metallurgy, and geology- in brief, studies related to plants, animals, and natural phenomena.
>
> (p.2)

> And so this understanding that Indigenous peoples have is a very particular and very profound relationship with the natural world. This relationship is predicated on the fact that all Indigenous tribes- their philosophies, cultural ways of life, customs, language all aspects of their cultural being in one way or another- are ultimately tied to the relationship that they have established and applied during their history with regard to certain places and to the earth as a whole.
>
> (p. 4)

Epistemological differences separating aboriginal ways of knowing from a Western European scientific paradigm can be a difficult issue to discuss. Different dimensions of the mind are tapped into in order to provide principles of Native Knowing. Principles include mode, mind as agent, mind processes, oral literate, relationships, primal experience and laws of nature (Couture 1991). Knowing in an aboriginal context is all encompassing without the separation of the spiritual from the physical.

2.3 Defining and understanding traditional knowledge

Explaining the meaning behind an all-inclusive topic such as traditional knowledge is difficult. Indigenous cultures are diverse and applying the words "traditional" and "knowledge" to characterize all Indigenous knowledge can potentially be misleading especially from an aboriginal perspective (LaRocque 2001). Bielawski's (1993, 14) discussions with members of a northern community on Indigenous knowledge had traditional knowledge described as:

> Information which Aboriginal peoples have about the land and animals with which they have a special relationship.
>
> … a common understanding of what life is all about.

Traditional knowledge is knowledge that is derived or is rooted in the way of life of aboriginal people. Berkes (1999, 8) defines traditional ecological knowledge as:

> A cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment.

Definitions of traditional knowledge reflect the formulation of knowledge in relation to culture. The many ways traditional knowledge can be explained and even understood, the above definitions can be used as an example, is based upon how the concept is interpreted whether from an emic or etic viewpoint. No single view or definition of traditional knowledge is appropriate to explain all the different kinds of knowledge held by Indigenous peoples throughout North America and the world. As a non-aboriginal, the topic of traditional knowledge, in my opinion, needs to be approached with a flexible and open mind, with input from the community, in order to formulate a personal view of knowledge from a different culture.

3 Background: my relationship with the community

I gained permission to come and learn about traditional knowledge and conduct research in Biinjitiwaabik Zaaging Anishinaabek through the A/OFRC. A proposal was sent to the general manager of the A/OFRC and community biologist and subsequently to Harold Michon. Harold Michon, community elder and fisher, who worked closely with the A/OFRC as a member of the board of directors and whom aided in directing fieldwork for the field-unit in the community, agreed to my request. Harold confirmed that other experienced fishers within the community welcomed my presence in learning about traditional knowledge.

I resided in the community between June 5 and November 10, 2000. The community was comprised of roughly 250 on-reserve and 250 off-reserve members. Most everybody spoke English yet Anishinaabek was spoken by some. All experienced fishers knew of the term "traditional ecological knowledge", yet, preferred saying "traditional knowledge". I had not brought the term to the community. Many community members were experienced in the "worlds" (a term popularly used by the community) of the "city" and the "bush". Over the past decade, many elders who were very knowledgeable in the fisheries of Lake Nipigon had passed away leaving only a few very knowledgeable people.

Harold sponsored my presence in the community and took a large role in providing me with teachings and learning experience to give me a basis to better understand what was traditional knowledge and to share knowledge in regards to lake trout. Important and special fishers within and near the community I met and learnt from were Dennis Lesperance, Frank Goodman, Moses Kowtiash, Abraham Kowtiash and James Hardy. Harold provided me with contacts to the most experienced and knowledgeable fishers of Biinjitiwaabik Zaaging Anishinaabek and Beardmore. Frank Goodman resided in Beardmore yet was raised in Rocky Bay. Others whom I met and developed relationships and learnt from were Donny Onakanakis and Gilbert Panimick. Both were spiritual advisors within the community and provided teachings and ceremony. I had cultivated different relationships with each contact through visiting and working on their boats out on the water. All agreed to allow me to include their names in the thesis.

4 Methodology

Acknowledging Indigenous ways of knowing requires the recognition of Indigenous methodology or one relevant to the aboriginal community. Every relationship produced different experiences and degrees of information/knowledge. Some participants welcomed my presence on their boat and agreed to be interviewed. The methodology was consistent with participant observation. Others were proactive in teaching traditional knowledge and provided direction and experiences to better communicate what traditional knowledge meant for them. Those who were proactive shared traditional knowledge in a manner that was more consistent with a methodology that was more aboriginal.

Simpson (1999) describes Anishinaabe methodology in her doctoral thesis. I elected to describe my experiences and how traditional knowledge was passed on to myself based upon the description of the methods by Simpson (1999). I felt I could only parallel Indigenous coming-to-know because I am non-aboriginal. Moving away from the social sciences and attempting to reflect Indigenous knowledge will be better achieved by using postpositivism to inform methodology. Combining Simpson's (1999) descriptions of Anishinaabe methodology in conjunction with Lather's (1986) description of post-positivism produced the methodology I used for better understanding traditional knowledge and will be described as *postpositivism paralleling Anishinaabek ways of knowing*.

The degree of relationship forged between the individuals determined the categorization of methods, as some were more involved than others. People with whom I had a fully integrated working and learning relationship were characterized as postpositivism paralleling Anishinaabek ways of knowing. My relationships with Harold Michon and Dennis Lesperance were, to a greater degree, consistent with such a methodology. I had the chance to visit and work with other fishers but not often enough to become incorporated in a teaching and working relationship. Others whom I developed cordial rather than in-depth relations to gain insight to traditional knowledge are categorized into a methodology consistent with those undertaken from a social sciences context.

4.1 Participant observation

Requests were made to work as a deckhand on boats in order to foster relations, obtain a better understanding of the labor involved in being a fisher, geographical area and to observe samples of fishes, from differing stocks. Traditional knowledge is described as a complex of knowledge, practice and beliefs (Berkes 1999). Working alongside fishers on their boats allowed me to better appreciate the application of the knowledge and strategy of where to set nets, the practice of efficiently working the boat and the ethics pertinent to the belief system of fishers' traditional knowledge. Within the context of participant observation, methods such as the semi-directive interview, unstructured interview and participant mapping were used, at appropriate times, to learn fishers' knowledge.

Participant observation involves establishing rapport with the community, becoming somewhat integrated and building a trust with members in order for to create a comfortable relationship to share knowledge (Bernard 1994). Participant observation allows, but is not limited to, studies in processes, relationships among people and events organization of peoples and events and sociocultural contexts (Jorgensen 1989). Elements of participant observation, according to Jorgensen (1989,13-14), include:

- A special interest in human meaning and interaction as viewed from the perspective of people who are insiders or members of particular situation and settings.
- Location in the here and now of everyday life situations and settings as the foundation of inquiry and method.
- A form of theory and theorizing stressing interpretation and understanding of human existence.
- A logic and process of inquiry that is open-ended, flexible, opportunistic, and requires constant redefinition of what is problematic, based on facts, gathered in concrete settings of human existence.
- An in-depth, qualitative, case study approach and design.
- The performance of participant role or roles that involves establishing and maintaining relationships with locals in the field.
- The use of direct observation along with other methods of gathering information.

Participant observation focuses on obtaining practical and theoretical truths about human life grounded in the realities of daily existence (Jorgensen 1989). Participant observation will provide the researcher with the ability to collect different kinds of data, and a more intuitive understanding of what is going on in a culture and presents the findings with confidence (Bernard 1994).

4.2 Interviews

Interviews with fishers were conducted on a voluntary basis. Huntington's (1998) method for documenting traditional knowledge was based on the semi-directive interview. The method allows participants to determine the scope of the interview and discussions to proceed according to the associations made by the participants rather than those potentially made by the interviewer. Semi-directive interviews and participant observation will help ensure a focus on what people do and why, within a larger framework of what they know and think (Weinstein 1996). Open-ended questions allows for greater flexibility in responses, when combined with the semi-directive approach. This is accepted as an appropriate method for better understanding relationships between the land and its users (Huntington 1998).

Structure in an interview exposes every informant to the same stimuli (questions) (Bernard 1994). The uniform questionnaire allows the researcher to ask specific questions every time with different insiders (Jorgenssen 1989). Structured interviews requires the researcher to have a sense of what answers are specific enough to proceed to the next question and the researcher should have a sense of the relevancy of each question. Uniform sets of data are collected quickly and efficiently. A preliminary questionnaire (Table 1) has been devised, for this research, as a guide to record the traditional knowledge of lake trout stocks:

Table 1. Basic structured questions for fishers regarding stock identification for Lake Nipigon lake trout.
How many different stocks/races/types of lake trout are present in Lake Nipigon?
What physical features set each kind apart?
What is the geographic distribution of each stock?
Do the stocks occupy different depths of water?
When does the spawning occur and for how long?
Are there any noticeable population cycles for lake trout?

Along with the interviews, participatory mapping will allow fishers to delineate the distribution of lake trout throughout Lake Nipigon. Maps can help people to talk or remember more regarding the topic (Hart 1995).

A difficulty in working with traditional knowledge may be misinterpretation due to cross-cultural miscommunication. There exists the potential of transcribing information into a Eurocentric context, which would lead into a misrepresentation of far more complex messages than in the original native narrative (Huntington 1998, Hoare 1993). Emphasis must be placed on the fact that all information derived from interviews need to be verified by the interviewee in order to ensure that the information is correct and the context reflects the views held by the individual and was not biased by an etic interpretation of the researcher.

4.3 Postpositivism

The understanding and representation of truth or truths can be subject to biases of the researcher and the methodologies employed in order to know or generate results. Postpositivism attempts to remove obstacles creating the biases in order to reach a different and better level of awareness between the researcher, and everybody included in the research, and the occurrence being studied (Lather 1986). Postpositivism intends on instituting alternate methodology, conforming to the social context, to ensure alternate ways of knowing are supported and represented in an ethical and equitable manner (Lather 1986).

Methodologies are the framework prescribing how research is performed in order to answer the research question. Science and knowledge are a construction of culture and epistemology. Methods are therefore the same. Whose epistemology should one use to gain an understanding and the truth? Social sciences have been forging a new paradigm of research in the methodology or tools to understand the world experienced by people. Such a paradigm is needed in research done in a cross-cultural setting where differences in epistemology may skew research and detract away from an understanding of the issue being investigated or the interpretation of social and even cultural phenomena. Postpositivism is a research method allowing:

> ... a search for different possibilities of making sense of human life, for other ways of knowing which do justice to the complexity, tenuity, and indeterminacy of most human experience (Mischler in Lather 1986, 259).

Principles of postpositivism, according to Lather (1986) include:

- Recognition of knowledge as being socially constituted, historically embedded, and valuationally based.
- Possessing a research design characterized as being interactive, contextualized, humanly compelling because they invite joint participation in the exploration of research issues.
- Coming to understand on the terms of those of interest.

Categories of research falling under the postpositivistic are emancipatory, participaroty-action and collaborative research.

4.3.1 Postpositivism and traditional knowledge

Traditional knowledge has been described as a way of life rather than a body of knowledge. How does one gain a better understanding or even research a way of life? What if the way of life is rooted in a completely different epistemology and cultural context? According to those who were teaching me I had to immerse myself mind, body and spirit into their "world". I had to integrate, as much as possible, into the community, and immerse myself into the work involved on the boats and foster relationships among my teachers and my environment. My teachers directed the learning process and provided experiences necessary to teach traditional knowledge. Epistemological misunderstandings of traditional knowledge needed to be minimized for better comprehension. Harold suggested being open-minded while not forcing myself would help change my perception.

Authors also acknowledge integration into a community, gaining trust through relationship building, according respect to community members and adapting to their framework of what constitutes as traditional knowledge will better enable a researcher to understand what is being shared (McGregor 1999, Brizinski 1993). Respecting the shared knowledge and building good rapport and reciprocal relationships will result in a more truthful and complete subject regarding the topic of study. An end result is the increased ability of the researcher to begin to understand sensitive or sacred topics such as traditional knowledge.

Social scientific inquiry aims to generate knowledge as a final result. I was not attempting to generate knowledge by studying fishers because the knowledge already existed whether or not written in a thesis. Traditional knowledge is gained through sharing and goes beyond answers to questions. I wanted to learn about knowledge fishers possessed in regards to lake trout yet I respected the fact that I was going to learn beyond a single fish. I needed to learn about the context of the knowledge and the lifestyle.

On whose epistemological terms does one gain a better understanding of traditional knowledge? Upon Anishinaabek terms one learns about traditional knowledge through experiences and interactions with a single or a multitude of mentors. Social science researches phenomenon positivistically in order to 'know' and generate data. Traditional knowledge belongs to individuals within a community and in order to gain a better appreciation and understanding of what people wanted to share with me, I needed to shift my personal worldview. Science needs to interpret aspects of aboriginal culture on its own terms for understanding. Those involved with me in the community urged me to learn on their terms and would shape my understanding. When thinking about my time in the community, I feel uncomfortable writing about having conducted a "study" on or having "researched" traditional knowledge since making such a statement gives me a sense of validating the knowledge through a scientifically based research:

> The power of a social scientist lies in the author's ability to shape views of reality by focusing attention on particular elements of reality, defining knowledge about reality and expressing knowledge through language (McGovern 1999, 19).

A person learns best from traditional knowledge through sharing and experience and not through empirical examination. In my opinion, a person should focus on respectfully learning rather than studying.

The process of understanding traditional knowledge related to whether I was going to learn about traditional knowledge based on experience or based on answers to questions. I wanted to go beyond a student watching people work and become the participant alongside of those who were working the waters of Lake Nipigon. A person watching people work was examining traditional knowledge, while the teachers and elders I was in close relations with were making me an active participant of a team working the water.

I was adopting, as much as possible, the methods pertinent to the community or Nation. Experiential learning, learning by doing, ceremony, story telling, dreaming, apprenticeship, tutorship and self reflection are examples of methods used by Anishinaabek and other aboriginal cultures in order to understand ones' environment and place within the environment (Simpson 1999). The danger of adopting such a methodology, as an "insider" to a foreign culture, is the lack of epistemological background to provide understanding of the dimensions of knowledge aboriginal people possess and interpretation of occurrences both physical and spiritual. I lacked what Ermine (2000, 103) terms an "eminence" to provide understanding:

> In the Aboriginal mind, therefore, an eminence is present that gives meaning to existence and forms the starting point for Aboriginal epistemology.

I elected to parallel the methods of the Anishinaabek with the only factor preventing me from wholly adopting the method was the lack of epistemological understanding of the culture. Experiencing and understanding the spiritual dimension of aboriginal coming-to-know would be non-existent. I was capable of participating in ceremony but I was not at the same level of function or ability to experience and interpret as others who are rooted in the paradigm. I could only use certain Anishinaabek methods I could relate to and understand. Principle methods of Anishinaabek I used were experiencing, learning by doing, ceremony, self-reflection and apprenticeship. The power and direction of the "research"/learning process was in the hands of the teachers. Each had the power to decide what was going into the thesis and what experiences were going to shape the student.

The strategy for the methods was to be very adaptive. When meeting fishers I decided to start by not asking questions, as much as I possibly could, and simply get to know them as an individual. Most of the first four months were spent building relationships and not asking for interviews. Visits and offering services gave me an opportunity to get to know people in the community. With my elder, I began working, doing odd jobs in the yard and learning how to work alongside him. Requests to go fishing and work in the boats came later in the season.

5 Experience through working, relationships and ceremony

Describing the experiences I encountered on Lake Nipigon is basically impossible. Unfortunately this will inevitably leave room in the thesis to focus on mere aspects of traditional knowledge and the "tid-bits" of information rather than truly communicate the greater context of traditional knowledge. Some aboriginal scholars express experience as the methodology to understand a way of life:

> Experience is the way to determine personal gifts and patterns in ecology. Experiencing the realms is a personal necessity and forges an intimate relationship with the world. In the Aboriginal quest for knowledge, such experiences are focused on helping one understand the nature and structure of a particular realm, on how realms interchange yet remain related, and on how language may create an elegant way of explaining an implicate order composed of complex systems of relationships and interdependence (Youngblood Henderson 2000, 265).
>
> It is an experience in context, a subjective experience that, for the knower, becomes knowledge within itself. The experience is knowledge (Ermine 1995, 104).

Harold decided to let me live under his guidance. My needs would be taken care of in terms of lodging, food and a proper teaching environment. I stayed in a trappers' plywood shack in his backyard. Dimensions of the shack were two meters wide and six meters long with no heating, lighting or running water, and with two small windows adorning the front and back. My furnishings were a small table, chair and a bunk with a mattress for my sleeping bag. The shack would be home until my departure. Meals were provided at his expense and no rent was required. Harold's reason for placing me in this trapper shack was to provide me with a challenging environment in order to develop mentally. Being able to get into a particular "thinking mode" was the rationale behind placing me into such an environment. Living under the same conditions as a trapper and attempting to acquire a similar mental thought process might provide me with a better understanding of traditional knowledge. I was told in order to learn about traditional knowledge I had to think differently. Any "practitioner" of traditional knowledge, when out in the bush or water put him or herself in a particular thinking mode and I was challenged to appreciate the mental ability of living in shack with few commodities for the next five months.

Another benefit of living in a shack in the backyard was my presence in the community. To build relationships, having interactions with as many people as possible throughout the community was crucial. Being able to live in and among people of the community and meeting, conversing and visiting enabled me to develop rapport and trust between fishers and other families. Visiting families and talking about my presence reassured people about my intentions. Gaining the respect of the community provided me with a sense of community, which eventually lead, to a certain degree, to becoming part of the community. Dropping by for coffee, casual conversations not related to any specific topic and offering any particular services to help forged relationships:

> The Aboriginal value of sharing manifests itself in relationships. Relationships result from interactions with the group and with all creation (Little Bear 2000, 79).

> … being in relationships is the manifest spiritual ground of Native being. In traditional perception, nothing exists in isolation, everything is relative to every other being or thing. As Indians are wont to exclaim: "And all my relations". Native thinking in its modality precludes dichotomous categories. In other words, traditional knowledge, as Brown states, is characteristically one of "… interrelatedness across categories of meaning, never losing sight of ultimate wholeness" (Couture 1991, 59).

I had no previous experience working on a boat, handling fish or conducting any kind of 'social research'. Harold wanted me to learn about traditional knowledge by being out on the water: "*In order to properly study traditional knowledge, it is important to be out on the water and I need to be in a mode* [particular frame of mind] *before I can speak*". The meaning behind the comment was for me not to continuously be asking questions, as any social scientist would like to do. An apprentice is quiet and works diligently learning about the land and water by studying the goings-on and patiently waits until the mentor shares knowledge. Only when the time was appropriate did sharing take place.

Before anything else, I had to learn how to work with my elder and develop the skills and work ethic appropriate to work alongside most fishers. The more time Harold and I spent working together, the more the dynamics changed to conform to an apprentice-like relationship. Many times when I came in Harold's house in the morning for a briefing on the day's workload or when we would be eating supper, we would sometimes have discussions regarding traditional knowledge. I learned about what traditional knowledge was for Harold and how he learned as a child from experienced fishers. Many stories of Rocky Bay's past provided me with historical context to appreciate how people worked together and knowledge passed from one generation to the next.

Harold was moving his house back twelve meters to make room for a new one. I was going to help with the preparation work. Being able to spend time together gave us the chance to get to know one another. During the work we would have talks about our "travels in life", family, work experience, etc. By working together almost everyday a relationship was developed based on trust, respect and labor. Having Harold obtain a sense of how I worked and I getting a sense of how to work under his direction furthered the relationship and improved communication. Harold's fishing partner, Dennis Lesperance, helped with the preparation work and we got to know each other well. Donny Onakanakis provided assistance and through helping Harold we got to know each other. Community members would lend help to Harold and I had the opportunity to befriend a handful of people. Learning about principles underlying learning and working alongside Harold became a way of training for the time when we would go fishing together.

Harold asked Donny Onakanakis, a spiritual person of the community, to take me under his guidance to teach me Anishinaabek spiritual aspects in order to appreciate some of the context of traditional knowledge. We practiced ceremony together and spoke about the spirits among us and we discussed fish. I learned about tobacco and other sacred medicines, the sweatlodge and other important principles pertinent to aboriginal ways of understanding the natural landscape. Donny shared knowledge and medicines and views about traditional knowledge. I had the opportunity to participate in sweats on a number of occasions.

The first two months were spent not only becoming integrated into the community, yet gaining experience on the water by helping out the A/OFRC doing the fieldwork on the lake for a week at a time. Before venturing onto the lake with the commercial fishers, I had to learn the basics of a deckhand. The work was physically demanding. I had to learn a whole new set of job skills. Tying knots, picking fish, lifting and stacking fish boxes, boxing the net and having to move out of the way when another was walking down the hall were the new tasks I had to learn and master. Before coming out to Lake Nipigon, I had basically never touched a fish in my life. Duties included quickly handling large volumes of fish by removing individuals from the net, placing the catch into boxes and cleaning economically valuable fish.

Not only properly executing the physical requirements of work, but also being able to function socially among co-workers was essential. Getting along with fishers required a positive and joking attitude. Nobody wanted to hear any complaining or pouting about the amount of work or conditions on the boat; laziness was definitely discouraged. Talking about issues other than the fish was another criteria. Chores on the boat were divided and adhered to. Some responsibilities I had with the A/OFRC were to pick knots from the net as it came out of the setting wheel and was going towards the water. Cleaning the deck, helping with meal preparation, clipping empty jugs of Javex on the cork-line at particular intervals, washing and stacking empty fish tubs and attaching line to anchors. Stowing away and accounting for lengths of rope after lifting the nets from the water was a duty expected by the captain and deck-boss. Recording biological data was a main responsibility I took upon myself on later trips.

Just after the full moon at the end of July, fishers went back to the Lake once the fish had gone deep. I started working with Harold and Dennis. My objective was to become accustomed to working on a fishing boat. Working on the water with Harold and Dennis was not easy at first. Additional responsibilities included dressing, icing the catch and picking fish directly from the net as it was lifted onto the boat without breaking mesh. Crews typically left Monday and returned Wednesday and left the next day in order to return Saturday night. At the end of the day we would relax, eat and laugh. Fishing stories were passed around and at times traditional knowledge was shared. I was reminded not to ask questions and assured knowledge would be shared at an appropriate time when fishers were ready. I had to keep my ears open and be receptive at any particular moment. Traditional knowledge is typically not shared at a time when one is particularly attentive with pen and paper handy. Showing interest and initiative by diligently working the boat, experiencing Lake Nipigon and becoming an integral part of a crew brought me closer to my teachers and the lifestyle. My sponsor reminded me to shift my thoughts about my role and purpose in the community. When thinking about traditional knowledge I could not interpret the subject through my educational context. The need to think differently was the challenge because traditional knowledge was an altogether "*different world*".

6 Fishers' traditional knowledge

Knowledge is entrusted to individuals through storytelling and by passing on teachings and through ceremony. Years of working on the water and studying the environment, with a foundation of knowledge passed down from generations of experience with the lake and its fish, all come together to make a Biinjitiwaabik Zaaging Anishinaabek fisher. Traditional knowledge is a sacred part of an individuals' being; it is a source for survival and a connection to the land and culture. Because every person is a unique individual, the knowledge held by that person is unique. Everyone has a different way of explaining traditional knowledge. People have different teachers, learning experiences, spiritual relationships and aptitude to learn, ability to apply the knowledge and produce new insights. Some may be more knowledgeable than others with particular animals or plants or may have knowledge specific to an area. When someone shares traditional knowledge, it is a reflection of their being. Reciprocating through sharing and creating genuine relationships of trust is important in sharing knowledge.

Having conversations about ones' knowledge, expertise and experiences revealed important insight to what traditional knowledge was to an individual. I did not want to misinterpret what was meant when people spoke about traditional knowledge. Simpson (1999) writes about the implications of researchers defining the term "traditional ecological knowledge" and the inevitable misrepresentation and appropriation of the knowledge. McGregor (1998) writes how defining traditional ecological knowledge determines what will be gathered, documented and then later used by the researcher. The greatest challenge to having someone define a topic with broad implications was the potential to completely miss the entire point of what was being shared.

6.1 Traditional knowledge: "*a feeling*"

In discussions with Harold Michon on the topic of traditional knowledge, I was told that I could only understand or have communicated to me less than 10% of fishers knowledge. The remaining 90% was a "feeling" that cannot be put into words. Harold described the feeling or instinct as one which "*grabbed you in the guts and directed you where to go*". The feeling directed where to set the nets or what area to fish next. The feeling could occur anytime. One could be sitting in his kitchen or targeting fish out in the Lake and the feeling will come.

> *One day I was just heading for South Bay I was going to start planting [setting a net in an ice hole] in South Bay then all of a sudden I stood around drilled my first hole put a little bit of tobacco in there and then all of a sudden it was like something came over me and it says to go to Grand Bay gap and I was thinking: "Grand Bay gap, Grand Bay gap..." and then I says [speaking to fishing partner]: "Let's go to Grand Bay and try it out" so we went to Grand Bay gap and start putting one net and as soon as I hit sixty feet, I stay off at sixty feet because I knew I was going to hit trout, so we started going along the shoreline and the next morning we lifted and the whitefish were thick* (Moses Kowtiash, Biinjitiwaabik Zaaging Anishinaabek fisher).

Every fisher acknowledged the feeling came with spending years working on the water and forging a relationship with the water. Just as traditional knowledge is different for everybody the feeling is different for each person.

> *If you were asked to paint a picture in the same way an artist just did, you could not because you don't feel the same way the artist did* (Harold Michon, Biinjitiwaabik Zaaging Anishinaabek fisher).

Some may have more knowledge than others on a particular topic. Harold mentioned "*Everyone gets at different depths within this world* [traditional knowledge]". A characterization of an active traditional knowledge versus a passive traditional knowledge was made. Active traditional knowledge was the ability to apply what a person has learned and to be receptive to the "feeling" directing a person to a place. Passive traditional knowledge was seen as the ability to only recount stories about the past.

Capturing and representing traditional knowledge is impossible due to the personal nature of the subject. A person like myself learning from knowledgeable people in the community can never take away a feeling, the traditional knowledge, of another. Some authors write about the dynamic nature of traditional knowledge and how it is impossible to capture the knowledge on paper (Cruikshank 1993, Nadasdy 1999).

Fishers were asked to define "traditional knowledge" during interviews or casual conversations. Defining only provided an idea of the community's traditional knowledge that could be summed up in a few words.

> *Traditional knowledge is a science passed down verbally from generation to generation, based on years of gathering, hunting and fishing* (Harold Michon, Biinjitiwaabik Zaaging Anishinaabek fisher).

> Inner thoughts on survival, not only for myself, but also for the people around me. Instinct to survive based on feeling and timing. It comes to the heart and goes to the mind (Dennis Lesperance, Biinjitiwaabik Zaaging Anishinaabek fisher)

> *Traditional knowledge is knowing the area where you live, what you eat and watch what you do all the time. Just by watching and being there all the time* (Moses Kowtiash, Biinjitiwaabik Zaaging Anishinaabek fisher)

> *Traditional knowledge is something taught to you by elders; fishing being passed down from generation to generation* (Abraham Kowtiash, Biinjitiwaabik Zaaging Anishinaabek fisher).

> *I'm taught how to hunt in order to survive. I'm taught how to fish in order to survive. Everything I learn and do is to survive. That, to me, is traditional knowledge* (Donny Onakanakis, community spiritual advisor).

The cultural context of the words fishers and spiritual leaders shared with me and wrote down needs to be acknowledged in an attempt to better represent fishers' knowledge. Many times definitions of traditional knowledge may not reflect the aspect that most of the knowledge is spiritually derived (Simpson 1999). The above definitions may not necessarily make reference to spirituality, yet one must keep in mind the cultural context of definitions that incorporate spirituality. The English words spoken to me still needs to be interpreted in the cultural context of the teachers. I can interpret the physical sense of the words but I need to acknowledge the spiritual.

For some spirituality may be more important than others, as mentioned different people have different spiritual relationships. A fisher or hunter needs to leave with happy feelings because the Creator will only give to you if your heart is "happy". That's because gifts (fish) are given based on what is in your heart. Being a good hunter is not completely based on your technical skill, but what is in your spirit. A fisher or hunter will offer tobacco to the Creator, water spirits or the fish. A ceremony can be performed or a spirit dish can be offered where the fishers will ask the Creator to provide fish and protection while on the water. The Creator provides a fisher or a hunter with the feeling that directs him to an area.

> *"We listen to the land, trees, sky and water and they teach us"* (Gilbert Panimick, community spiritual advisor).

> *When I go hunt beaver, I don't go sit there all day waiting to get a good shot. Based on time of day, temperature, and what I feel inside I just show up and shoot. When it's trout time I get restless, I become more short tempered. The moon dictates this; my mood changes* (Harold Michon, Biinjitiwaabik Zaaging Anishinaabek fisher).

> *When the time comes to hunt moose, I can picture the animal in my mind. I know where they are. When the appropriate time arrives, and the feeling is right I know to go to a certain place and shoot* (Dennis Lesperance, Biinjitiwaabik Zaaging Anishinaabek fisher).

Fish give themselves to the net. Respecting and thanking the fish and the Creator is fundamental. Reciprocating what the Creator has been given with tobacco is important in keeping a balance. A fisher can never ask for too much or become disappointed with what was given. I was told about a particular fisher, who had since past away, that would not bring too many fish tubs to the front of the boat at once because such an action was asking for too much. One must not waste fish because such actions will offend the spirit world and can affect future catches. One fisher described himself as becoming so involved and absorbed in his work that while targeting he becomes the fish.

When fish are caught in the commercial net, any live bi-catch (typically fish other than lake whitefish, lake trout and ciscoes) must not be returned to the water. Respecting and maintaining the "balance" among the populations of fish in the water needs to be accomplished. Fishers say humans should not alter the population of one species without balancing out other populations of other species. If lake trout and lake whitefish are removed while bi-catch such as suckers, burbot and herring are placed back into the lake alive, their populations may alter the allocation of resources for other species in the area. All harvested fish are killed, apart from juveniles that are placed back into the lake.

Harold Michon was the only fisher who formally described traditional knowledge as a "science" implying the presence of a methodical process behind fishing. A good fisher/'Native scientist' will listen to the feeling pushing him to go at a certain place at a certain time when the conditions are right. Noting everything in the surroundings, for example, the amount of leaves on trees, temperature of the wind, precipitation, moon phase, when the feeling arrives will a hunter know to return to a particular place when those conditions return. Keeping an eye out for the appearance of loons, otters and eagles can help a fishers to decide where to set nets because "*...those animals are fishermen, like us*" (Moses Kowtiash, Biinjitiwaabik Zaaging Anishinaabek fisher). Through the years of keeping track of the time and place where nets are set, noting catch composition, keeping of track of environmental indicators and parameters and comparing trends between years, a base of information is created and passed on. Depth is mentally recorded (with the use of an electronic sounder or a rock on a string), moon, temperature, catch composition, size of fish and location of fish within the net are examples of what is noted. All knowledge passed on or personally accumulated help target fish: *Where we fish is where the fish are* (Moses Kowitash, Biinjitiwaabik Zaaging Anishinaabek fisher).

The fishers themselves continuously test the validity of traditional knowledge. Areas historically fished by ancestors and sets commercially fished in the past are still used. Every good fisher studies, looks for patterns and take mental notes to benchmark in order to keep track of the quality of the catch. Another key to being a good fisher is to move around Lake Nipigon and fish in different areas. Moving around also ensures the protection of younger year class in each area, the possibility to catch mature year classes in the new areas, the harvesting of different stocks of fish, and the capability to learn and monitor many areas of Lake Nipigon. While cleaning the day's catch around the gut-barrel, many times I would notice the more experienced fishers point out whether the fish previously caught in the area were of a different size class, or if any physical changes, such as size and color, were apparent among the fish and if the composition of the catch was any different. Any anomaly in fish found by one would be shown to the others in order for them to note for future reference.

A good fisher would listen to stories and remember what was taught. Stories about the past would always be listened to because each included a basic important principle of traditional knowledge: time and place.

> *Listening to elders is one of my biggest things because I used to sit around elders a long time ago. There were a lot more elders when I was younger there was a lot around the ages of sixty-five and seventy. When I was younger I would listen a lot to the older people when I would sit around*

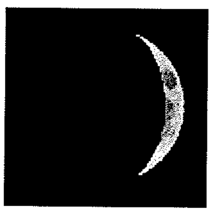
> *cause I was raised by my grand-parents and we used to visit the elders, like when we used to visit we had to sit around and listen and a lot of them used to talk about stories about how we used to get good fishing over here at such and such a time and some would say "Oh yeah I remember getting good fishing over here or over there"* (Moses Kowitash, Biinjitiwaabik Zaaging Anishinaabek fisher).

Harold Michon stated: "T*raditional knowledge begins with the solving of a puzzle*". The concept of the puzzle applies to anything from wanting to know, for example, the location of caribou at particular times of the year or the timing and depth of whitefish spawning at a particular location. An ancestor long ago encountered a problem, studied the problem and solved the issue with patience. The knowledge gained is then placed into a story and passed onto the next generation. As stories are passed down, people will return to an area at the same time and place, as instructed in the story, and may not necessarily know why they are present. All that is known is there is a need to be at a particular place because there will be plants or animals to feed your family.

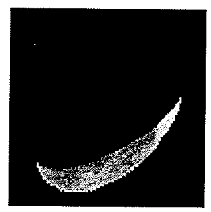
6.2 Fishing by the moon

Elders who shared traditions and knowledge with the younger generation through stories have passed on teachings pertaining to the relationship between moon and fish. In the web of Anishinaabek relations, the moon is Grandmother. Generations upon generations of family occupation throughout the Lake Nipigon region have correlated lunar phases with the timing of events pertinent to the harvest of fish. The moon provides a reference for the timing spawning, depths and movement of Lake Nipigon fish throughout the year. Even with the arrival of a commercial fishery on Lake Nipigon, the practice of fishing according to lunar cycles has been passed-on, adopted and adhered to by aboriginal fishers.

Harold explained that in Anishinaabek culture, every phase of the moon in each month has a name and reveals something about the land. Examples of events the moon signals are the arrival of waterfowl in the spring, harvest for white and longnose suckers, moose rut and whitefish and lake trout spawn. An example is the "*wet moon*" (Fig. 2). The tilt of the crescent moon changes in the month of October with the oncoming of the fall season. Initially, the tilt of the crescent moon resembled a bowl. The moon at such a position was said to be catching water. When the October crescent moon arrives with a change in angle, the bowl was tilted and the spirits were pouring water onto the land in order to, for example, draw moose out to feed and drink.

*


"The bowl (moon) is catching water"



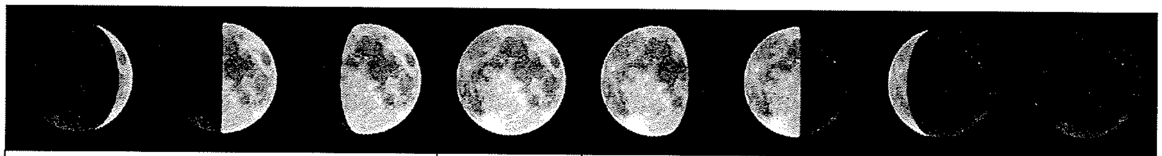
"Wet moon"
Water is poured out of the bowl.

Figure 2. The October 'wet moon', according to Harold Michon.
*All lunar illustrations in the thesis are from the Time Services Department, US Naval Observatory (2002).

Many animals in the fall are preparing for the winter and are drawn to water. The moon can be an indicator of animals being drawn to bodies of water and is a sign for the timing of a moose hunt. Moose in the fall are drawn to bodies of water and the proximal location of the animal to water makes the hunt, kill and transportation of game much easier by boat. The wet moon is a signal of precipitation coming either as rain or snow.

Lake Nipigon fishers say it is better to cease fishing when the moon is full because the effort to catch any fish increases dramatically. Fish become more stationary at their particular depth on a full moon. Fishers notice a remarkable difference from catches between a full moon and the subsequent phases when the moon wanes and waxes

(Fig. 3). Catches during the full moon when compared to those on the new moon have a 75-80% difference. Just after a full moon catches increase approximately 15% during each two-day period. No one knows for certain why the fish behave in such a manner. As soon as the moon changes to a darker phase the fish will move. Catches increase with the waning and slowly decrease with the waxing of the moon until full.



Waxing moon "Bright side of the moon"	Full Moon	Waning moon "Dark side of the moon"	New Moon

Figure 3. Lunar phases throughout a month.

After full moons, an increased amount of what fishers describe as "freshwater shrimp" (decapods) can be found in whitefish, sucker and cisco gut contents. Fishers view shrimp as hatching according to a full moon and are subsequently followed and predated upon by fish. In the early part of summer-fishing, shrimp follow the thermocline and throughout the month of June, as the water heats up, move towards the bottom.

7 Fishers' knowledge of lake trout

7.1 Lake trout stocks

According to fishers, four sexually isolated stocks of lake trout inhabit Lake Nipigon. Three stocks are named according to morphological features while the fourth is named after an ecological attribute. The stocks are called (1) 'blacks', (2) 'browns', (3) 'silvers' or 'greys' and (4) 'deep-water' (Fig. 4). Fishers say 'blacks' and 'browns' are native to Lake Nipigon while the 'silvers' and 'deep-waters' are introduced stocks. Each stock possesses unique characteristics (Table 2).

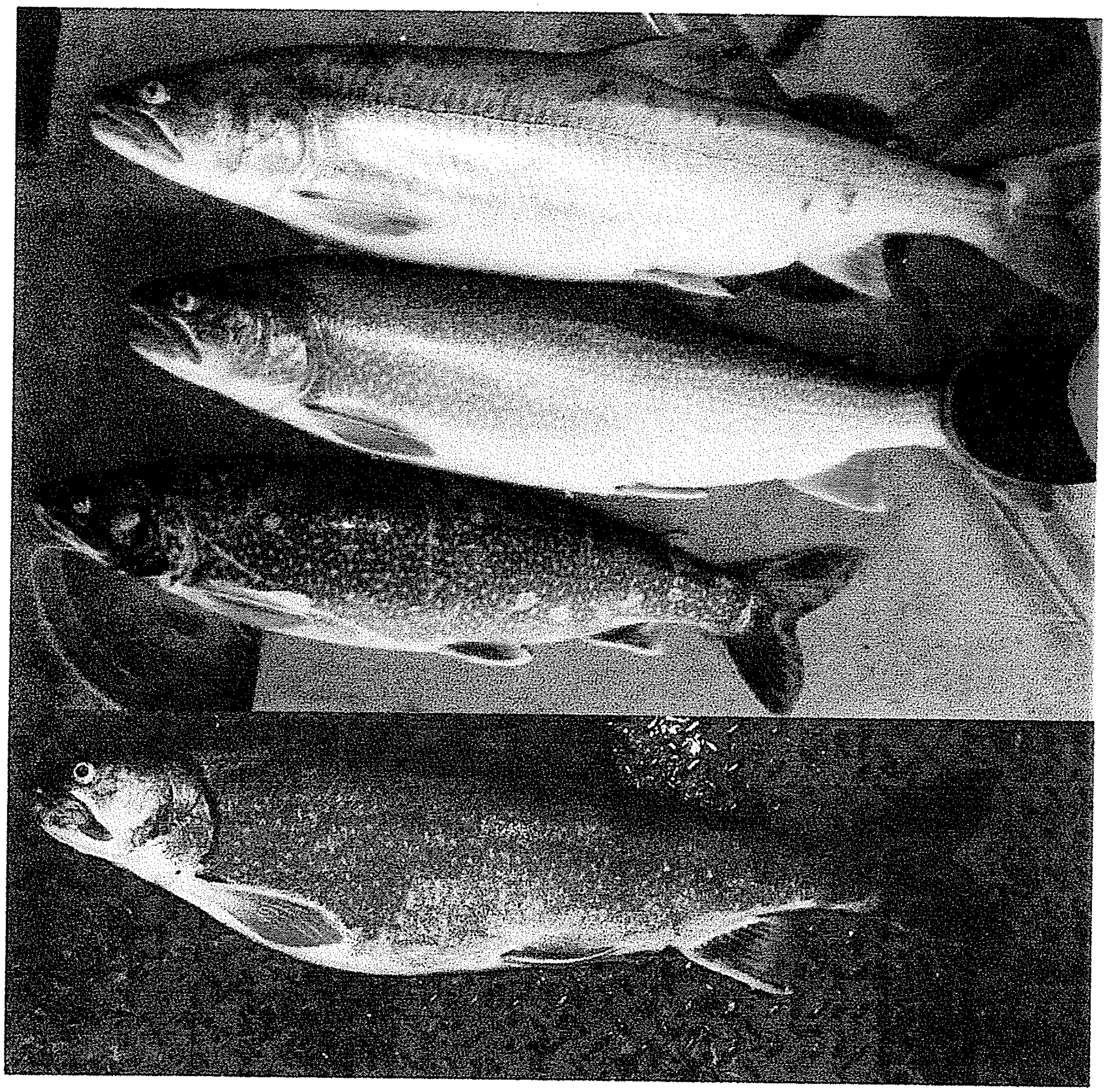


Figure 4. 'Silver' (top), 'brown' (second from top), 'black' and 'deep-water' (bottom) stocks of Lake Nipigon lake trout. Photo: Colin Gallagher.

Table 2. Attributes of Lake Nipigon lake trout stocks according to fishers.

	Blacks	Browns	Silvers/greys	Deep-water
Morphological characteristics	Black colouration of the body. Margin of the fins black, pronounced in the anal fin. Black opeculum. Ventral area white in colour with a hatched pattern of black lines. (Fig. 5) Shortest head relative to body length. Eyes closest together compared to other stocks. Smaller 'blacks' will have small white circular dots throughout body. (see fig. 5). Larger 'blacks' typically have large rectangular white spots below lateral line.	Brown colouration of the body. Margin of the fins brown, pronounced in the anal fin Brown operculum. Ventral area white in colour with a hatched pattern of brown lines. (Fig. 6) Slightly concave head.	Silver colouration of the body, pronounced above lateral line. Margin of the fins a dark grey, pronounced in the anal fin. White operculum. (Fig. 7) White ventral surface. (Fig. 8) Longest head relative to body length compared to 'blacks' and 'browns'. Flat head.	Grey colouration of the body. Grey fins, white operculum. White ventral surface. Largest/longest head relative to body length. Largest fins, largest eyes, largest distance between eyes and large gut.
Length (Trout caught in 4.5" gillnets)	Shortest Generally: 75-99 centimeters (2.5-3.3 feet).	Thickest/stockier Generally: 84-105 centimeters (2.8-3.5 feet).	Second longest Generally: 99-117 centimeters (3.3-3.9 feet).	Longest Generally: 99-123 centimeters (3.3-4.1 feet).
Weight (Trout caught in 4.5" gillnets)	General range: 3.6-9 Kg.	General range: 3.9-9 Kg.	General range: 2-11.3 Kg.	General range: 9-16 Kg
Timing of spawning	Spawn in late September. Approximately one week after September full moon. Spawning occurs on shallow shoals.	First to spawn. Generally between the third and fifteenth of September. Spawning occurs on shallow shoals.	Generally spawn after the September full moon. Spawn after blacks. Spawning occurs on shallow shoals.	Last to spawn. Late October and early November. Spawning typically occurs in deep waters (~ 18 m).

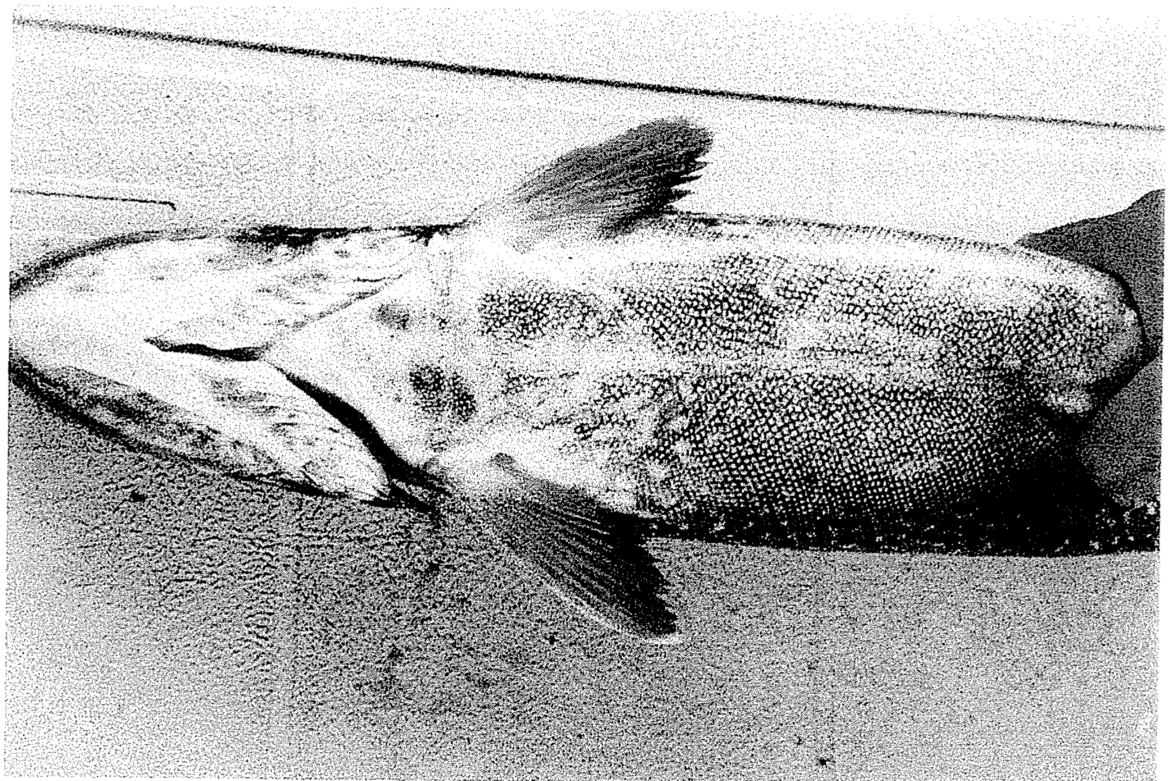


Figure 5. The ventral surface of a 'black' Lake Nipigon lake trout. Photo: Colin Gallagher.

Figure 6. The ventral surface of a 'brown' Lake Nipigon lake trout. Photo: Colin Gallagher.

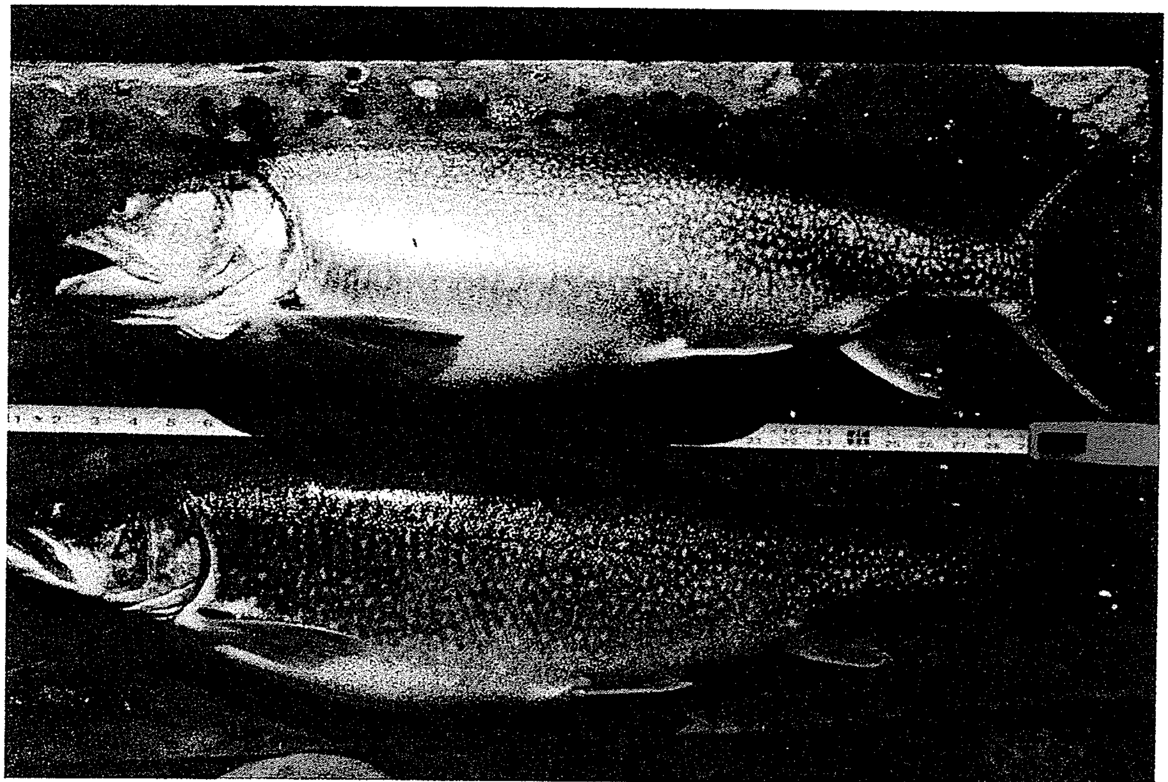


Figure 7. 'Silver' (above) and 'brown' (below) Lake Nipigon lake trout.
Photo: Colin Gallagher.

Figure 8. The ventral surface of a 'silver' (above) and 'brown' (below) Lake Nipigon lake trout. Photo: Colin Gallagher.

7.2 Geographic distribution

Fishers mention that prior to the introduction of 'deep-water' and 'silver' lake trout and the invasion of smelt (*Osmerus mordax*) into Lake Nipigon, 'blacks' and 'browns' were found together throughout the lake although a distinction could be made between areas north and south of Kelvin Island. 'Blacks' were predominantly concentrated in the northern portion of Lake Nipigon while the 'browns' were present to a larger extent in the southern areas of the lake (Fig. 9). 'Browns' were never found in the extreme northern areas of the 'blacks' distribution and 'blacks' seldom-occupied far southern reaches of Lake Nipigon. Although the distribution of 'browns' and 'blacks' overlapped, schools of the two stocks rarely mixed, making it possible for fishers to target a particular stock.

'Silvers' and 'deep-waters' gradually spread throughout the Southern portions of the lake, roughly occupying the same area as 'browns' (see Fig. 9), and rarely occupying northern areas. Lake trout inhabited depths generally greater than 20 meters throughout the lake. Kelvin Island is a point where the general distributions of the stocks converge and a reference point to delineate the geographic distribution of each stock. The island is seen as good 'trout grounds', whereby a fisher can be guaranteed to catch lake trout. Kelvin Island possesses multiple steep underwater edges (fast edges) and rugged topography that lake trout occupy in large numbers.

The advent of smelt, noticed by fishers in 1977, has changed the distribution of lake trout stocks throughout Lake Nipigon. Lake trout started to follow schools of smelt, rather than ciscoes, in order to feed. The great abundance of the new food source has increased the number of lake trout, and has shifted their distributions. Fishers, while

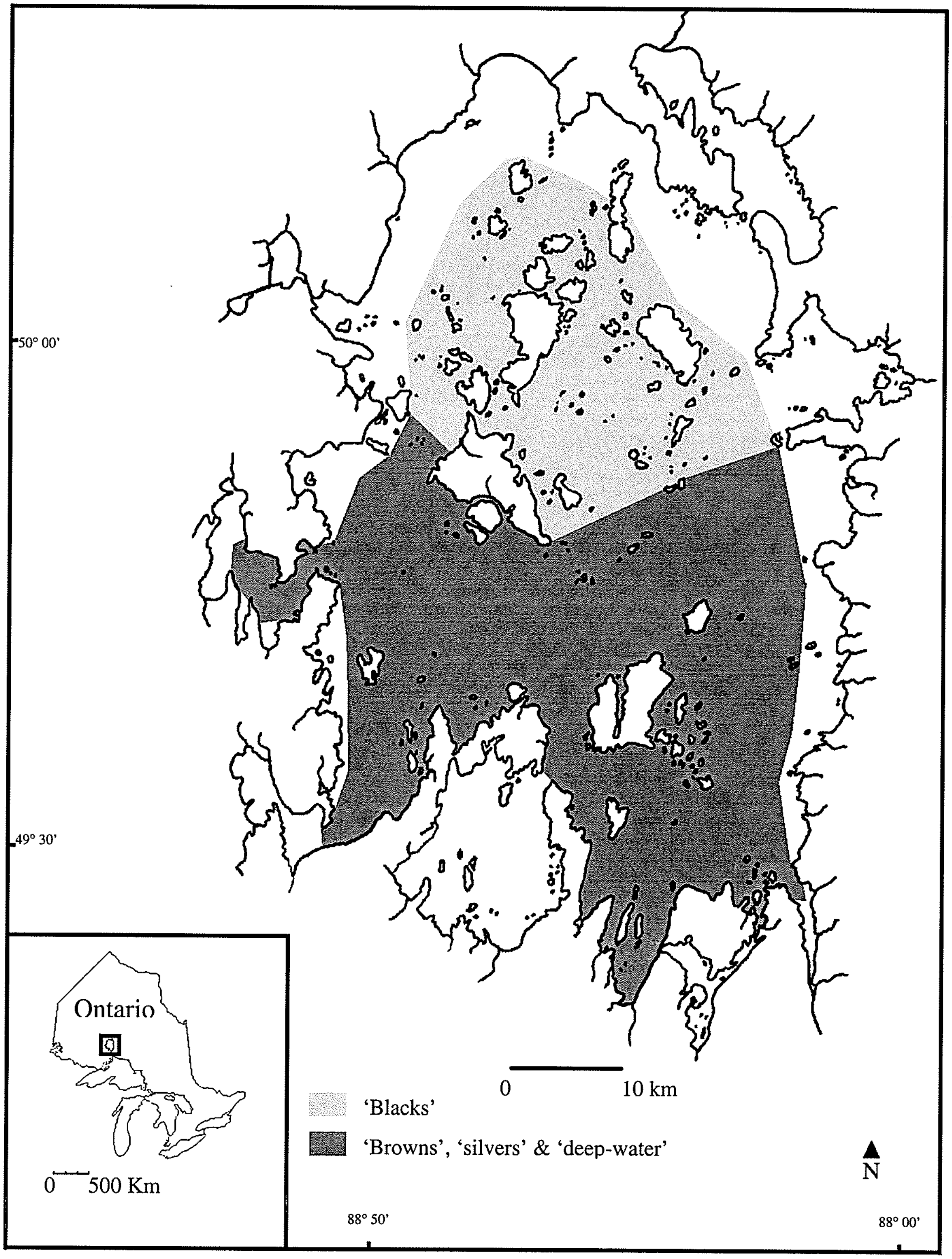


Figure 9. Distribution of lake trout stocks prior to the invasion of smelt (approx. 1977). Shaded areas delineate the primary distribution of stocks still observed subsequent to the invasion.

targeting for lake whitefish, are now catching lake trout in areas in which historically they did not occur (Fig. 10). The harvest of lake trout near the Ombabika gap was unheard of in the past, yet there have been increased numbers of lake trout caught in that area. Macintyre Bay was devoid of lake trout, although some trout would spawn just inside the Bay. Since the invasion of smelt, the entire bay has become populated by lake trout. Humbolt Bay has been heavily invaded by lake trout since about 1995. The distribution of Lake Nipigon lake trout stocks has changed through the occupation of shallower waters. The stocks are also pushing the margins of their distribution with more 'blacks' being caught in the south while the remaining stocks being caught in greater numbers in the north.

A fishers' ability to target a specific stock has been all but lost. Lake Nipigon is now described as a mixed bag of lake trout with all stocks found together throughout the lake. 'Browns' and 'silvers' are caught, in small numbers, on the Ombabika flats. 'Blacks' are harvested in Macintyre Bay. However, even with the original distribution of stocks expanding, the northern and southern characterization of 'browns', 'silvers', 'deep-waters' and 'blacks' remains. The greatest abundance of 'blacks' remains the north and the 'browns', 'deep-waters' and 'silvers' are concentrated in the south.

Lake trout have become fatter since feeding on the smelt. The meat of the lake trout used to be a brighter red but has since become more white and greasy with layers of fat. People in the community eat less lake trout than before the smelt invasion because of the changed taste.

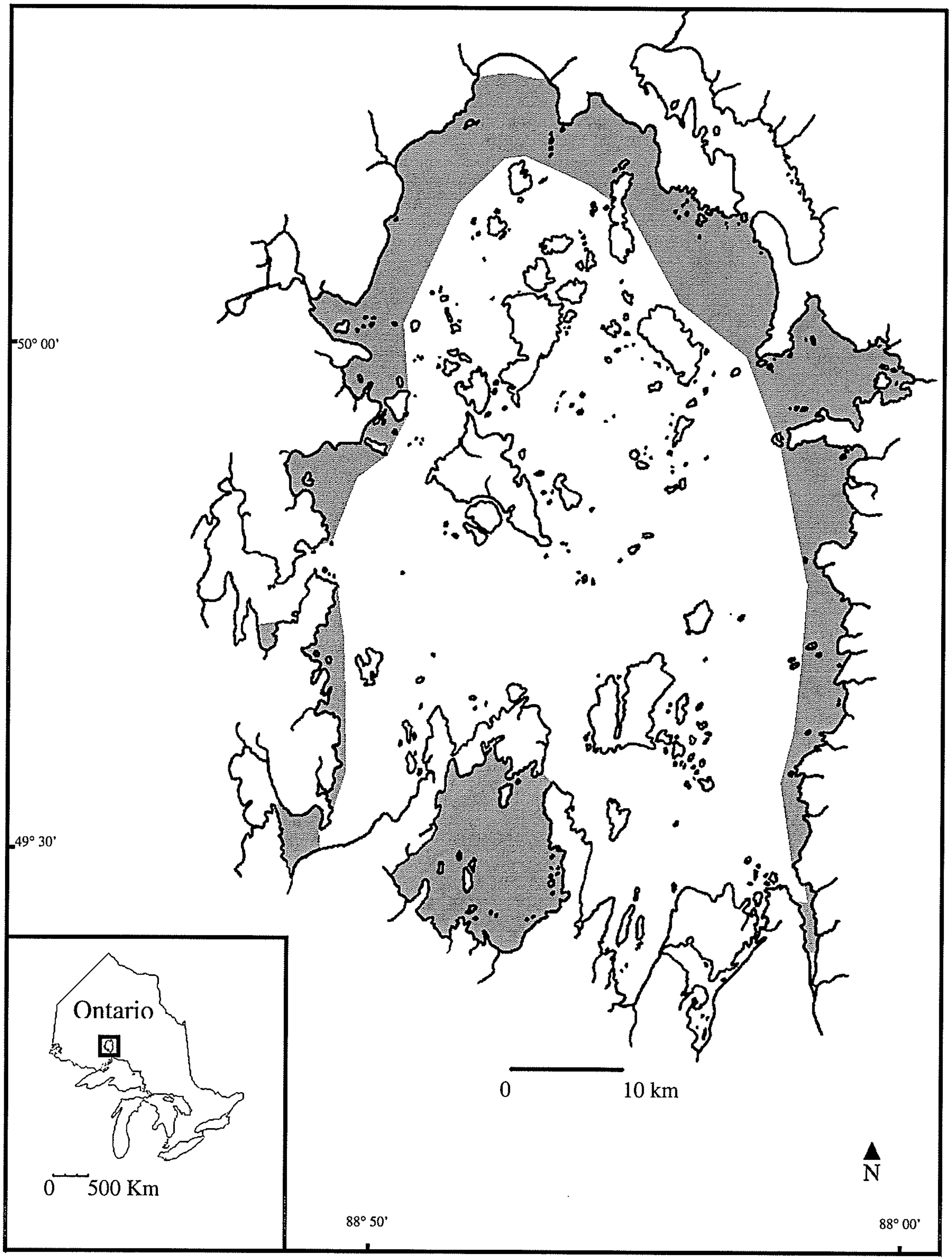


Figure 10. Shallow waters and bays occupied by lake trout only since the invasion of smelt.

7.3 Vertical distribution of lake trout

Lake trout change depths throughout the year mainly following their primary food source in order to feed. Each month lake trout generally occupies a different depth and fishers must adjust gear accordingly in order to target for lake trout. Lake trout occupy a particular depth at which they can be located at most times. The "dominant water" for lake trout is approximately 24 meters. Generally, lake trout are found near and below or near and above the dominant water.

Lake trout will vary in depth throughout the year (Fig. 11). According to fishers, during winter months, lake trout occupy the bottom of the lake whereas in summer and fall there is two separate migrations towards the surface separated by a month spent at the bottom. Generally a change in depth is noticed each month. Fishers speak about the change in the depth of fish by equating the change to the full moon of the particular month, referred to as "moon". Some "moons", or months, are better to harvest fish over others. Full moons of a particular month can roughly indicate to a fisher the particular depths at which fish can be targeted.

Fishers can nets (place nets close to the surface) in June because lake trout and lake whitefish are found near the surface and close to shore. Lake trout are found to a greater extent at a depth between 4 and 12 meters from the surface yet can generally be found to a depth of approximately 24 meters below the surface. Most species of fish are located near the surface of the lake, making June's full moon a "*good moon*" to catch fish.

The July moon is considered to be "*a bad moon*" to fish for lake trout and lake whitefish, since most fish are found halfway between the bottom and the surface. When

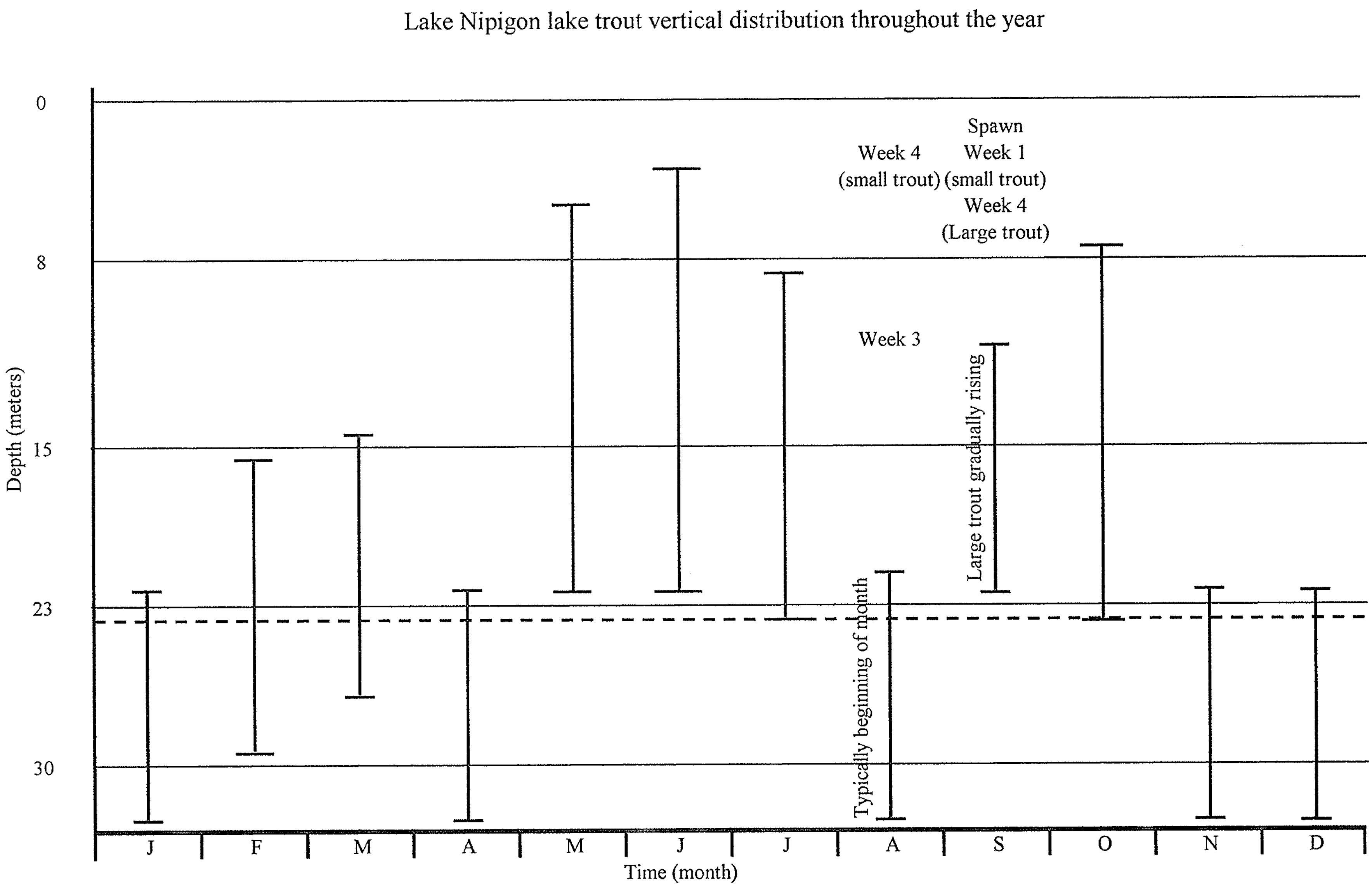


Figure 11. Approximate depth of lake trout throughout the year.

- - - - : "dominant water" for lake trout (approx. 24 meters) fish are located in mid-water, setting nets becomes more difficult and the effort is not worth the economic returns. Lake Nipigon mid-water is approximately at or just above 12 meters and lake trout occupy between 9 and 21 meters of water.

The August full moon is "*good*" for lake trout because the lake trout and whitefish have gone deeper beyond mid-water and are at or near the bottom of the lake. A sign the lake trout have gone deep is the arrival of young-of-the-year gulls typically seen during the first week of August. Harold was told a story by his grandmother about lake trout and how gulls must dive deeper and work harder to get to the fish in early August; the lengthy story goes on for a day or so. Lake trout, once they go deep, are found near or at the bottom at depths ranging between 21 and 27 meters. Closer to the end of the month, some small and medium sized lake trout begin to slowly surface in order to prepare for spawning.

September is the beginning of the spawning season for lake trout. Lake trout can easily be harvested during a period as they come to shallow waters for spawning. Lake trout which have spawned in September start to go back to deeper waters during the October moon in order to feed. Nets could be generally set, especially near the end of the month, at depths of eleven meters; near mid-water.

Lake trout in the months of November and December are near the bottom, on average fifteen to 22 meters with some at bottom. January moon, like August, is another good moon for harvest because lake trout are found at the bottom of the lake. Ice fishing during the February moon is "*bad*" because the lake whitefish and lake trout have risen on average 5 meters off of the bottom with some being found near mid-water only to go back down during the months of March and April.

The 'deep-water' stock of lake trout does not follow the similar extent of annual vertical distribution as the other stocks. The 'deep-water' lake trout generally occupy a depth of 37 meters. The 'deep-water' will not necessarily be found in great abundance above the "dominant water" level.

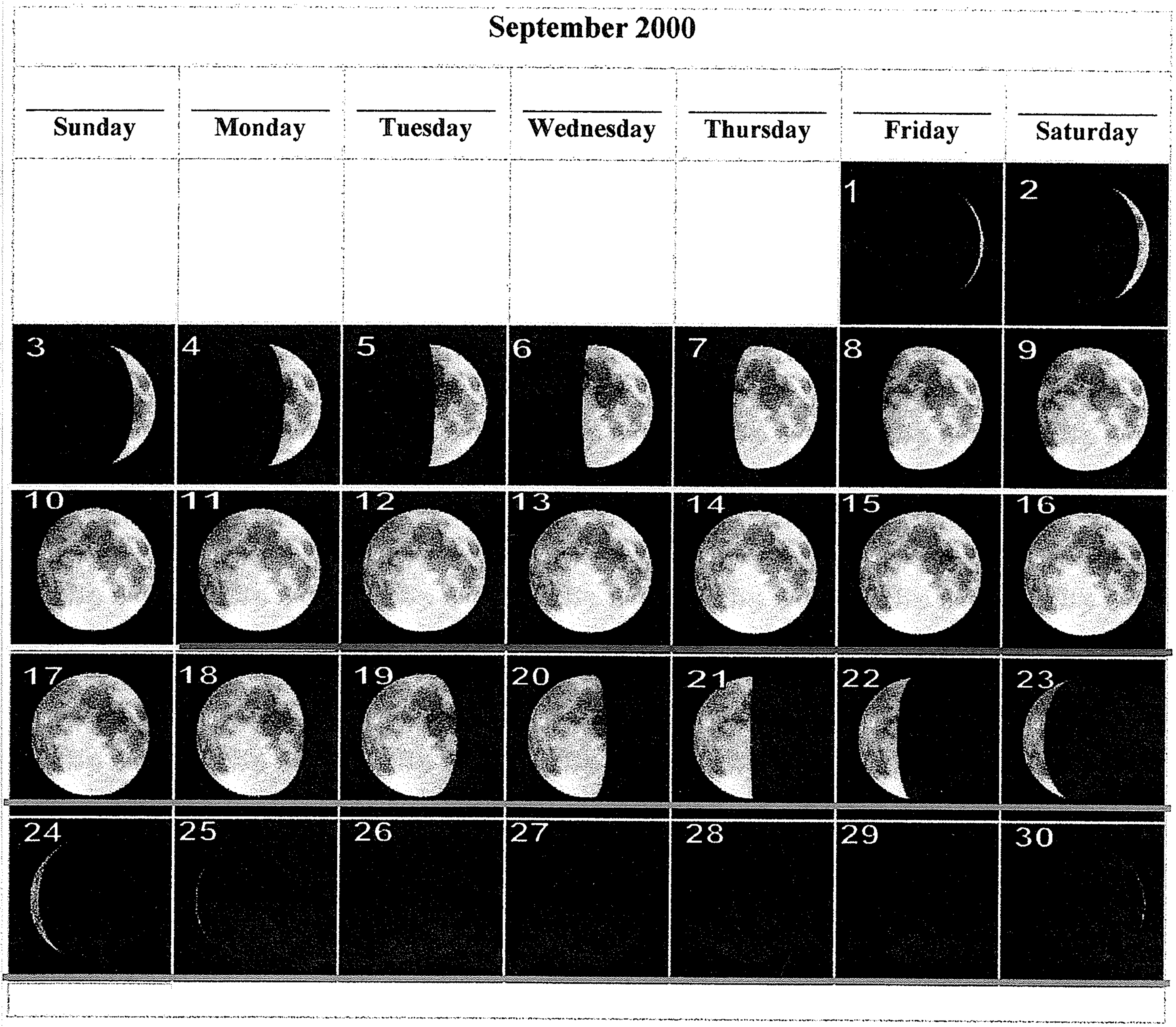
7.4 Lake trout spawning

Lake trout gradually rise and travel towards the spawning shoals. In late August and very early September, the lake trout begin to rise in successional steps of six to nine meters per week, moving towards the spawning areas. Smaller sized 'brown' lake trout are primarily the first to arrive upon the spawning areas. Lake trout will gather together into "spawning pits" before going onto spawning areas. Spawning pits are deep holes located near the shallow spawning areas where lake trout will congregate, awaiting for the proper moon, to travel up in one single move to arrive upon the shoal to spawn. During the spawning period, lake trout cease to eat. Catches of lake trout during spawning have empty stomachs. In the spawning pits, Harold mentioned lake trout are "*packed together like cordwood barely moving, looking at the moon*" waiting to spawn.

According to fishers' knowledge, spawning begins in stages during September. Two distinct periods are observed: pre-spawning and the spawning period. The two periods are split based upon the September full moon. Pre-spawning begins on the "trout moon", a phase between the crescent and half-moon on the bright side of the full moon. Spawning takes place after the full moon. Pre-spawning is characterized as a period of smaller-scale active spawning with the presence of relatively smaller males in greater abundance than small females. Overall, there are only small numbers on the spawning areas at night, with the males present to "milk" the few females and clean the spawning area. Lake trout will clear accumulated silt from the spawning areas by fanning debris with their fins. Three to four days before the full moon, males prepare the beds for the actual spawning (Fig. 12).

The general dates for the spawn for the majority of the small to medium sized 'browns' is between September third and fifteenth "plus or minus moon". Each year, the full moon of a particular month occurs during different weeks. Just as the date of the September full moon changes each year, so does lake trout spawning. "Plus or minus moon" is a reflection of the changing date of the full moon. In the year 2000, the September full moon appeared on the tenth, thereby the "trout moon" occurred on the third. In 2001, the full moon occurred on the tenth and the trout moon on the 26th of August. Fishers say that the spawning occurs "*plus moon*" from the September third and fifteenth dates spawning typically start. In 2002 the September full moon will occur later in the month and the fishers will describe the timing of the spawning as "minus moon" from the third and fifteenth as the observed spawn will then occur later in the month.

Upon the arrival of and for the duration of the September full moon, activity on the spawning areas dramatically decreases, and the lake trout typically remain in the spawning pits. Not until the arrival of the first sliver of darkness of the waning gibbous moon does spawning commence with great intensity. When ready, lake trout will come onto the spawning areas with the current and spawn against the current. A majority of the 'browns' are found on spawning beds, potentially accompanied by 'silvers'. The 'browns' are usually first to spawn in small numbers during the pre-spawn and for a short time after the full moon. The 'silvers' follow closely after the full moon, and the 'blacks' generally spawn in great numbers the week after the 'silvers'. The timeline for the



Pre-spawn.

General pause in spawning activities.

Spawn.

Figure 12. Lunar phases and significant timing events of the lake trout spawning.

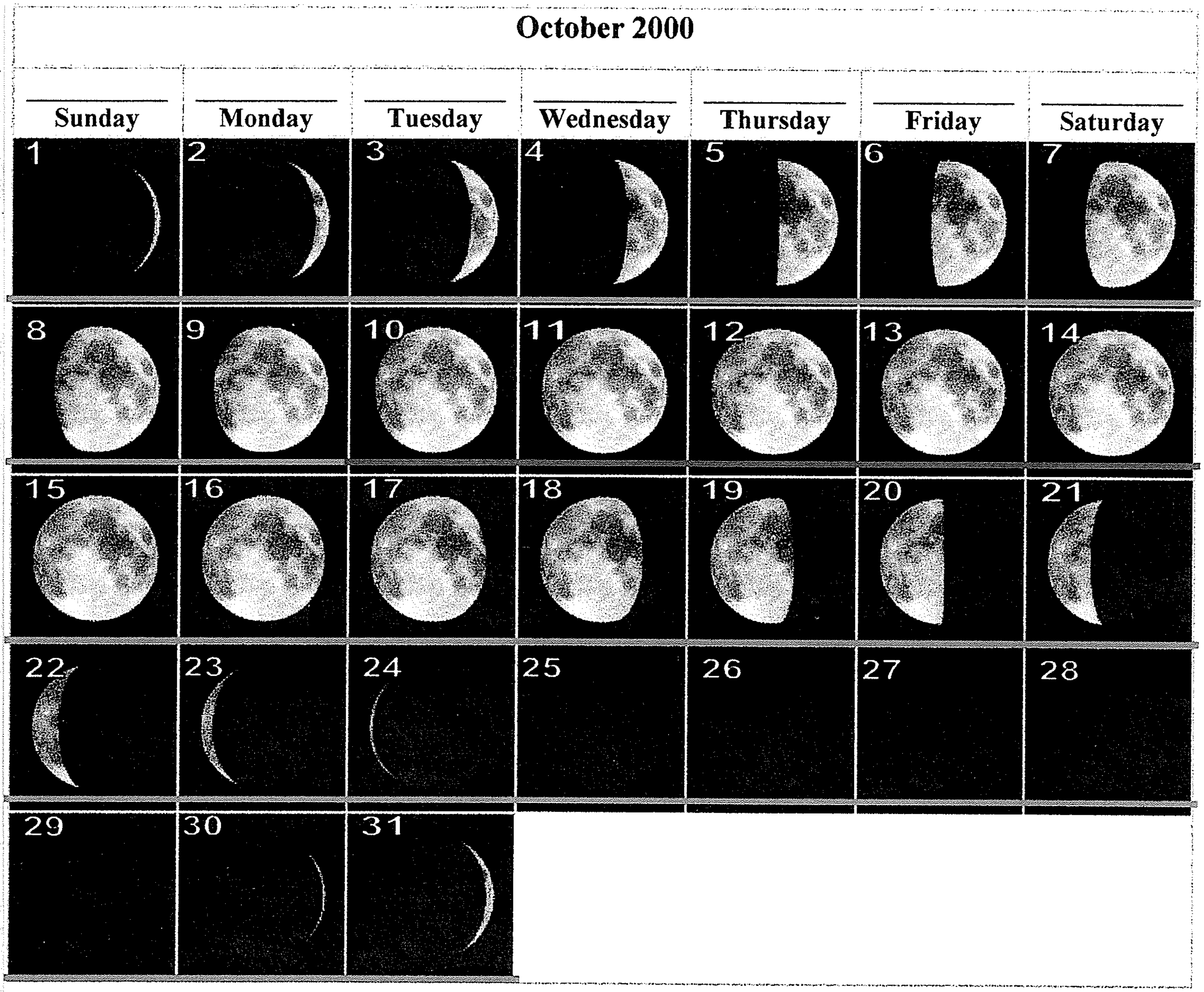

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Fig. 12. Cont'd

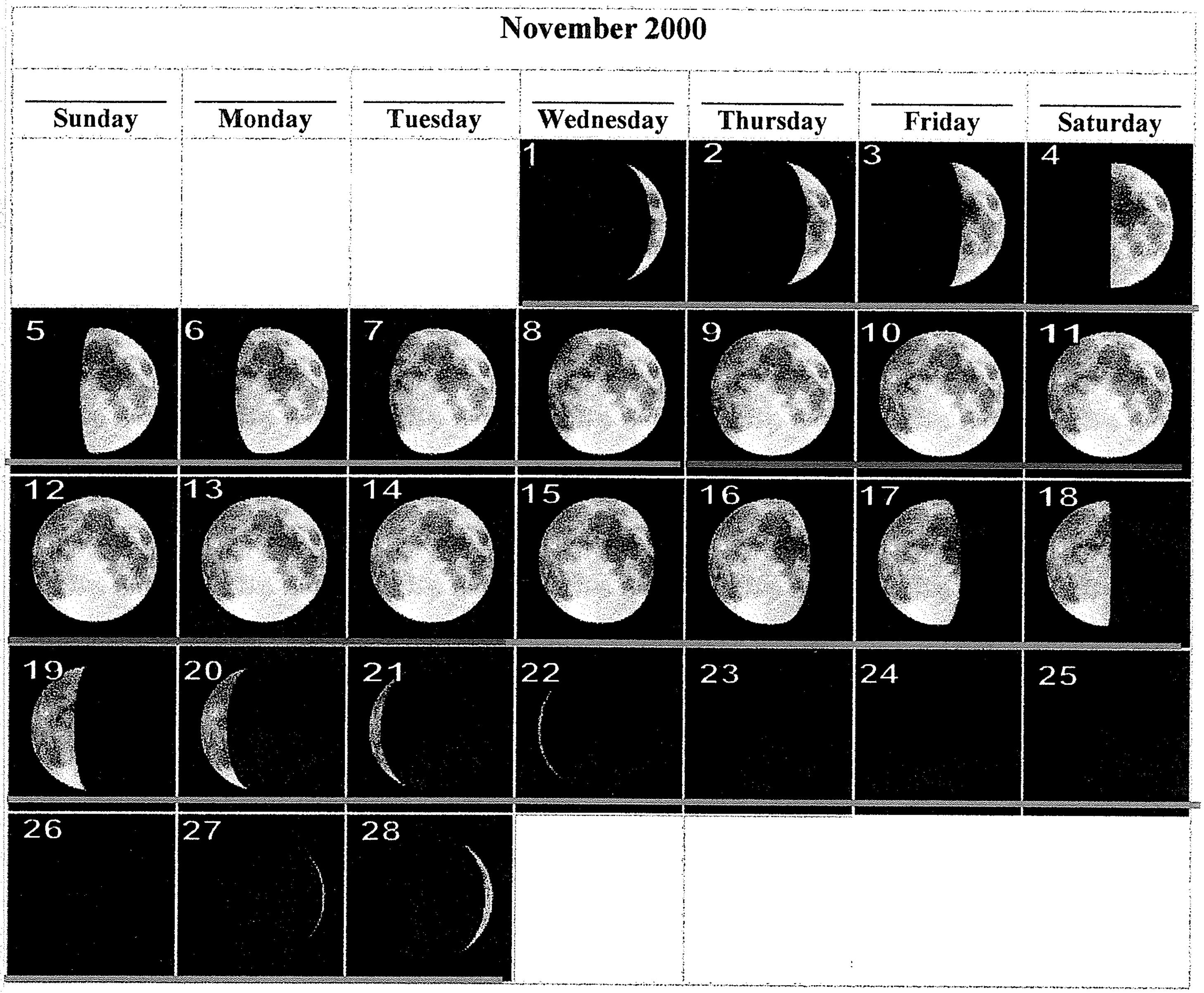
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Fig. 12. Cont'd.

majority of the spawn for lake trout will occur until the October full moon. The large-sized lake trout will come upon the spawn bed just after the October full moon until the November full moon. The larger lake trout are slower to rise in the successional steps compared to the smaller lake trout. The numbers of fish spawning between the October and November moons are decreased significantly.

After the November full moon, the majority of 'deep water' lake trout will spawn. The 'deep-water' stock will generally spawn at greater depths than the three other stocks. 'Deep-water' lake trout spawn between 37 and 18 meters below the surface. The majority of the spawning activity will generally continue until the next full moon.

Particular spawning areas can be utilized by each of the different stocks of lake trout. All four stocks can use spawning areas near Kelvin Island. Fishers have caught different stocks of lake trout on a single spawning area at the same time. A lake trout may come up to the spawning area overnight but will not necessarily be ready to spawn. Fishers are adamant that the "milk" of one stock will never fertilize the eggs of another. The timing of the spawn is the only segregating factor, according to fishers, separating lake trout stocks.

Lake whitefish go through a similar period of cleaning the spawning areas yet do so in order to decrease predation by Northern pike. Fishers notice that lake whitefish go through a "false rut". The false rut is the precursor to the actual spawning. The false rut is characterized as the presence of large "old sows" (old females) nearing the end of their lives with an even greater abundance of smaller young mature males. Both males and females, according to fishers, clean the spawning beds of accumulated silt, and to draw the attention of Northern pike, the main predator during spawning. Pike can easily predate upon the large volume of whitefish within the area during the spawning season. The false rut lures the pike to feed on the young males and the old females. With the majority of pike having fed, less will be present in the area during the actual spawn. Eggs laid by old females may not necessarily be viable as ones in younger population cohorts. Suckers are found in abundance on spawning beds eating eggs. By having eggs from old females more available to suckers, the better the chances are for eggs from younger females not to be eaten. Those lake whitefish, which are the least important part of the population, are sacrificed to the pike in order to increase the odds for the prime whitefish. Protecting the females rather than the males ensure an abundance of eggs laid on the spawning beds. Lake trout are different from lake whitefish because of their status as a predator. Pike will not approach lake trout spawning areas. Fishers say there is no need for a false rut in order to sacrifice individuals for the good of the overall population.

7.5 Lake trout population cycles

Until the 1970's, lake trout populations went through abundance cycles every seven years (plus or minus one year) from peak to peak. The lake whitefish cycle was five years. Lake trout cycles followed cisco cycles. Fishers could follow the cycles by noting the abundance and size distribution of lake trout. When fishers noticed an abundance of large lake trout with an overall decrease in catch, the population cycle was at the bottom. When the cycle peaks, lake trout are in greater abundance while the size of lake trout decreases. Lake trout were low in the early nineteen-sixties, high in the late sixties and low in early seventies. The cycle was at a high peak in the late seventies when smelt invaded and have substantially increased since. No one has observed a distinctive population cycle of lake trout since rainbow smelt invaded Lake Nipigon. The fishers say the population cycle for Lake Nipigon lake trout has been disrupted due to the presence of smelt.

8 Conclusion

Participants from the community shared knowledge in regards to the land and water, including lake trout, in the context of Anishinaabek culture. Gaining a better appreciation of traditional knowledge from a non-aboriginal and academic viewpoint required a shift in thought and research process (Gallagher 2002). Attempting to learn knowledge from the community's perspective required submission to the conventions laid out by elders and teachers. An attempt to change the way I perceived commercial fishers, the community, the culture and the environment was requested and fostered by those who were proactive in communicating traditional knowledge through words and experiences.

The shift in perception required intensive experiences, time, and an acceptance on my part, of what those involved wanted to accomplish. A change in mind, body and spirit was cultivated through learning on and off the water. Being deprived of familiar environments, the fishing experience itself, and getting rid of my expectations as a researcher provided the necessary elements for change. A graduate student may measure progress by the amount of data acquired and have research as the primary objective. Through rigorous training and working relationships, the learning process paralleled the way traditional knowledge is typically passed on in the community.

I slowly adopted the role of apprenticeship in order to learn traditional knowledge. I had to work for knowledge without expectations about receiving materials directly on my thesis area. I gradually learned to wait for the proper place and time to receive knowledge. Over time, I learned not to think about the thesis and my field notes, and to concentrate instead on doing the assigned tasks on the boat. People and relationships, rather than the progress of the thesis, became the primary objective. I felt like I was not conducting research, but existing as an everyday community member in training to develop the skills to be a good deckhand. The experiences did change my mind, body and spirit. The people I met in the community changed my perspective through making me appreciate aboriginal ways of knowing. My body was physically put to the test by working as a deckhand and enduring the rigourous training required to properly execute tasks. Participating in ceremony enlightened my spirit.

The methods used for traditional knowledge were a combination of participation and experience. The results were not only measured as the amount of knowledge acquired, but the amount and degree of relationships developed. The aptitude to learn and apply the knowledge and training were also a measure. The product of "research" surrounding traditional knowledge was not necessarily what was placed on paper, but my personal development as an apprentice. The knowledge and experience acquired by the apprentice resides in the apprentice rather than in the thesis. Attempting to immerse in the culture and community and opting to transform perceptions of my surroundings provided a framework for "...embarking on an intellectual adventure to connect more deeply with Indigenous ecologies", as Battiste and Henderson (2000, 39) describe. Life experience, personality, age, maturity and whether an elder was confident in the ability of the apprentice to receive knowledge determined the transmission of traditional knowledge. Such an approach placed the control of the learning process and what knowledge was shared into the hands of the community.

In the context of fishers from Biinjitiwaabik Zaaging Anishinaabek, I have learned that traditional knowledge is:

> A personal knowledge used to survive and is developed through learning mind, body and spirit from teachers such as elders or from the fish and water. Through years of working the waters, a feeling is developed, based upon environmental and spiritual indications, directing the fisher towards a certain place at a certain time.

Lake Nipigon fishers make a distinction among four stocks of lake trout. The stocks are morphologically different and fishers have named the stocks 'blacks', 'brown', 'silvers' and 'deep-water'. The 'blacks' and 'browns' are native to Lake Nipigon while the two others were introduced through government stocking programs. During the spawning season, fishers say the stocks do not necessarily isolate themselves geographically although the timing of when the males will "milk" the females of the same stock separates the stocks from one another. The stocks are found throughout Lake Nipigon although the abundance of particular stocks is greater in certain areas over others. North of Kelvin Island, 'blacks' are found in greater abundance while the remaining stocks are more abundant south. Thirty-seven meters is a water level where a fisher can harvest lake trout at any time of the year. Over the course of a year, lake trout will either move above or below 37 meters of water. The 'deep-water' stock is predominantly located in 37 meters of water throughout the year. The 'black', 'brown' and 'silver' stocks display more vertical latitude than the 'deep-water' stock over the course of a year. Fishers attempt to protect the stocks of lake trout by taking into account the location of their gear in the water column and by selecting different locations to set their nets in order not to remove more lake trout than what is needed.

A year after my arrival, I returned to the community with a draft of my thesis. I delivered a copy of the draft to those involved with the project. I stayed in the community for three weeks and gave everybody the time to read and tell me whether they were satisfied with the results. Any changes that were requested were accommodated.

CHAPTER III: LAKE TROUT POPULATION GENETICS

1 Introduction

A region of the cytochrome-b and d-loop genes of Lake Nipigon lake trout mitochondrial DNA (mtDNA) was sequenced to elucidate stock structure. Management of Lake Nipigon lake trout can benefit from genetic information as integrated approaches to long-term conservation and management of populations must incorporate ecological, demographic and molecular data (Mace et al. 1996). Establishing the number of populations will increase the effectiveness of monitoring studies because they can be done on a stock-by-stock basis.

Fishers' traditional knowledge can be used to identify stocks and help direct scientific research. Lake Nipigon fishers make a distinction among four different stocks of lake trout that are thought to be sexually segregated during spawning (Chapter 2, section 6.1). The stocks of lake trout identified by the fishers are morphologically different from one another. Fishers have named the stocks 'blacks', 'browns', 'silvers' and 'deep-water'. Each stock is distributed throughout Lake Nipigon although particular areas are occupied in greater abundance by certain stocks over others. 'Blacks' predominantly inhabit areas north of Kelvin Island, while the remaining stocks are more concentrated in southern locations.

Lake trout samples were collected during the spawn and visually classified to a particular morphological category according to fishers' descriptions. Examining the frequency distribution of haplotypes among morphological categories will examine whether there is evidence of genetic differences among morphotypes. The polymorphisms that are detected through sequencing may not be associated with a morphological category because of morphotype misclassifications in the field, or due to inherent genetic variability among different morphotypes or because of a combination of both factors.

The geographic distribution of the haplotypes may provide information of spatial divergence among populations. Fishers predicted the number of stocks that would be present at each sampling location. Geographic patterns of haplotypes that are indicative of stocks will be compared to fishers' predictions.

Fishers' interpretation of lake trout stocks and the genetic results may or may not support one another. If similarities arise between fishers' predictions and genetic results, this will provide support of fishers' understanding of lake trout genetic population structure. Similar results would indicate that the genes examined did provide proper resolution to resolve stocks. If discrepancies arise, either fishers are correct yet the portion of the genome sequenced cannot resolve stocks, or vice versa, or neither are able to provide information to discern the genetic stock structure.

Haplotypes from Lake Nipigon will be compared to haplotypes of lake trout from regions outside the boundaries of genetic interaction. This will examine to what extent the haplotypes are unique to Lake Nipigon. Based solely on the phylogenetic information, the results may indicate the level of resolution the assayed genes provided. The results may support Wilson and Hebert's (1998) study where restriction fragment length polymorphism (RFLP) analysis of the mtDNA of samples of lake trout from throughout North America, including Lake Nipigon, resolved mtDNA lineages derived from lake that survived glaciation in different refugia.

Genetic polymorphisms will be examined to determine whether sequencing is useful to detect lake trout populations in Lake Nipigon. Stocks will be inferred by examining whether certain haplotypes are specific to a particular morphotype, and whether frequency distributions of haplotypes among sampling sites indicates restricted gene flow reflective of the presence of stocks.

2 Background

Disruptions in the gene flow among groups of individuals within a species will cause, over time, genetic differentiation and the stratification of the species into populations. Genetic differences among populations arise due to events including mutation, selection and random drift. Detecting genetic differences among populations can be achieved through the use of various assays including protein electrophoresis, RFLP and direct sequencing. Direct sequencing is a procedure whereby the nucleotide sequence of a targeted region of DNA is established.

Sequencing will discriminate among populations by detecting mutations such as substitutions, deletions and insertions. Mutations that need to be considered in DNA sequence data analysis are transition and transversion substitution events. Transitions are mispairs in which a purine (adenine or guanine) is replaced by another purine or a pyrimidine (thymine or cytosine) is replaced by another pyrimidine. Transversions involve the replacement of a purine with a pyrimidine or a pyrimidine with a purine. Transition events typically occur more frequently than transversion events (Aquadro and Greenberg 1983). The ability to accurately reconstruct phylogenetic relationships based upon the transition/ transversion substitutions is limited by the occurrence of homoplastic mutations that are more frequent with transitions because of their greater evolutionary rate (Broughton et al. 2000). Weighing transitions relative to transversions is an option to increase the reliability and resolution of phylogenetic trees. Problems are encountered when determining what the exact weights should be due to the potential loss of phylogenetically informative transitions.

Mitochondrial DNA and nuclear DNA (nDNA) will detect population structure at different phylogenetic levels. Mitochondrial DNA has been described as a genome appropriate for examining the evolutionary history and historical structure among populations (Avise 1994, Park and Moran 1994). Mitochondrial DNA reflects the historical stratification because it does not evolve fast enough to truly reflect the current structure of populations. Examining nDNA, particularly variable number tandem repeats, may provide a better source of polymorphisms to detect stocks (O'Connell and Wright 1997, Bagely and Gall 1998).

Stocks can be elucidated through sequencing certain hypervaraible mtDNA genes. Specific regions of mtDNA such as the d-loop, which mutate at higher rates than other areas, can be examined to infer stock structure. The sequencing of the d-loop has been useful for the detection of population structure in some freshwater and anadromous species of fish with a geographic distribution occurring in northern North America such as walleye (*Stizostedion vitreum*) (Stepien and Faber 1998), Arctic charr (*Salvelinus alpinus*) (Brunner et al. 2001), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) (Wirgin et al. 2000) and Dolly Varden (*Salvelinus malma*) (Reist unpubl.). Although d-loop has been useful in detecting population structure, not all North American freshwater fish have demonstrated informative variability in the d-loop. Lake whitefish (*Coregonus clupeaformis*) is an example of the inadequacy of sequencing d-loop to detect variation on a limited geographical scale (Bodaly et al. 1996). Sequencing the d-loop may be more useful in some species of fish over others due to alternate rates of d-loop mutation among species. Adjacent to the d-loop is the cytochrome-b gene. Rates of mutation in cytochrome-b make the gene, like d-loop, a potential candidate for direct sequencing to identify populations. Problems encountered from examining cytochrome-b include alternate mutation rates among lineages and early saturation of codon positions (Meyer 1994). Apostolidis et al. (1997) detected variation among populations of Greek brown trout (*Salmo trutta*) by sequencing a portion of d-loop and cytochrome-b.

Vitic and Strobeck (1996) stated the need to genetically characterize and identify lake trout populations throughout their geographic distribution. Understanding the consequences of stocking a lake containing endemic populations of a species with non-endemic individuals will improve management objectives. Potential negative effects of introducing a non-native population are the disruption of the ecology of native populations. The introduced stock may be a superior competitor for resources or may crossbreed with endemic populations thereby causing the extinction of the population, thereby decreasing the level of genetic diversity. Lake Nipigon was stocked with Lake Superior lake trout between 1920 and 1976 (Table 3). The objective of the stocking program was to maintain the commercial fishery over a long-term period (Schraeder 1983). The effects of introducing non-native lake trout into Lake Nipigon are unknown. Baseline data of the amount of genetic diversity will provide a benchmark for future population studies or monitoring programs. The results of studies on lake trout genetic population structure in Lake Nipigon may contribute to the understanding of the characterization of native stocks present in the Laurentian Great Lakes region.

Table 3. Number of lake trout stocked into Lake Nipigon on an annual basis, 1920-1976 (Schraeder 1983).

Year	Numbers stocked		Year	Numbers stocked		Year	Numbers stocked
1920	734,000 f		1933	200,000 F		1944	40,000 f
1921	110,000 f		1934	200,000 F		1946	50,000 F
1922	810,000 f		1935	50,000 F		1948	50,000 F
1923	1,000,000 f		1936	50,000 f		1949	50,000 F
1924	1,000,000 f		1937	50,000 F		1950	30,000 F
1925	2,250,000 f		1938	50,000 F		1951	2,000 Y, 60,000 F
1926	500,000 f		1939	50,000 f		1953	40,000 F, 5,000 Y
1927	945,000 f		1940	60,000 F		1954	30,000 F, 12,000 Y
1928	1,810,000 f		1941	60,000 F		1956	15,000 Y
1929	1,375,000 f		1942	40,000 F		1975	44,000 Y
1930	30,000 F		1943	50,000 f		1976	14,000 Y

f=fry, F= fingerlings, Y=yearling

Although Lake Nipigon is not classified as one of the Great Lakes, the proximal location and large size make the Lake Nipigon watershed important to Lake Superior. Lake trout from separate glacial refugium overlap in the areas of Lakes Nipigon and Superior (Wilson and Hebert 1996 and 1998). These two lakes may share very similar or related stocks. Attention has been focused on the conservation and rehabilitation of native lake trout stocks in the Great Lakes. Decreases in lake trout populations in the Great Lakes have resulted in the complete loss of endemic stocks in Lakes Ontario, Erie and Michigan, and the loss of all but two native stocks in Lake Huron (Ihssen et al. 1988). Lake Superior retains the greatest number of native stocks (Goodier 1981). Lake Nipigon has never endured the loss of lake trout stocks through the invasion of sea lamprey (*Petromyzon marinus*) and has retained a sustainable fishery primarily focused on lake whitefish and lake trout.

3 Literature review

3.1 Population stratification

Inferences of population structure begin with the examination of phylogenetic information, which is a quantitative representation of genetic variation (Nei and Kumar 2000). The genetic variation that will be examined for this study will be the haplotype. The relationship among the haplotypes is characterized through the use of an algorithm and cluster analysis. The degree of divergence among the haplotypes will help substantiate and quantify the level of genetic distinction. Phylogenetic results and the confidence values associated with gene trees will depend on the extent of the differences among the sequences. Phylogenetic trees will typically display deep branching patterns subdividing into a number of shallow clades (Avise 2000). The frequency distribution of each haplotype is also calculated in order to examine the spatial divergence among populations.

A gene tree with deep monophyletic branching is evidence of the historical isolation among populations reflected by relatively large differences in allelic composition (Moritz 1994). From a management perspective, deep monophyletic branching has been called evolutionary significant units (ESU) reflecting the long-term evolutionary history among populations (Ryder 1986). When a gene tree is derived from mtDNA and displays deep phylogenetic branching, a monophyletic branch can be described as a mtDNA lineage. Lineages may provide information in regards to historical isolation yet may not be very informative towards describing the current population structure in a lake.

Within the deep monophyletic branching of a mtDNA gene tree, a substructure may be present. A single clade or group of clades with relatively similar phylogenetic gaps along with a specified geographic delineation may be an indication of the presence of populations (Avise 2000). Different frequency distributions among sampling sites can be considered as an indication of the presence of restricted gene flow indicative of a population.

Stocks of fish are segregated reproductively in time and/or space albeit no uniform definition of a stock exists. Confusion lies in the multitude of ways gene pools are structured and the hierarchical nature of these structures (MacLean and Evans 1981). Scientists, managers and economists often use the term in different context (Gauldie 1991). Stocks need to be primarily differentiated based on ecological and genetic differences among populations. Ecological discreteness is due to spatial and temporal heterogeneity while genetic discreteness is based on gene flow, mutation, genetic drift and natural selection (MacLean and Evans 1981). Separation among populations over time may lead to morphological, behavioural, and genetic differences (Ihssen et al. 1981). The morphology of a fish can be controlled either by the genetic makeup or influenced, in part, from environmental factors thereby compromising the reliability of the sole use of morphology for stock identification.

Stock definitions include Larkin's (1972, 11):

> a population of organisms which, sharing a common environment and participating in a common gene pool, is sufficiently discrete to warrant consideration as a self perpetuating system which can be managed.

Ricker (1972) characterizes a stock as fish spawning in specific location that are temporally and spatially reproductively segregated. Hilborn and Walters (1992, 67) define a stock as:

> an arbitrary collection of populations of fish that is large enough to be essentially self-reproducing, with members of the collection showing similar patterns of growth, migration and dispersal.

A genetic stock is defined as a genetically isolated group of individuals which are not intrinsically reproductively isolated from other stocks but maintain genetic distinctness through spatial and/or temporal separation of spawning (Bailey and Smith 1981). Booke's (1981) definition of stock is a population of fish maintaining and sustaining Castle-Hardy-Weinberg equilibrium.

The glacial history of North America has had a profound effect on the genetic structure of fish occupying glaciated regions (Hewitt 1996, Bernatchez and Wilson 1998). Ice from the previous glaciation period, called the Wisconsinan glacial period, retreated between 15,000 and 8,000 years ago (Dyke and Prest 1987). Ice sheets covered most of northern North America, altering the zoogeography of fish occupying northern North America (Bernatchez and Dodson 1991, Bernatchez and Dodson 1994, Hewitt 1996). Some areas, called refugia, remained ice-free during the glacial period providing habitat for some displaced species. Each refugium was geographically separated for thousands of years providing the conditions for genetic divergence among refugia. Phylogeographic structure of the mtDNA of certain northern freshwater fish species has been shown to correspond with glacial refugia and the historical presence of proglacial lakes (Bernatchez and Wilson 1998). The relatively rapid recolonization of many freshwater fish will result in glacial races from different refugia to be distributed over large geographic expanses. Genetic examination of species that were disrupted by glaciation will typically result in low intraspecific phylogenetic divergence when compared to southern species not disrupted by glaciation. Substantial genetic divergence may only be observed among mtDNA lineages associated with different refugia.

3.2 Mitochondrial DNA

DNA is primarily located in the nucleus of a cell, although organelles, such as mitochondria, possess DNA independent of the nuclear genome. Mitochondria are organelles responsible for cellular respiration. They create adenosine triphosphate (ATP) by breaking down sugars, fats and other fuels with the use of oxygen. Mitochondrial DNA is inherited clonally from the cytoplasm of an ovum and is haploid. Mitochondrial DNA is generally comprised of between 16,000 and 20,000 base pairs, facilitating extraction compared to nDNA. Lake trout have a mitochondrial genome of 16,800 ± 200 base pairs (Grewe and Hebert 1988).

The reduced quantity of DNA in the mitochondria, as compared to the nucleus, accentuates effects of genetic drift (mutation) at a faster rate than nDNA resulting in a greater potential to show differences among populations (Ward and Grewe 1994). This makes mtDNA an ideal candidate for observing polymorphisms among populations. Mitochondrial DNA does not undergo recombination, and is therefore more likely to show a clean gene tree branching structure. Within mtDNA, particular regions evolve (mutate) to a greater extent than do others. Areas commonly studied include the d-loop control region, and the genes coding for cytochrome-b and nicotinamide adenine dinucleotide dehydrogenase (NADH). Examining sections prone to greater mutation increases the potential to detect population structure. A drawback regarding the use of mtDNA is that one or two genes from the organelle may not be as informative than assaying multiple nuclear genes (Hartl and Clark 1997).

Lake trout, and salmonids in general, exhibit relatively slow rates of mutation in the mitochondrial genome (Grewe and Hebert 1988, Bernatchez and Danzman 1993, Vitic and Strobbeck 1996, Wilson and Hebert 1996 and 1998, Altukohv 2000, Brunner et al. 2001). Genetic population studies using mtDNA may encounter difficulties in. determining the presence of populations. The relatively slower rates of mtDNA mutation combined with the Wisconsinan glaciation that decreased genomic diversity makes the detection of polymorphisms to infer the current stock structure challenging. Wilson and Hebert's (1998) RFLP study demonstrated low variability in lake trout mtDNA with interclade divergence ranging between 0.45% and 0.86%.

3.3 Previous genetic research on lake trout stocks

Previous research on lake trout population genetics has focused primarily on detecting variation in the mtDNA through RFLP. Variation has been examined in order to understand genetic characteristics, including the amount of diversity in mtDNA and the potential use of mtDNA as a marker (Grewe and Hebert 1988, Grewe et al. 1993). Mitochondrial DNA has also been assayed to determine the phylogeography of lake trout (Wilson and Hebert 1996 and 1998). Vitic and Strobeck (1996) used both RFLP and direct sequencing to compare the ability and feasibility of both assays to detect stock structure in sites from Western Canada.

Previous lake trout population studies that incorporated samples from Lake Nipigon have detected a relatively high degree of polymorphism within the lake. Protein electrophoresis of Lake Nipigon lake trout revealed the highest amount of genetic diversity in terms of average proportion of polymorphic loci and average number of alleles per locus as compared to all other sites studied (Ihssen et al. 1988). Wilson and Hebert's (1998) lake trout phylogeography study revealed genetic polymorphisms with fifteen restriction enzymes. Thirty samples from Lake Nipigon resulted in the most abundant haplotypes, the highest nucleotide diversity along and the highest number of restriction sites compared to other locations. RFLP results from the previous studies demonstrate an abundance of polymorphisms in Lake Nipigon lake trout.

A description of the results from Wilson and Hebert‘s (1998) lake trout phylogeography study is important in order to understand the historical factors that may influence the present stock structure of Lake Nipigon lake trout. Through RFLP, three important mtDNA lineages were detected for lake trout along with a fourth that was not phylogenetically distinct as the others and was only distinguished based on two restriction site characters. Each mtDNA lineage was geographically oriented towards areas where refugia persisted during the Wisconsinan glacial period. Wilson and Hebert (1998) concluded that lake trout recolonized North America from at least Beringia, Nahanni, Mississippi, Atlantic and Montana glacial refugia. Mitochondrial DNA lineages were associated with Beringia, Nahanni, Mississippi and Atlantic refugia. A Montana glacial refugium had been proposed based upon the geographic distribution of some of the Beringia haplotypic group although significant phylogenetic substructure in the group was inconclusive. Every mtDNA lineage overlapped in Lake Nipigon.

Vitic and Strobeck (1996) performed amplified restriction fragment length polymorphism (ARFLP) and direct sequencing analysis of lake trout mtDNA from ten populations from Alberta, Saskatchewan and Manitoba. ARFLP was completed using eight restriction enzymes and four haplotypic groups were resolved. The ATPase-6-COIII gene from each population was sequenced and 17 haplotypes were resolved. Greater variability was detected with sequencing as compared to ARFLP, yet many sequencing haplotypes differed from one another by single bases and were considered phylogenetically uninformative. Phylogenetic analysis of the sequenced haplotypes also produced four main clades. The authors observed that the haplotypes were widely distributed over a large geographic range with little variation among populations. The low amount of phylogenetic differentiation at the ATPase-6-COIII site was attributed to the Wisconsinan glacial advance. Another source of low variability was thought to be transfers and recruitment of individuals from one population to another resulting in shared haplotypes. Vitic and Strobeck (1996) concluded sequencing did not provide greater resolution of intraspecific structure than ARFLP and questioned the sole use of sequencing to characterize populations.

4 Methods

4.1 Sampling

Samples of lake trout were taken from four sites in Lake Nipigon over the month of September 2000. Knowledgeable fishers of Lake Nipigon chose four sampling sites. Sites sampled were Willegger Creek, Wilson Island, Whiteaves Island and Flatland Island (Fig. 13). Adipose fins were removed from each sample and placed in a coarse salt (NaCl) and 20% dimethyl sulfoxide (DMSO) solution.

Fishers were familiar with the pattern of lake trout spawning in Lake Nipigon. Sampling sites and times were chosen by the fishers in order to ensure samples from all stocks of lake trout were collected. Fishers mentioned that sampling the particular sites

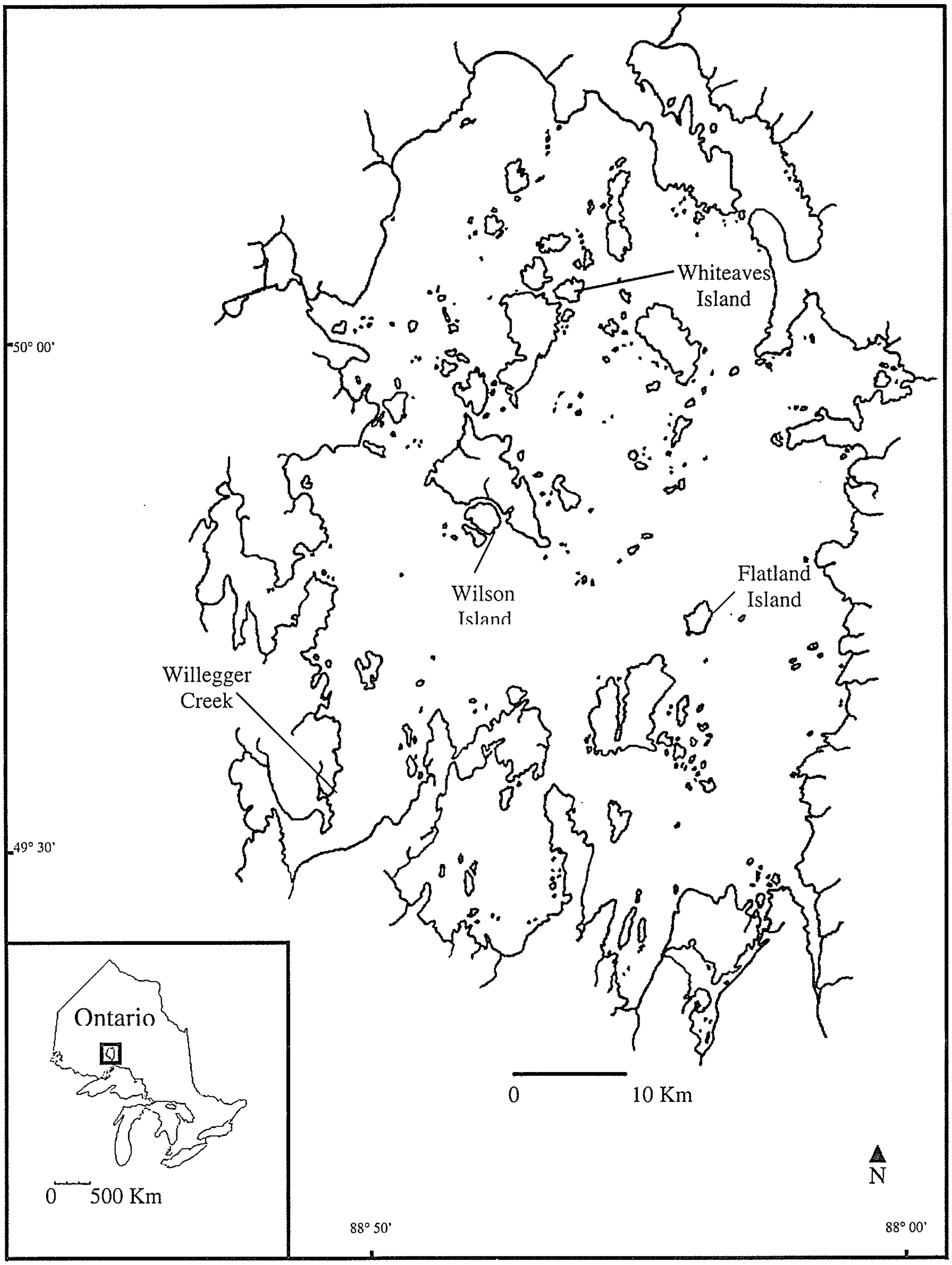

Figure 13. Locations on Lake Nipigon where lake trout were sampled.

throughout September would yield 'brown', 'silver' and 'black' stocks of lake trout. 'Deep-water' trout were said to not necessarily be present on the spawning areas. Fishers predicted the number of stocks that would be present at the spawning areas at the particular time the sampling took place, and whether 'black', 'brown' or 'silver' lake trout would be present (Table 4).

Sampling was carried out with the assistance of the A/OFRC (Table 5). Nets were set shallow, typically between three and twelve feet deep directly on top of a spawning shoal. The nets used were the same as those used for the A/OFRC's Fish Community Index Netting with 3.25, 4.5 and 5.5 inch (82.6, 114.3, 139.7 mm, respectively) stretched mesh panels. Temperature probes were attached for comparison to typical spawning temperatures of lake trout in order to help ensure the timing of sampling in relation to spawning.

Each adipose fin was qualitatively labeled, based upon personal observation of morphology, as a 'black', 'brown', 'silver' or 'unknown' lake trout. No 'deep-waters' were apparent when sampling.

4.2 Genetic analysis

Tissue samples were brought to the population genetics laboratory at Fisheries and Oceans Canada, Freshwater Institute, for mtDNA extraction and analysis. Samples, in DMSO, were frozen for further preservation.

To analyze mtDNA, the DNA was separated from the organelles by breaking down the cellular structure through the use of a digestive enzyme. A specific region of the mtDNA was targeted and amplified into multiple copies through polymerase chain

Table 4. Information received from commercial fishers on types and timing of spawning of different stocks of lake trout in Lake Nipigon, Ontario.

Location	Willegger Creek	Wilson Island	Whiteaves Island	Flatland Island
Types that should be present	'Browns' and 'silvers'	'Browns', 'blacks' and 'silvers'	'Browns', 'blacks' and 'silvers'	'Blacks' and 'silvers'
Order of sampling	To obtain mostly 'browns', the earliest stock to spawn, the site should be sampled early. ('Silvers' have the potential to be present)	'Silvers', 'blacks' & 'browns' will be found on the spawning bed after the full moon.	'Silvers', 'blacks' & 'browns' will be found on the spawning bed after the full moon.	Sampled later in order to obtain mostly 'silvers' with some 'blacks'.

Table 5. Location, water temperature, time of sampling, and number and presumed identity of lake trout stocks sampled in September 2000 in Lake Nipigon, Ontario.

Location	Willegger Creek	Wilson Island	Whiteaves Island	Flatland Island
Date sampled (September, 2000)	6 and 7	19	26	28
Temperature	10°C	13°C	11.5°C	11.5°C
Latitude and longitude	49° 38' N 88° 55' W	49° 47' N 88° 40' W	50° 03' N 88° 31' W	49° 45' N 88° 16' W
Sample catch (n) Total= 199	39	66	45	49
Stocks identified based upon personal observation of morphology	Assumed 'browns' (all small trout)	'Silvers', 'blacks' and 'browns'	'Silvers', 'blacks' and 'browns'	'Silvers' and 'blacks'

reaction (PCR) for easier manipulation of the molecules and to provide enough copies to ensure proper cycle sequencing reactions. Cycle sequencing attaches nucleotides to a particular segment of the PCR product along with a single modified nucleotide (dideoxynucleotide). Each dideoxynucleotide is fluorescently labeled and will attach itself to a complementary base of the PCR product. There are four possible types of ucleotides (adenine, thymine, guanine and cytosine) utilized in the reactions. Each dideoxynuleotide has a particular fluorescent colour. Each dideoxynuleotide will terminate the cycle sequencing reactions resulting in many copies of variable fragments length. Automated sequencing will determine the base pair order of the target area by detecting the fluorescent dye specific to a nucleotide and measure the distance between the dye and primer. Once the base pair sequence of the target mtDNA region was determined, analysis proceeded by comparing the order of the bases of one sample to another.

Digestion of tissue was achieved through the use of Qiagen Dneasy Tissue Kits (see Qiagen 2000). Approximately 25mg of tissue was placed in a test tube with 180μl Buffer ATL and 20μl of Protease K. Each sample was incubated at 55°C overnight. Buffer AL (200μl) was directly added and then incubated at 70°C for ten minutes. Ethanol (200μl) was added just after incubation. Samples were then transferred into a new test tube and centrifuged at 8,000 rpm for one minute. Buffer AW1 (500μl) was added and centrifuged for one minute at 8,000 rpm. Buffer AW2 (500μl) was added and samples were then centrifuged for three minutes at 14,000 rpm. The sample was then placed into a new test tube with 200μl of Buffer AE and pipetted onto the membrane of the DNeasy column and centrifuged for one minute to elute the DNA.

PCR amplified the cytochrome-b and d-loop control region of the mtDNA with H2B (Reist unpbl.) and Cytochrome-b1 (Miller et al. 1998) primers. DNA (1.5µl) was added to 77.2µl of deionized water, 10µl of 10X PCR buffer, 1.0µl of $MgCl_2$, 2.0µl dNTP's, 4.0µl of each primer and 0.3µl of Taq polymerase into each test tube for PCR. PCR was undertaken in Techne GENIUS thermocyclers. The thermocycler was programmed with an initial denaturation temperature of 95°C for four minutes followed by 32 cycles consisting of one minute at 94°C, one minute at 48°C and one minute and thirty seconds at 72°C. Electrophoresis (5% agarose gel) of 5µl of sample verified the presence of PCR products.

PCR products were filtered using a Qiagen QIAquick PCR purification kit. Buffer PB (500µl) was directly added to each PCR sample (100µl). The sample was then transferred into a QIAquick column and centrifuged for 60 seconds. The flow-through was discarded. Buffer PE (750µl) was added and the sample was then centrifuged for 60 seconds and the flow-through discarded. The DNA was eluted with 50µl of Buffer EB and centrifuged for 60 seconds. Samples were diluted to a standard 20ng/µl.

Samples were cycle sequenced using ABI Prism's DNA Sequencing Kit. The primer H2A (Reist unpbl.) was used to target the region of mtDNA where cytochrome-b and d-loop are linked. DNA (1.5µl) was added to 6.50µl deionized water, 4.0µl of primer, 4.0µl half-term and 4.0µl d-rhodamine. The cycle sequence reactions were programmed in a Techne GENIUS thermocycler with an initial denaturation temperature of 96°C for two minutes with 25 cycles of 30 seconds at 96°C, 15 seconds at 53°C and 4 minutes at 60°C. Cycle sequencing products were cleaned using Centriflex™ Edge Gel Filtration Cartridges and subsequently dried in an Eppendorf vacufuge for one hour. To each sample, 4μl of a 5:1 solution of deionized formamide and loading buffer was added to suspend the DNA.

A 5% Long Ranger™ polyacrylamide gel was prepared for automated sequencing. The ABI Prism 377 DNA Sequencer would accommodate between 36 and 48 individual samples. Between 1.8 and 1.5μl of sample was pipetted into an individual lane and left to run overnight. Results were properly aligned according to lane trackers and individual chromatograms were printed.

The simple text DNA sequencing files were converted to MacVector 7.0 files and aligned and analyzed using MacVector 7.0. A reference was selected from a Lake Nipigon sample and compared to each sample from Lake Nipigon to detect variation and assign haplotypes. Substitutions, deletions and insertions of bases were verified manually. Errors were corrected directly in MacVector 7.0.

4.3 Data analysis

Phylogenetic trees represent the evolutionary history and quantify the genetic relationship among haplotypes through specified algorithms. Many algorithms exist to create phylogenetic trees (Weir 1990, Nei and Kumar 2000). The following will describe analysis methods used for characterizing the variation in Lake Nipigon lake trout.

The first step will be to quantify the differences (distance) between all possible pairs of haplotypes. Distance between two DNA sequences can be calculated with the Jukes and Cantor algorithm. Jukes and Cantor calculates distance as the number of observed nucleotide difference between each pair of sequence (Weir 1990). An assumption of Jukes and Cantor is that all possible nucleotide changes occur at a constant rate. The distances are then clustered based upon the degree of similarity. Nucleotide bases and deletions were quantified (A= 1, T= 2, G= 3, C= 4, deletions= 5) and distances were calculated in the Numerical Taxonomy and Multivariate Analysis system (NTSYS, Rohlf 1993).

Cluster analysis enables the representation of complex data structure in a readily interpretable and meaningful manner. A common algorithm is unweighted arithmetic average (UPGMA). Clustering begins by grouping the two individuals with the smallest distance and the subsequent fusions are based upon the unweighted average distance between fused groups. An important assumption of UPGMA is an equal rate of mutation among populations.

Phylogenetic trees are created based upon the clustering algorithm. UPGMA trees attempting to demonstrate clusters can be unrooted and reflect the distance among haplotypes without notion of ancestry. Determining the reliability of UPGMA trees is achieved through bootstrapping. Bootstrap values indicate the level of statistical confidence for each branch of the phylogenetic tree. The Phylogenetic Analysis Using Parsimony (PAUP version 3.1) program (Swofford 1991) was used to calculate bootstrapping values for the phylogenetic tree produced by NTSYS.

5 Results

A total of 186 individual fish were successfully sequenced. The 590 base-pairs sequenced from the 5' end, covered both the areas of cytochrome-b (316 base-pairs) and d-loop control region (274 base-pairs). A total of nine (1.5%) variable positions were detected consisting of five substitutions and four deletions (Fig. 14). Two positions exhibited a combined total of twenty-two insertion events and were removed from further data analysis resulting in the observed nine variable positions. The five substitution

```
                                                            50
TCTACTACAT TAAGTAGGAC TGATGCTGAA AGTTGGTGGG TAAAGACGGA

                                            *     *        100
GCCCGTGTTA GTTGGAGTTT TATTAATATA GCAATTGCCT AGGTTAAGAC

                                                           150
AACCTAGGTG GTTATTATCA CGTGTTTAGC TTATGTAAAT CTTGGGTTTA

                                                           200
TGCTGATATA TGAGGGCTTA AATTCACTTA TGTTGATAAT ACATATGATG

                         **                                250
TACTACTCAC CACCCAGATA TTATATATAT GGGTAAATAC ATAATATGTA

                                                           300
ATATTATACA TAGATGTATT ATAACACTAA TTTGTTGAGA TACAACGTTC

                  **                                       350
ATTGTTGTAC ATATTAGGGG GGGCCAGAGG GTAGTTTAAC TTAGAATCTT

                                                           400
AGCTTTGGGA GTTAAGGGTG GGAGTTAAAA GCTCCTCTCT CTGAGCACTA

                  *                   *                    450
GGGAGGGTTT TAACCTCCGA CCTCCGGATT ACAAAACCGG CGCTCTGGCG

                                                 *         500
CTGAGCTACT AGGGCAGGCT CATTCAAGGG CTTTATTTTC GGCCCAACCG

                                                           550
GCTAGGGGGG CGAGGACTAG GAAGATGGTG AAGTAAATCA CGGAGGCAAC

                                              590
TTGGCCGATA ATGATAAATG GGTGTTCTAC AGGCATGCCT
```

Figure 14. The 590 base sequence of the cytochrome-b and d-loop region from haplotype 1 (reference). Asterisks indicate the 9 variable positions among the 6 haplotypes. Underlined bases indicate a deletion event.

events were transitions. Four transition mutations were between purines while one involved pyrimidines. The nucleotide diversity for Lake Nipigon lake trout derived from sequenced portions of cytochrome-b and d-loop was 0.008, demonstrating little intraspecific variation.

A total of six haplotypes were identified (Table 6). Haplotypes 3 through 6 were very different from haplotypes 1 (reference sample) and 2. Haplotype 2 differed from 1 by the deletion of two bases located next to each other. Haplotypes 3 and 4 differed from the reference by four substitutions and two deletions. Haplotype 5 differed from haplotype 1 by four substitutions and four deletions. Haplotype 6 was characterized by four substitutions and three deletions.

The frequency of haplotypes among the four sampling sites (Table 7) was combined (Fig. 15). Four abundant haplotypes were observed. Haploytpe 1 and 2 accounted for 17% (n= 32) and 12% (n= 23) of the total sample, respectively. Haplotype 4 constituted 24% (n= 45) of the total sample. Haplotype 6 was the most abundant haplotype in Lake Nipigon accounting for 41% (n= 77) of all samples. Haplotypes 3 and 5 were very small in frequency comprising of 2% (n= 3) and 3% (n= 6), respectively, of all fish.

5.1 Phylogenetic analysis

Relationships were first examined among Lake Nipigon haplotypes only. The degree of divergence among haplotypes was inferred based upon pairwise dissimilarity derived from Jukes and Cantor distance measurements (Table 8). A 50% majority-rule bootstrap analysis (n=1000 replicates) revealed a strict consensus UPGMA tree (Fig. 16).

Table 6. Mitochondrial DNA haplotypes of Lake Nipigon lake trout. Letters indicate nucleotide substitutions at the particular base number. Periods indicate no change from the reference sample and dashes indicate a deletion of the nucleotide at the base number.									
	Sequence position of nucleotide substitutions and deletions								
Haplotype	87	92	223	224	317	318	422	435	491
1	G	G	A	T	G	G	C	A	G
2	•	•	•	•	–	–	•	•	•
3	A	A	–	–	•	•	T	G	•
4	A	•	–	–	•	•	T	G	A
5	A	•	–	–	–	–	T	G	A
6	A	•	–	–	–	•	T	G	A

Table 7. Lake Nipigon haplotype frequencies among sampling sites.							
	Haplotypes						
	1	2	3	4	5	6	Total
Willegger Creek	0	0	0	21	1	14	36
Wilson Island	13	13	1	18	1	16	62
Whiteaves Island	12	4	2	5	1	16	40
Flatland Island	7	6	3	1	0	31	48
Total	32	23	6	45	3	77	186

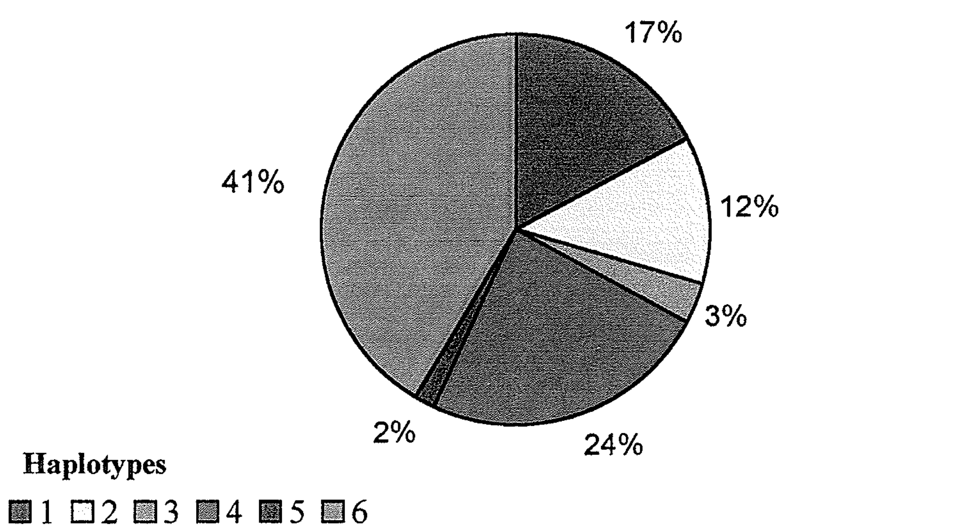

Figure 15. Combined frequency of all Lake Nipigon lake trout haplotypes.

Table 8. Pairwise Jukes and Cantor dissimilarity matrix of Lake Nipigon lake trout haplotypes and *S.fontinalis*.

	1	2	3	4	5	6	*S.f*
1	0						
2	0.0577	0					
3	0.1885	0.2636	0				
4	0.1885	0.2636	0.0577	0			
5	0.2636	0.1885	0.1203	0.0577	0		
6	0.2251	0.2251	0.0833	0.0283	0.02831	0	
S.f	9999*	9999*	9999*	9999*	9999*	9999*	0

* Denotes infinite distance due to abundant differences.

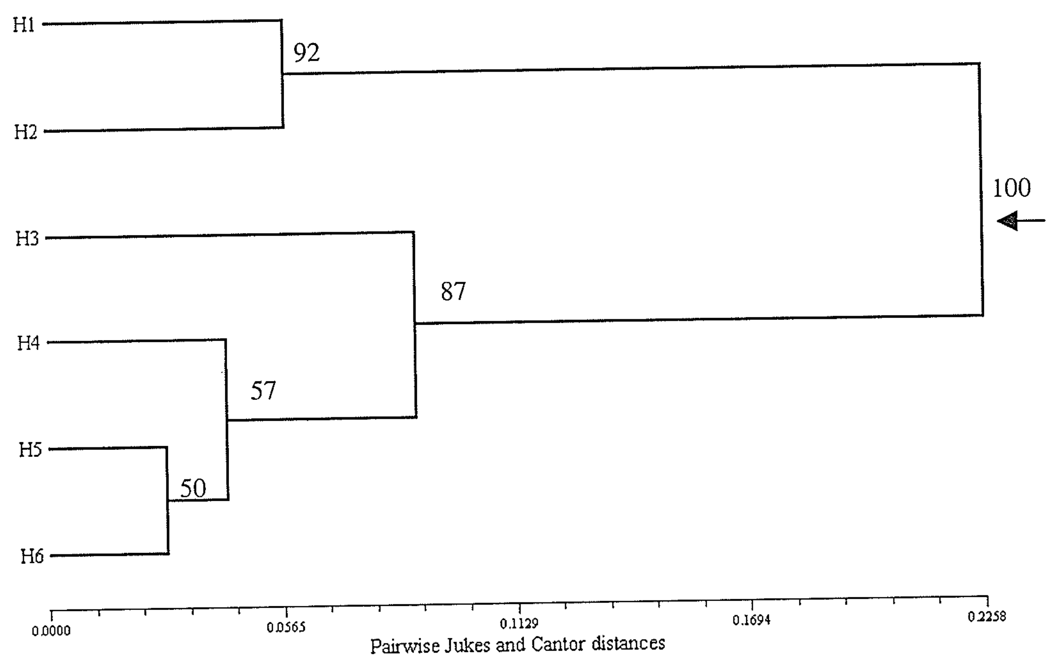

Figure 16. A 50% majority bootstrap of UPGMA consensus tree of sequence data from the cytochrome-b and d-loop region of Lake Nipigon lake trout mtDNA. Arrow indicates branching position of *S. fontinalis* (100%).

Bootstrap analysis supported two clades with 100% certainty. Haplotypes 1 and 2 were grouped together while haplotypes 3, 4, 5 and 6 constituted the second major clade. In the first clade both haplotypes clustered with 92% confidence. This is consistent with the fact that the two haplotypes differed by only two deletions. In the second clade, an important division among the haplotypes was observed. Haplotype 3 was separated from the closely related haplotypes 4, 5 and 6 with 87% certainty. Haplotypes 6 differed from haplotypes 4 and 5 by a single base pair. The strict consensus tree clustered haplotype 5 and 6 with 50% confidence and subsequently haplotype 4 with 57% confidence. Thus, the six haplotypes in this study separated into three clusters (haplotypes 1 and 2; 3; and 4, 5 and 6) with statistical confidence greatly exceeding fifty percent.

Lake Nipigon haplotypes were also compared with haplotypes of lake trout sampled from Quamutissiat Lake, Québec, Travaillant Lake and Great Bear Lake, Northwest Territories, and George Lake, Manitoba (Table 9) (Fig. 17). The locations were geographically distant from Lake Nipigon. Few differences existed among haplotypes from Lake Nipigon and out-group locations. Two samples differed from Lake Nipigon haplotypes by single base substitutions while the remaining four were similar or identical to Lake Nipigon haplotypes. The single lake trout sampled from Quamutissiat Lake shared the same sequence as haplotype 6. One sample from George Lake was identical to haplotype 4. One haplotype from Great Bear Lake was identical to haplotype 1 while another sample from Great Bear Lake differed from haplotype 3 by a single substitution. One sample sequenced from Travaillant Lake differed from the reference by one substitution.

Table 9. Mitochondrial DNA haplotypes of Lake Nipigon lake trout with compared to samples from Quammutissiat Lake, Québec, Travaillant Lake, Northwest Territories, Great Bear Lake, Northwest Territories, and George Lake, Manitoba (Reist unpbl.) and to brook trout (*Salvelinus fontinalis*) (GenBank ascension number NC00861). Letters indicate nucleotide substitutions at the particular base number. Periods indicate no change from the reference sample and dashes indicate a deletion of the nucleotide.

Sequence position of nucleotide substitutions and deletions

Haplotype	72	78	80	87	92	98	140	148	213	214	215	223	224	225	242	276	285	290	297	300	305	317	318	320	324	422	435	491	497	505	506	512	542	566	581	590
1	A	A	A	G	G	G	T	T	C	C	C	A	T	C	T	A	T	A	C	C	T	G	G	G	C	C	A	G	A	G	G	G	G	A	A	T
2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	–	–	•	•	•	•	•	•	•	•	•	•	•	•	•
3	•	•	•	A	A	•	•	•	•	•	•	–	–	•	•	•	•	•	•	•	•	•	•	•	•	T	G	•	•	•	•	•	•	•	•	•
4	•	•	•	A	•	•	•	•	•	•	•	–	–	•	•	•	•	•	•	•	•	•	•	•	•	T	G	A	•	•	•	•	•	•	•	•
5	•	•	•	A	•	•	•	•	•	•	•	–	–	•	•	•	•	•	•	•	•	–	–	•	•	T	G	A	•	•	•	•	•	•	•	•
6	•	•	•	A	•	•	•	•	•	•	•	–	–	•	•	•	•	•	•	•	•	–	•	•	•	T	G	A	•	•	•	•	•	•	•	•
Quamutissiat L.	•	•	•	A	•	•	•	•	•	•	•	–	–	•	•	•	•	•	•	•	•	–	•	•	•	T	G	A	•	•	•	•	•	•	•	•
George L.	•	•	•	A	•	•	•	•	•	•	•	–	–	•	•	•	•	•	•	•	•	•	•	•	•	T	G	A	•	•	•	•	•	•	•	•
Travaillant L.	•	•	•	A	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Great Bear L. 1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Great Bear L. 2	•	•	•	A	•	•	•	•	•	•	•	–	–	•	•	•	•	•	•	•	•	•	•	•	•	T	G	•	•	•	•	•	•	•	•	•
S.fontinalis	G	G	T	•	•	A	C	A	T	T	G	T	•	G	C	C	–	G	T	T	C	•	•	C	T	T	G	A	G	A	T	A	A	G	G	C

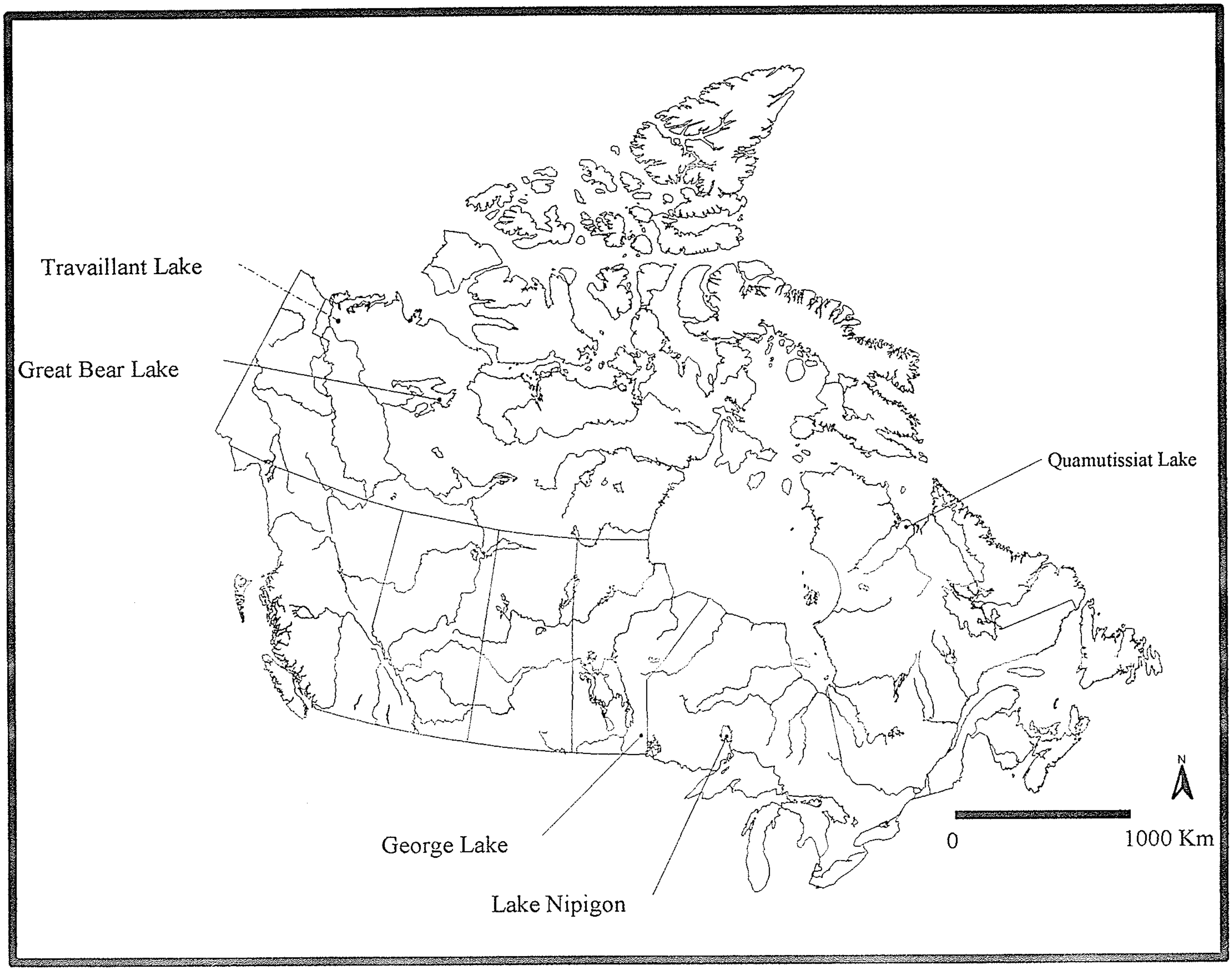

Figure 17. Various locations of lake trout samples used to compare results from Lake Nipigon.

When the out-groups are included in the cluster analysis, the results do not alter the general phylogenetic pattern observed among Lake Nipigon haplotypes (Table 10) (Fig. 18). Two major clades with 100% certainty were still observed. Haplotype 1 clustered more closely with haplotypes from the Northwest Territories than with haplotype 2. Within the second major clade, haplotype 3 and a haplotype from Great Bear Lake clustered together. The second division between haplotype 3 and the remaining haplotypes was still supported with 84% certainty. The George Lake haplotype and haplotype 4 clustered together. Haplotype 6 and Quamutissiat Lake haplotype clustered and were subsequently clustered with haplotype 5. When the relationships among the haplotypes from Lake Nipigon were examined alone, haplotype 4 was separated from 5 and 6 with 57% confidence. When the haplotypes outside of Lake Nipigon are included, the separation of haplotype 4 from 5 and 6 was no longer supported.

5.2 Distribution of lake trout haplotypes among sampling sites

Differences in the geographic distribution of lake trout haplotypes were noticeable among some of the abundant haplotypes (1, 2, 4 and 6) (Fig. 19). Frequency differences among sampling sites were examined using Fisher's exact test (Table 11). The null hypothesis being tested was there is no difference in the frequency of haplotypes among sampling sites. The probability that the genotypic distribution was identical between pairs of sampling sites was calculated. Statistically significant ($P \leq 0.05$) differences in frequencies were observed when Willegger Creek was compared to Wilson Island, Whiteaves Island and Flatland Island. Significant differences were also observed between Wilson Island and Flatland Island. No statistically significant ($P \geq 0.05$) differences were

Table 10. Pairwise Jukes and Cantor distance among Lake Nipigon haplotypes including out-groups Quamutissiat Lake (QL), George Lake (GL), Travaillant Lake (TL), Great Bear Lake (GBL) and *S. fontinalis* (*S.f.*).

	H1	H2	H3	H4	H5	H6	Q.L	G.L.	T.L.	GBL1	GBL2	*S.f.*
H1	0											
H2	0.0577	0										
H3	0.1885	0.2635	0									
H4	0.1885	0.2635	0.0577	0								
H5	0.2635	0.1885	0.1203	0.05772	0							
H6	0.2251	0.2251	0.0883	0.02831	0.0283	0						
Q L	0.2551	0.2250	0.0834	0.02831	0.0283	0	0					
GL	0.1885	0.2635	0.0577	0	0.0577	0.0283	0.0283	0				
TL	0.0283	0.0883	0.1536	0.1536	0.2251	0.1885	0.1885	0.1536	0			
GBL1	0	0.0577	0.1885	0.1885	0.2636	0.2251	0.2251	0.1885	0.0283	0		
GBL2	0.1536	0.2251	0.0283	0.0283	0.0883	0.0577	0.0577	0.0283	0.1206	0.1536	0	
S.f.	9999*	9999*	9999*	9999*	9999*	9999*	9999*	9999*	9999*	9999*	9999*	0

*Denotes infinite distance due to abundant differences.

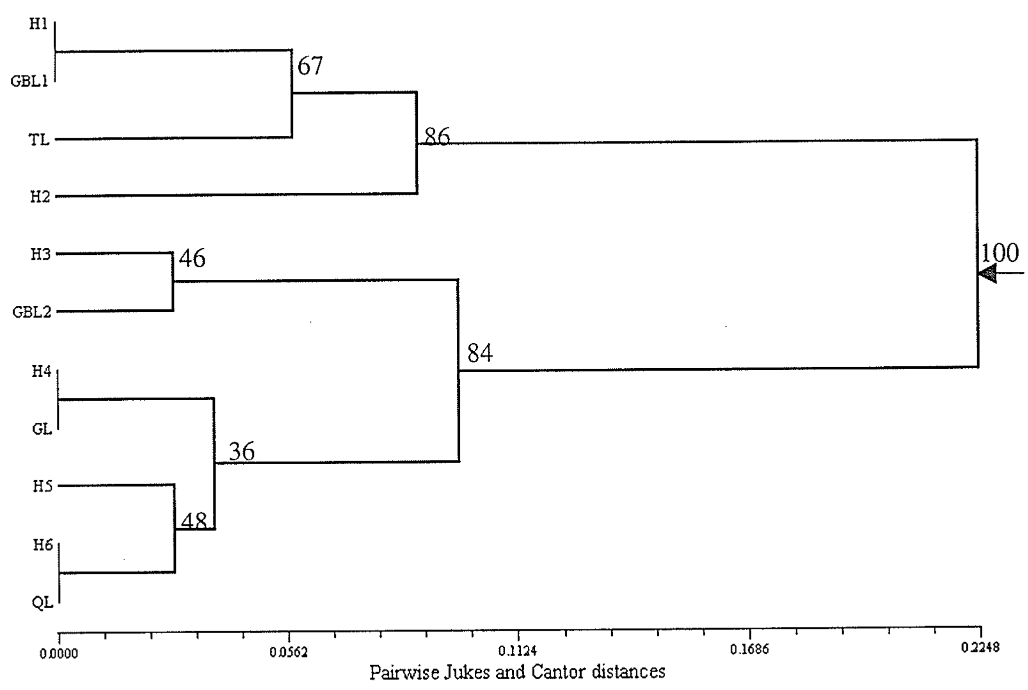

Figure 18. A 50% majority bootstrap of UPGMA consensus tree of sequence data from the cytochrome-b and d-loop region of lake trout mtDNA from Lake Nipigon, Quamutissiat Lake (QL), George Lake (GL), Travaillant Lake (TL), Great Bear Lake (GBL) along with a sample from *S. fontinalis* (*S.f.*). Arrow indicates branching position of *S. fontinalis* (100%).

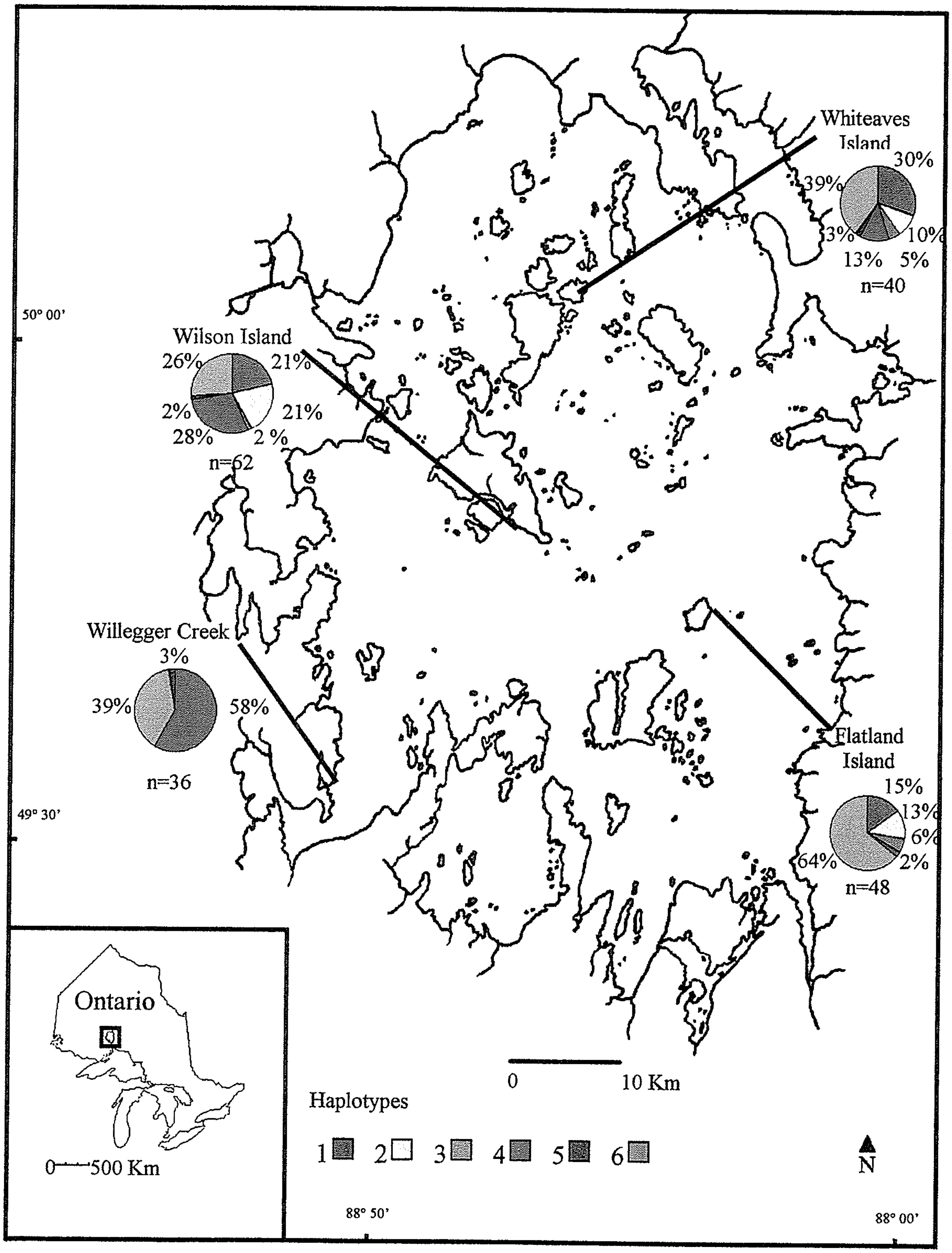

Figure 19. Distribution of haplotype frequencies of lake trout from four spawning locations in Lake Nipigon, Ontario.

Table 11. Fisher's exact test for differences in frequency of haplotypes between pairs of sampling sites. Values test the probability of generating the observed results if sites were not different.

	Willegger Creek	Wilson Island	Whiteaves Island	Flatland Island
Willegger Creek	-			
Wilson Island	P < 0.0005	-		
Whiteaves Island	P < 0.0005	P= 0.1041	-	
Flatland Island	P < 0.0005	P < 0.0005	P= 0.0647	-

observed between Wilson Island and Whiteaves Island, or between Whiteaves Island and Flatland Island.

Haplotypes 1 and 2 were detected with almost equal frequency at each site apart from Willegger Creek. Wilson Island and Whiteaves Island were almost equal in combined percent frequency of haplotypes 1 and 2, 42% and 40% respectively. The frequency decreased at Flatland Island (28%). Haplotype 4 was most abundant at Willegger Creek, accounting for 58% of all samples, and decreased in frequency at Wilson Island (28%) and subsequently at Whiteaves Island (13%). A single sample of haplotype 4 was detected at Flatland Island. Haplotype 6 was the most frequent haplotype in Lake Nipigon and was detected at every sampling site. Haplotype 6 was most abundant at Flatland Island accounting for 64% of all samples. Haplotype 6 comprised 39% of all samples at Willegger Creek and Whiteaves Island, and 26% of Wilson Island samples. Haplotype 3 was detected at Wilson Island, Whiteaves Island and Flatland Island with percent frequencies ranging between 2 (n= 1) and 6 (n= 3). Single samples of haplotype 5 were detected at Willegger Creek, Wilson Island and Whiteaves Island.

5.3 Distribution of haplotypes among morphotype categories

An indirect method of identifying genetic differences among populations is to analyze morphological features. Methods include meristic and morphometric measurements. In order to examine whether the lake trout morphs, described by fishers, were genetically different, samples were labeled with a morphological designation. Assignments were done by a personal visual examination of specimens. Morphology was discriminated according to the descriptions provided by fishers through interviews and through knowledge acquired from first-hand observation before sampling took place. The categories were 'black', 'brown', 'silver' and 'unknown' (Fig. 20).

Calculations of the distribution of haplotypes among morphotypes were made based on the number of observations and categorization from Wilson (n= 62), Whiteaves (n= 40) and Flatland (n= 48) Islands. Willegger Creek was excluded because all samples were assumed to be 'brown'. Further discussion with fishers revealed the potential for the presence of 'silver' lake trout at Willegger Creek. Different morphological types at Willegger Creek were not noticeable during sampling in part because most samples were collected in the dark.

The frequency of haplotypes in every morphological category was calculated (Table 12). A Monte Carlo significance test was calculated to examine whether haplotypes were randomly associated with each morphological category. The results supported the rejection of the null hypothesis, that haplotypes were completely independent of morphology, with 99% confidence. The majority of haplotype 1, 64%, and haplotype 2, 71%, were designated as 'blacks'. Haplotype 4 was categorized as 'brown' 64% of the time while haplotype 6 received a 'silver' labeling 60% of the time. The low frequency of haplotypes 3 (n=6) and 5 (n=2) excludes both from being associated with a certain morphological category. The results demonstrate genetic differences among the morphotypes.

Figure 20. 'Silver' (top), 'brown' (middle) and 'black' (bottom) Lake Nipigon lake trout. Photo: Colin Gallagher.

Table 12. Frequency and percent total of Lake Nipigon haplotypes among morphotype categories. Categories are 'black' (Bl), 'brown' (Br), 'silver' (Sil) and unknown (Unk).

	Frequency					**Percent total**			
Haplotypes	**Morphotypes**				**Frequency Total**	**Morphotypes**			
	Bl	Br	Sil	Unk		Bl	Br	Sil	Unk
1	21	7	4	1	33	64	21	12	3
2	15	3	2	1	21	71	14	10	5
3	4	0	2	0	6	67	0	33	0
4	6	16	1	2	25	24	64	4	8
5	0	1	1	0	2	0	50	50	0
6	19	5	38	1	63	30	8	60	2

6 Discussion

Intraspecific genetic structure was detected in Lake Nipigon lake trout. The small amounts of variation present in lake trout cytochrome-b and d-loop provided phylogenetic information to discriminate three mtDNA lineages while the frequency distribution of the haplotypes among sampling sites and morphotype categories was indicative of spatially restricted gene flow and genetically different morphs, respectively. The results indicate the presence of stocks.

Results support Vitic and Strobeck's (1996) observation that sequencing was no more informative, in terms of detecting genetic population structure, than RFLP. Sequencing Lake Nipigon lake trout did not detect variation beyond what has already been identified in lake trout through RFLP (Grewe and Hebert 1988, Wilson and Hebert 1996 and 1998). Sequencing resolved nine variable nucleotides and six haplotypes with a nucleotide diversity of 0.008. RFLP of Lake Nipigon samples detected nine haplotypes and a nucleotide diversity of 0.387 (Wilson and Hebert 1998). RFLP of Lake Nipigon lake trout may be more informative than sequencing cytochrome-b and d-loop because of the higher level of variability detected.

Sequenced haplotypes from Lake Nipigon are similar or identical to out-group haplotypes and the phylogenetic tree is similar in structure to the tree produced by Wilson and Hebert (1998). Wilson and Hebert (1998) detected three highly discernable mtDNA lineages that corresponded with refugia from the Wisconsinan glaciation (Beringia, Mississippi and Atlantic) along with a less evident fourth lineage (Nahanni). RFLP results demonstrated that identification of lake trout from four different refugia could be achieved through examining phylogenetic information alone. Sequencing resolved genetic variation derived from fish that survived the Wisconsinan glaciation in separate refugia. Associating an out-group haplotype to a particular refugium is limited due to a small sample size (n= 5) and because the out-group locations could have been re-colonized by descendants from multiple refugia.

Haplotypes 1 and 2 are either similar or identical to haplotypes detected in northern Canada, specifically the northern Northwest Territories. Wilson and Hebert (1998) hypothesized that lake trout from the northern Northwest Territories are descended from fish that survived the last glaciation in the Beringia refugium. Phylogenetically, lake trout descendant of the Berigia refugium differentiated with 100% certainty from other refugia. Lake Nipigon haplotypes 1 and 2 separate with 100% certainty from all other haplotypes.

A Great Bear Lake haplotype similar to Lake Nipigon haplotype 3, yet distinct from haplotype 1 and 2 (hypothesized descended from Beringia), may have descended from lake trout that survived the last glaciation in the Mississippi refugium. Wilson and Hebert (1998) delineate the northern distribution of lake trout from the Mississippi refugium at Great Slave Lake, Northwest Territories. The possibility of a more northern distribution lake trout descendant from the Mississippi refugium should not be discounted. Wilson and Hebert (1998) found that lake trout from the Mississippi refugium separated with 78% certainty from the Nahanni and Atlantic refugia. Haplotype 3 clustered separately, with 86% certainty, from haplotypes 4, 5 and 6.

Sequencing did not provide enough polymorphisms to resolve a fourth mtDNA lineage that would possibly distinguish the Nahanni refugium from the Atlantic refugium, thereby limiting hypothesizing which haplotypes of the cluster comprised of 4, 5 and 6 could be derived from the Atlantic and Nahanni refugia.

The area of Quamutissiat Lake has been colonized by lake trout descended from the Beringia, Mississippi and Atlantic refugia (Wilson and Hebert 1996). The haplotype from Quamutissiat Lake is very phylogenetically different from other haplotypes that have been proposed as descended from the Beringia and Mississippi refugia. It can be hypothesized that the haplotype from Quamutissiat Lake is derived from lake trout that survived glaciation in the Atlantic refugium. When the Quamutissiat Lake haplotype is compared to a single sample from George Lake, located in an area thought not to be occupied by lake trout descended from the Atlantic refugium, both differ from one another by a single base pair substitution. George Lake is located in an area that is overlapped by the distribution of lake trout descended from the Beringia, Mississippi and Nahanni refugia. The George Lake haplotype is also very phylogenetically different from haplotypes associated with the Beringia and Mississippi refugia. Wilson and Hebert (1998) did not detect any haplotypes associated with an Atlantic mtDNA lineage west of Lake Nipigon and Lake Superior and also demonstrated that the Atlantic and Nahanni refugia were very phylogenetically similar with a nearly exclusive geographic distribution. It is therefore possible that the George Lake haplotype could be descended from lake trout that survived glaciation in the Nahanni refugium. The alternative is the lake trout derived from the Atlantic refugium did colonize areas west of Lakes Nipigon and Superior and that the George Lake haplotype is a variant of lake trout descended from the Atlantic refugium.

The three mtDNA lineages, based on the sequencing results, are (1) haplotypes 1 and 2, (2) haplotype 3, (3) haplotypes 4, 5 and 6. It is hypothesized that haplotypes 1 and 2 are associated with the Beringia refugium, haplotype 3 with the Mississippi refugium, and haplotype 4 with the Nahanni refugium and haplotypes 5 and 6 with the Atlantic refugium when the results from Wilson and Hebert (1998) are incorporated.

Evidence of genetic differences among morphotypes was apparent, as particular haplotypes were more abundant in certain morphotype categories over others. Caution must be placed in the interpretation of the data due to the large potential for morphologically mislabeled fish. Variability of the data precludes resolving with confidence whether different morphotypes are genetically pure. Either misidentification occurred and the haplotypes are specific to a morphotype, or the variation is a true representation, or because of both factors. Haplotypes 1 and 2 were abundant in the 'black' category. Haplotypes 4 and 6 were abundant in the 'brown' and 'silver' categories, respectively. The data supports, to a certain point, some degree of genetic isolation among morphotypes that would indicate they could be considered stocks.

Haplotype frequencies were significantly different between four out of six pair-wise comparisons of sampling locations that would indicate spatially restricted gene flow and the presence of stocks. The frequency distribution of haplotypes 1, 2, 4 and 6 were indicative of stocks. The same four haplotypes were also associated with a particular morphotype.

Haplotypes 1 and 2 were similar in abundance at the three locations where they were detected and both were associated with 'black'. Haplotype 4, associated with 'brown', exhibited a relatively distinct geographic distribution when compared to haplotypes 1 and 2. Sampling sites where haplotypes 1 and 2 were detected consisted of relatively low frequencies of haplotype 4. Willegger Creek had an abundant frequency of haplotype 4 and was devoid of haplotypes 1 and 2. The results suggest a north-south spatial difference between both stocks.

Haplotype 6 was associated with 'silvers' and relatively abundant at each sampling site. Haplotype 6 was detected among relatively exclusive haplotypes 1 and 2, and haplotype 4. If complete genetic exchange occurred between lake trout comprised of haplotype 4 and haplotype 6, and haplotypes 1 and 2 and haplotype 6, there should theoretically be no difference in any frequency or distribution of any of the abundant haplotypes in Lake Nipigon. The available data indicates the presence of three morphologically different populations of lake trout in Lake Nipigon.

The results suggest that stocks might be relics of fish that survived glaciation in different refugia. The data does not determine whether the lake trout descended from every refugium are still segregated in Lake Nipigon. It is possible that lake trout descended from certain refugia are segregated to a certain degree. The haplotypes hypothesized as descended from three refugia display frequency differences among morphotype categories and sampling locations that indicated the presence of stocks.

When the genetic data are compared to the predictions made by the fishers, the results complement one another very well. Two stocks of lake trout were predicted for Willegger Creek ('brown' and 'silver'). Two haplotypes, 4 and 6, both associated with different morphotypes, were detected. Fishers also predicted two stocks at Flatland Island ('silver' and 'black') and the majority of the haplotypes detected were associated with two stocks. A third, haplotype 4 (n=1), and fourth, haplotype 3 (n=3) were also detected at Flatland Island. Fishers predicted that both sites would have two stocks yet share a particular stock ('silver'). Willegger Creek and Flatland Island shared haplotype 6.

Wilson and Whiteaves Islands were predicted to have three stocks of lake trout ('brown', 'blacks' and 'silvers'). Fishers predicted that the same stocks detected at Willegger Creek and Flatland Island would be detected at Wilson and Whiteaves Islands. The same haplotypes detected at Willegger Creek and Flatland Island was detected at Wilson and Whiteaves Islands.

Fishers mentioned the presence of a fourth stock that typically spawns later in the season. Although the data is inconclusive in regards to the presence of a fourth stock, this is a possibility. If stocks were structured according to refugia, then the notion of a fourth stock is not out of the question. Lake Nipigon lake trout hypothesized as descended from the Mississippi refugium (haplotype 3) were very small in frequency (n= 6). Although fishers predicted three stocks would be detected based on the timing of the sampling, they mentioned there was a possibility that some lake trout from the fourth stock could have been present on the spawning grounds. The fourth stock is described as a 'deep-water' lake trout that typically spawn in November.

Results from this study also support the observation of low levels of genetic variability in lake trout mtDNA (Wilson and Hebert 1998, Vitic and Strobeck 1996). Lake trout displays very low levels of variable nucleotides when compared to previous studies where salmonid d-loop (Brunner et al. 2001), or both d-loop and cytochrome-b (Apostolidis 1997) were sequenced. Arctic charr taken from throughout its geographic distribution demonstrated 16.1% nucleotide variability (Brunner et al. 2001). Greek brown trout d-loop demonstrated 3.9% while cytochrome-b demonstrated 2.1% variable positions (Apostolidis 1997). Four variable nucleotide sites in cytochrome-b (1.3%) and five variable nucleotides in d-loop (1.8%) out of 590 bases were polymorphic in Lake Nipigon lake trout. The results demonstrate relatively low levels of nucleotide variability from a lake deemed to possess the highest levels of lake trout genetic diversity.

The genetic results and fishers' predictions did complement one another in that three stocks that differed morphologically showed some genetic differences. The results also support fishers' description of the spatial segregation of certain stocks. 'Blacks' would be predominant in the north while 'browns' would be abundant in the south. The results provide information that might suggest that lake trout descended from certain refugia have not completely genetically mixed since converging into Lake Nipigon after glaciation. The results also support the use of sequencing cytochrome-b and d-loop in order to gain a coarse resolution of the genetic population structure of Lake Nipigon lake trout although RFLP may provide more informative polymorphisms.

7 Conclusion

Six haplotypes were detected through direct sequencing of a portion of the cytochrome-b and d-loop genes of the mtDNA of Lake Nipigon lake trout. Phylogenetic results of the haplotypes from Jukes and Cantor distances and UPGMA analysis demonstrated significant structure in the variation. When Lake Nipigon haplotypes were compared to out-group haplotypes, the results supported the usefulness of the assayed genes to resolve mtDNA lineages derived from lake trout that survived glaciation in separate refugia.

There is evidence of limited gene flow among the morphologically different lake trout described by local fishers. Certain haplotypes were abundant in morphotype categories over others. Haplotypes 1 and 2 were abundant in the 'black' category. Haplotype 4 and 6 were abundant in the 'brown' and 'silver' category, respectively. The different lake trout morphotypes were not consistently categorized with a single particular haplotype either due to misclassification in the field or the genetic variation is not specific to a particular morphotype, or because of both factors. The frequency distributions of the haplotypes that were abundant in morphotype categories were also different among sampling sites and indicated spatial differences among stocks. Haplotype 4 was primarily located at Willegger Creek, a southern site, and decreased in abundance at more northern sites. Conversely, haplotypes 1 and 2 were predominant in northern sites where haplotype 4 infrequent. Haplotype 6 indicated the presence of a population because of its co-occurrence with relatively exclusive haplotype 4 and haplotypes 1 and 2. The results also support fishers' interpretation of the stock structure of Lake Nipigon lake trout.

The results also support the general observation of relatively low levels of genetic variation in northern freshwater species (Lafontaine and Dodson 1997, Billington and Hebert 1988, Bernatchez 1995, Bernatchez and Dodson 1990, Wilson and Hebert 1996, Wilson et al. 1996). Although variation was minimal, the results support the use of the haplotypes to detect both mtDNA lineages and indicate the presence of genetically divergent populations. Intensive sampling of spawning areas over different time periods throughout the spawn along with a more quantitative approach towards morphological characterization will need to be done in order to better examine the relationship between morphology and genetic variation.

CHAPTER IV: THE TIES BETWEEN TRADITIONAL KNOWLEDGE AND SCIENCE

A cooperative understanding of Lake Nipigon lake trout stocks was accomplished through the efforts of exploring and applying the knowledge of commercial fishers of Biinjitiwaabik Zaaging Anishinaabek, and the use of molecular genetics. This chapter reviews the objectives of the thesis and describes how traditional knowledge and biological science came together in this thesis.

The first objective was to learn traditional knowledge regarding stocks of Lake Nipigon lake trout while the second objective was to examine the genetic population structure of Lake Nipigon lake trout. The use of both traditional knowledge and molecular genetics was done to ensure a thorough approach from two sources of information to understand Lake Nipigon lake trout stocks. Applying both traditional knowledge and molecular genetics required an approach that would satisfy both scientific and community expectations.

Building bridges of understanding between traditional knowledge and science can depend on what kind of bridge is built. Those from the scientific or community perspective may not share the same view of bridge. Based on my experience, I view two kinds of bridges of understanding. The first is a technical bridge, or areas of convergence, between science and traditional knowledge as described in Reidlinger and Berkes (2001). The second is a conceptual bridge between traditional knowledge and the scientist.

Examining the sequence variation in the cytochrome-b and d-loop genes along with frequency distribution of haplotypes among morpholotype categories, and the frequency distribution of haplotypes throughout the lake provided scientific information of lake trout stocks. There was evidence indicating the presence of three morphologically and genetically different stocks of lake trout. The haplotypes that were linked with a stock were descendants of lake trout that survived the previous glaciation period in glacial refugia.

Fishers' knowledge was consistent with the genetic results. For example, fishers predicted one stock ('browns') would definitely be present at Willegger Creek along with the possibility of a second ('silvers'). The two stocks fishers identified at Willegger Creek were also predicted at Wilson Island, along with a third ('blacks'). Fishers predicted Whiteaves Island would produce the same stocks detected at Wilson Island ('browns', 'blacks' and 'silvers'). Flatland Island was predicted to primarily yield two stocks they termed 'silvers' and 'blacks'. The fishers predictions, along with the frequency and distribution of haplotypes did complement one another.

Practitioners of traditional knowledge accumulate knowledge of a particular place at a certain time. Sources of knowledge include information passed on from others, or knowledge obtained through harvesting and observing, or participating in ceremonies. The fishers believe that the common ground between traditional knowledge and science was place and time. Harold Michon mentioned "*Aboriginals and scientist view the same thing but speak a different language*". Time and place reflect a first step in building technical bridges of understanding between traditional knowledge and Western science.

Those trained in science need data in order to conceptualize the patterns of nature. They may take for granted the traditional knowledge of a community. However, the community can provide direction for data collection. Western science can really only use the "data" component of traditional knowledge. But this is a very small part of traditional knowledge that is highly contextualized and encapsulates the cultural wisdom of a community.

This thesis is an example of the scientific understanding of the "data" components of fishers' knowledge, as it is easier to write about "data" rather than experiences and spirituality that provide context. There are limitations if traditional knowledge and science attempt to complement one another. Science cannot directly incorporate the wider context of traditional knowledge such as spirituality.

A researcher should attempt to appreciate the culture and context of those who are providing their traditional knowledge to build conceptual bridges. A researcher should attempt to learn about traditional knowledge beyond its "data" components. Participation, experience, social relationships and an open mind are required to explore Indigenous knowledge. Focus needs to be primarily placed on people rather than the ecological information they share.

The result from such an approach is a bi-cultural model similar to that described by Colorado (1988). Based upon my experiences, the bi-cultural approach requires adopting different methodologies and different roles, and the development of different skills. Particular fishers treated me as an apprentice in order to communicate their traditional knowledge. I was discouraged from thinking of myself as a researcher and thinking of traditional knowledge from as something to be researched. The technical and social skills required for an apprentice were that of a commercial deckhand. Upon leaving the community, however, the skills that were needed were that of a biologist. Skills to produce scientific knowledge included extracting and sequencing mtDNA and carrying out statistical analysis. Anyone using a bi-cultural model is required to think and operate in multicultural and multidisciplinary environments.

The community's involvement in the thesis provided a chance to complement science and present information for Lake Nipigon fisheries management. The fishers wanted to communicate the importance of their knowledge. Fishers also wanted to present how traditional knowledge was important for their livelihood and how it was used every time they were on the water setting nets. Sustainability of Lake Nipigon fisheries has not only been a result of quotas, imposed by the government, but a result of the use of traditional knowledge, and values associated with it. Traditional knowledge is the fishers' means for ensuring the sustainability of their cultural identity and the economy of the community, as well as their natural resources.

The thesis provides an example of the usefulness and feasibility of examining both traditional knowledge and scientific data for management decisions. A growing trend is for managers to broaden their scope beyond scientific and economic disciplines. Decision-making based solely on scientific and ecological information may overlook other important factors that affect the sustainability of the fishery. The efficacy of fishery management through conventional stock assessment can be limited by inadequate budgets and information gaps.

Fishers' participation is an option towards a more thorough and realistic approach, by incorporating social aspects of the fishery. Involving local communities in the development of management objectives requires new types of information and considerations. Community involvement in resource management can range from consultative to cooperative partnerships. Any arrangement that includes fishers' knowledge will need to be built on trust and respect regardless of partnership structure. Fishery managers will need to take seriously the validity of Indigenous knowledge. Fishers' participation can include helping formulate objectives by providing information of the stocks they harvest, assisting in the development of scientific hypothesis, and helping interpret findings. Management can also address the values that reflect the way resources are used by fishers. Including fishers' knowledge is a multidisciplinary and pluralistic approach that managers of small-scale fisheries can adopt (Berkes et al. 2001).

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