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PROCEEDINGS OF THE SECOND LAKE TROUT SYMPOSIUM 2005, YELLOWKNIFE, NORTHWEST TERRITORIES

Edited by

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2 ABSTRACT

Mills, K.H., M. Dyck, and L.A. Harwood. 2008. Proceedings of the second lake trout symposium 2005, Yellowknife, Northwest Territories. Can. Tech. Rep. Fish. Aquat. Sci. 2778: xi + 247 p.

This report contains 84 short papers or abstracts of presentations from the second lake trout symposium held at Yellowknife, Northwest Territories, in 2005. The management of lake trout fisheries is presented in separate papers for Alaska, Northwest Territories and Nunavut, Yukon Territory, British Columbia, Alberta, Manitoba and Saskatchewan, Ontario, Quebec, and the Great Lakes. There are reviews of lake trout thermal niche, dissolved oxygen requirements, mercury and other contaminants, and stock assessment, as well as papers on impacts of land use activities and climate change on lake trout populations. Recent developments in the understanding of the phenotypic types of lake trout present in many lakes are reviewed and co-management of lake trout stocks with subsistence harvesters is presented. There are papers on the progress towards the rehabilitation of lake trout stocks in the Laurentian Great Lakes and on applications of new techniques in the study of lake trout biology.

RÉSUMÉ

Mills, K.H., M. Dyck, et L.A. Harwood. 2008. Activités du deuxième symposium sur le touladi 2005, Yellowknife, Territoires du Nord-Ouest. Can. Tech. Rep. Fish. Aquat. Sci. 2778: VI + 247 p.

Le présent rapport contient 84 brefs exposés ou résumés des présentations du deuxième symposium sur le touladi qui a eu lieu à Yellowknife aux Territoires du Nord-Ouest en 2005. La gestion de la pêche au touladi est présentée dans des articles distincts pour l'Alaska, les Territoires du Nord-Ouest et le Nunavut, le territoire du Yukon, la Colombie-Britannique, l'Alberta, le Manitoba et la Saskatchewan, l'Ontario, le Québec et les Grands Lacs. Certains portent sur des examens sur la niche thermique du touladi, les exigences en oxygène dissous, le mercure et d'autres contaminants et l'évaluation des stocks, alors que d'autres articles portent sur les répercussions de l'utilisation des terres et du changement climatique sur les populations de touladi. On examine les récents développements quant à la compréhension des types phénotypiques de touladi présents dans de nombreux lacs et on présente la cogestion des stocks de touladi en collaboration avec des chasseurs de subsistance. Il y a des articles sur le progrès en vue du rétablissement des stocks de touladi dans les Grands Lacs laurentiens et sur les applications des nouvelles techniques dans l'étude de la biologie du touladi.

3 Preface

The Second North American Lake Trout Symposium was held in the city of Yellowknife, NT in August 2005. A diverse group of participants -- ranging from subsistence, sport and commercial fishers, to scientists, managers, and regulators as well as representatives from the pipeline and diamond industries -- shared the objective of advancing conservation of lake trout and lake trout habitats.

The Department of Fisheries and Oceans, Western Arctic Area, was pleased to host the Symposium and to welcome all delegates to the City of Yellowknife. Delegates attended from seven aboriginal land claimant groups from the Beaufort Sea coast to the south shores of Great Slave Lake; from as far as Alaska and New York; and from Quebec, Ontario, the Prairie Provinces, British Columbia and all three of Canada's Territories – The Northwest Territories, Nunavut and the Yukon. In total, 121 delegates attended the symposium.

The management of intact, natural lake trout populations and fish communities dominated by lake trout is one of the toughest challenges facing fisheries managers today. Not only are large, old, slow-growing, and late-maturing lake trout stocks sensitive to exploitation and environmental changes, they are a prized species sought by recreational anglers and subsistence fishers. Stock changes and impacts resulting from over exploitation and habitat degradation are often gradual and difficult to monitor and detect, particularly in large ecosystems. Recovery of stocks is usually slow and sometimes requires major interventions.

These proceedings are a combination of the 300 word original abstracts submitted by authors prior to the symposium and extended abstracts submitted by authors after the symposium. When authors submitted an extended abstract, this replaced the original 300 word abstract.

We thank everyone for making the trip to Yellowknife, and for bringing their enthusiasm, knowledge and materials to share. We also thank the trade show delegates for their contributions and for providing informative display materials. Finally, a special thank you to our 15 partners, listed in the proceedings, for their generous and essential financial contributions.

The organizing committee for the meeting consisted of:

Ron Allen – Conference Chair
Lois Harwood – Symposium Coordinator
George Low – Science Chair and Fisher Panel Chair
Bruce Hanna – Trade Show, Logistics, Banquet, Across the Range Chair
Dave Tyson – Local Committee
Erin Hiebert – Poster Session Coordinator
Kelly Cott – Special Guests and Speaker Coordinator
Kim Howland – Science Review
Marge Dyck – Oral Presentation Transcriber and Coordinator for Proceedings
Pat Thagaard – Registration Coordinator
Diana Curtis – Graphic Design
Ken Mills – Primary Proceedings Editor

The Organizing Committee gratefully acknowledges the generous contributions of the following partners:

- Fisheries & Oceans Canada
- Environment Canada
- Indian & Northern Affairs Canada
- Northwest Territories Environment and Natural Resources
- Northwest Territories Industry, Tourism, and Investment
- BHP Billiton
- Fisheries Joint Management Committee
- Devon energy
- Golder Associates
- Paramount Resources Ltd.
- MSS Ltd., Hay River
- Salmo Consulting Inc.
- Envirosearch
- Fisher Scientific

Door prizes were provided by:

- Arctic Wild Harvest
- Book Cellar
- Birchwood Gallery
- City of Yellowknife
- Fisheries and Oceans Canada
- Explorer Hotel
- Gallery of the Midnight Sun
- Lake Awry Cap & Crest Ltd.
- Nor-Art International Gallery
- Northern Frontier Regional Visitors Centre
- Northern Images
- Wolverine Sports Shop & Northern Supplies

Opening Prayer
Mike Francis

We pray to God for our good luck and God bless us. In the name of the Father, the Son and the Holy Spirit, Amen. Our Father, who art in heaven, hallowed be thy name; thy kingdom come, thy will be done, as it is in heaven. Give us this day, our daily bread, and forgive us our trespasses. Forgive those who trespass against us and lead us now from temptation, but deliver us from evil.

Hail Mary, full of grace, the Lord be with you. Bless all the women and blessed Jesus. Holy Mary, mother of God, pray for us, now at the hour of death, Amen. Glory be to the Father and to the Son and to the Holy Spirit, Amen. It was beginning, now it should be world without end, Amen.

The Father, the Son, the Holy Spirit, Amen.

OUT AND ABOUT FOR TROUT Chic Callas August 18/05

C   F   C
I love fishing on Great Slave Lake. Mmm Hmmmm   Mmm Hmmmm

I love fishing for trout to bake.   Mmm Hmmmm   Mmm Hmmmm

I go fishing 'most every day.   My wife wants to kill me- but what can you say?

Mmm Hmmmm   Mmm Hmmmm   Mmm Hmmmm

I cast my my line the other day. Mmm Hmmmm   Mmm Hmmmm

Hooked a pike in a shallow bay. Mmm Hmmmm   Mmm Hmmmm

I threw that jack back right away! It's not a trout! What can you say?

Mmm Hmmmm   Mmm Hmmmm Mmm Hmmmmm

The next strike was a giant fish. Mmm Hmmmm   Mmm Hmmmm

I knew he'd make a tasty dish . Mmm Hmmmm   Mmm Hmmmm

He had to be a foot! No…two! When he spit the hook he was 6'2"!

Mmm Hmmmmm He was! Mmm Hmmmm It's true. Mmm Hmmmm

Of course no-one believed a trout that size.   Uhh uhhhhh

I'm sure there were contaminants nearby! Mmm Hmmmm

I travel now and tell my "whale of a tale" in any auditorium.

Like this North American trout symposium! Mmm Hmmmm

This song was written by Chic Callas for the Lake Trout Symposium

4 Opening Session

Symposium Chair: Ron Allen

4.1 Welcome Panel

Session Chair: Ron Allen

Ron Allen's Biography

In 1977 Ron Allen left the Wildlife Research Branch of the Ontario Department of Lands & Forests and went north to work for the Government of the Northwest Territories as a Wildlife Officer in Hall Beach, Igloolik, and Tuktoyaktuk. In 1982, Ron joined the Department of Fisheries & Oceans as a Fishery Officer in Rankin Inlet. From there he moved to Iqaluit (then called Frobisher Bay) to the position of Fishery Officer-In-Charge. In 1984 he became the Area manager of the Eastern Arctic Area. In 1990 he moved to British Columbia for a two-year assignment in Campbell River as the District Supervisor of North Vancouver Island. In 1992 he returned to the Arctic (Inuvik) as the Area Manager for the Western Arctic Area. Ron spent 18 months in Yellowknife as Arctic Habitat Coordinator after which he returned to the position of Area Director, Western Arctic Area.

4.1.1 His Worship Gordon Van Tighem

Mayor of Yellowknife

Good morning, everyone. Welcome to Yellowknife, a great place for this important conference, and thanks to those of you that came from slightly warmer places and brought us this beautiful weather that we have today.

I'm privileged to welcome you this morning for two basic reasons. One is that Yellowknife and Northwest Territories enjoys thousands of visitors each year that come here searching for the elusive trout, the work that you are involved in doing. Some of the things that you learn today may allow that resource to endure.

The second reason is probably a more subtle one, but it is the main reason that I'm here. It is because of lake trout. I grew up in Calgary and my father, brothers, sisters, sons, daughter and now granddaughter spend a lot of time going through the foothills of southern and central Alberta looking for little things that we could eat and I remember there were some little torpedo shaped fish with pink dots on them that were extremely aggressive. I remember one specifically because he grabbed the spoon part of the lure, but not the hook and wouldn't let go. They were easy to catch and they were easy to eat. When I finished high school, I got a job with the Alberta Department of Fish and Wildlife and there got to know some people who worked on something called the Three Rivers Study. We learned that those cute little fish with the pink dots on them that were voracious didn't spawn until they got to a certain large size. Something called "no black, put it back" became a terminology that allowed the species to work towards recovery. So that's the start of the story.

During one of the fishing trips, a gentleman came with us that my father was recruiting, and he was from the Northwest Territories. We met at lunch time to compare creels and my dad said to me: "How many did you catch?" I said: "Well, I've got three; I let two go." And he said: "I've got four." He turned to this gentleman and said: "How many did you catch?" You have to remember these are Foothills trout. He said: "Well, I only caught about six or seven, but none of them were over a foot-and-a-half, so I threw them all back." Who is this guy? We were consumptive naturalists. If we caught it, we were going to eat it. So I started questioning him. He started talking about the Lake trout in the Northwest Territories. Thirteen years ago I got the opportunity to move to the Northwest Territories, and now here I am.

So what you're doing is good for the future of many areas of our civilization. I've seen your schedule and I know you're going to be working very hard into the wee hours of the morning, but if you get a break in the action in your meeting, those of you that went on the tour yesterday may have noticed that we've got some very interesting hiking trails. The last couple of days I'm advised it's good to stay in the open windy areas because otherwise you'll have a whole bunch of company (mosquitoes). But if you get a chance to go out and wander around there, you'll get to see some of the natural areas that we have here in town.

The Prince of Wales Heritage Centre across the way has a very good display of the history and the culture of our area that we're very proud about. You wil also learn what to do the next time you have eight surplus moose hides because there are instructions in there on how to build a boat from the hides. We have got some very interesting stores in town for those of you that aren't from the North. There is some very interesting northern fare in our restaurants. So by all means, have a great time, remembering that we are the diamond capital of the Northwest Territories, so if you get the opportunity – and I have to be careful how I word this because sometimes people look for samples – you may want to purchase one or two to take home as gifts. But enjoy your visit, work hard, and please, those of you from away, please come and see us again. Thank you.

4.1.2 Frank Pokiak

Inuvialuit Game Council

Good morning, everyone. It is nice to see a lot of people here that I know and with whom I have worked. I'd like to thank you for making time to come down because we know you guys do a lot of traveling, and have taken time out of your busy schedules for something important like this. I live in Tuktoyaktuk. It's on the Beaufort Sea.

I'm just going to explain a little bit about lake trout. I think in the Inuvialuit settlement region lake trout is an important source of food for us. Also, in the spring time when we take our families out, that's the time we have to spend with our families fishing and enjoying the land. So that's part of our culture, what we do every spring. In the fall time we also fish under the ice with nets for our dogs and for our Elders. We give a lot of fish to the Elders in the fall time when we set out our nets.

I think we always feel that lake trout is an important source of food for us and I think what we have to do is support on-going studies when they're proposed to us. In Tuk I think they have studied trout for three or four years in Husky Lakes.

We always felt that the fish in the North grow slower, but Lois will update you on that but I think we're finding that they do grow faster than some of the areas down south and she'll explain why. I think we all used to think that because the water is colder up here; but with the new information that's coming out, that's not the case. And also the trout, the lake trout we're talking about, they live in the salt water. They're sort of different than other fish that people catch, different than fresh-water lake trout.

Right now there is a lot of development taking place in the Inuvialuit settlement region with gas exploration and the proposed Mackenzie Gas Project. We want to ensure that this development does not impact on the lake trout and the other species of fish, the wildlife that we depend on every day. I think it is important to have ongoing studies because of all the activities that are going to happen. We are not only talking about lake trout from Husky Lake, but there are a lot of other places like Holman and other places where they depend on lake trout too. I can only really speak for the area around Tuk because I am familiar with it. The Tuk area has a lot of lakes. People are starting to find out that some of these lakes are just walking distance from the beach, so they're concentrating more on fishing in the summertime in these lakes during this time of year.

I would like to thank you for this opportunity to say a few words. You will be hearing more of the work on Husky Lakes from Lois Harwood. I would also like to thank Lois for her efforts in organizing this forum and we look forward to working with you the next few days.

4.1.3 Gerry Leprieur

Director of Parks and Tourism
Government of the Northwest Territories

I wonder if we can attribute the shortage of trout in some of the lakes around here to our mayor, who is the consumptive type. Thank you very much. It is a pleasure to be here. I'm sure the Minister would have liked to be here to say a few words to you and welcome you to Yellowknife.

Fishing is a major source of dollars in the Northwest Territories. It is a major industry here as well. It is important to the livelihood of many northerners. Although the fish stock is still strong in many of our remote lakes and streams, stocks have definitely declined in the nearby recreational lakes. Please restock Prelude Lake for us.

Throughout the tourism industry as a whole in Canada, the fishing sector has shown somewhat of a decline in our younger generation. I am sure you've heard of that from many of the operators around who have asked "Where are our new fishermen going to come from? Where will our new sports fishermen come from?" There are many serious issues related to that and I think that finding great places to go fishing that are not so remote is probably one of those factors.

I am sure you are going to have an interesting week here. Do not forget to get out and enjoy the aurora late at night, even if you have to stay up past your bedtime. The Japanese have come a long way to see it. It's not just diamonds that we have here. We do have spectacular aurora borealis that is starting to bloom now on these nice clear nights. If you go to a remote spot where there is not so much light pollution, I guarantee a good show. Thank you.

Welcome Panel

4.1.4 John Cooley

Director, Central and Arctic Region
Fisheries and Oceans Canada

Good morning everyone, and welcome to Yellowknife. On behalf of the Department of Fisheries and Oceans it is my pleasure to welcome you to the 2nd North American Lake Trout Symposium. Like many of you, I am a visitor to Yellowknife. Although I grew up in the Toronto area, sustainable lake trout populations have been an issue I have been interested in since I joined the DFO, Department of Fisheries and Oceans, over 30 years ago. During my career, colleagues and I have worked with staff from the Great Lakes Fishery Commission, the Ontario Ministry of Natural Resources and numerous U.S. agencies. Those efforts were all related to lake trout. I am really pleased to see a number of those people are here today to report on the work that they have done.

Over the period of time the goal for lake trout in the Great Lakes has always been clear and that is to restore self-sustaining lake trout populations. The Great Lakes have had many other problems over the years, and thanks to the efforts of many agencies, things are very much improved.

This probably indicates how old I am, but I can remember the excitement at the GLFC (Great Lakes Fishery Commission) meetings when reports came in that non-fin-clipped lake trout had been caught in Lake Ontario. This was the first evidence that there had been successful natural reproduction after many years of no reproduction. This occurred as a result of collaborative efforts across the borders of two countries and many regulatory agencies. That was really important because lake trout had been extirpated from Lake Ontario years ago for a variety of reasons. You are probably familiar with these reasons. I know that you're going to hear more about some of these studies from some of my southern colleagues who are here at the symposium.

A year or so ago, when Ron Allen approached me suggesting that we host the event, it was really an easy decision for me. More than ever before, preserving and enhancing native species such as lake trout is a really important activity. So on behalf of DFO and the Central and Arctic Region, I wish you success in your discussions over the next few days. Thank you.

5 Lake Trout Across the Range:
An Overview of the Distribution, Harvesting and Issues Relating to Lake Trout

Opening Remarks
Session Chair – James Boraski
Fisheries and Oceans Canada

I am pleased to be here today to address the topic, Lake Trout Across the Range. Forty years ago my father took his son fishing on Labour Day weekend and the very first fish that I caught on my first real fishing trip was an eight-pound lake trout. That catch prompted a lot of interest in a career that has spanned 30 years.

I am pleased to have been asked to moderate this session, so thank you to the organizing committee. I will move on with our first introduction. Brendan Scanlon from Alaska began working for the Alaska Department of Fish and Game as a seasonal technician in 1995. He received his Bachelor of Science and Wildlife Biology from the University of Alaska-Fairbanks in 1997. And he received his Master of Science and Fisheries at this university in 2000. His thesis project involved investigating morphological variation and anadromy in Arctic char and dolly varden in Becharof Lake, Alaska. He became the research biologist in charge of northern pike research in 2000. Lake trout duties were added to his responsibilities in 2001 and Brendan advises that he attended the first Lake Trout Symposium in Whitehorse and had a great time. So please welcome Brendan Scanlon.

5.1 Alaska

5.1.1 Lake Trout Management in Alaska

Brendan Scanlon
Alaska Department of Fish and Game, Sport Fish Division
Fairbanks, Alaska

Introduction
Lake trout (*Salvelinus namaycush*) support important recreational fisheries in Alaska roadside and remote lake systems. The life history of lake trout, however, allows this species to be over-exploited when fisheries are not managed properly. Lake trout populations frequently have slow growth rates, low fecundity, alternate-year spawning regimes, strict habitat requirements (cold, deep, oligotrophic lakes with a sufficient prey base and few competitors), and extreme susceptibility to changes in habitat (Martin and Olver 1980). Careful monitoring of this species is important to manage the many popular lake trout fisheries in Alaska.

To provide sustainable fisheries for lake trout using regulations based on sound research, Alaska area managers developed a plan for the management of sport fisheries on wild lake trout *Salvelinus namaycush* stocks in the Arctic, Yukon, Kuskokwim, and Upper Copper/Upper Susitna management areas of Alaska (Region III; Figure 1). This plan was adopted for the Upper Copper, Upper Susitna area by the Alaska Board of Fisheries (BOF) in December 2005. In this abstract, a brief description of the Region's lake trout fisheries, including current levels of angler participation in the fishery and patterns of resource use, is detailed. Next, a brief review of the biology of the species is given to highlight its unique life history traits and constraints on the viability of the species. Finally, management options are considered for providing sustained yield from these stocks within biological constraints, with the goal of managing this species in an effective and uniform way across Alaska.

Description of the Fishery
The distribution of lake trout in Alaska is at the edge of the geographic range of this species and includes areas of very slow lake trout growth and low total lake productivity. Lake trout are found throughout the high elevation lakes of the Brooks Range, the Arctic coastal plain, the Upper Tanana, Susitna and Copper River drainages, Bristol Bay, and the Kenai Peninsula (Figure 1). This species is most frequently found in deep, oligotrophic lakes in the mountains and is rarely found at lower elevations (Morrow 1980; McPhail and Lindsey 1970). The habitats occupied by the species have experienced little impact from land use or from industrial contaminants and are mostly still in pristine condition.

The Alaska fisheries for lake trout are primarily on wild stocks. In the limited instances where lake trout have been stocked, the purpose was to introduce the species to a new water body rather than to enhance or rehabilitate a wild stock. There are currently no lake trout in Alaska hatcheries. The fisheries for lake trout include subsistence and sport uses; there are no commercial fisheries for lake trout.

Subsistence Fisheries
In Alaska, the subsistence use of lake trout is limited to stocks inhabiting waters situated near rural communities (Andersen et al. 2004; Gustafson 2004). Examples include harvest of lake trout from Chandler Lake by residents of Anaktuvuk Pass and from Old John Lake by residents of Arctic Village. While no quantitative measure of the annual subsistence harvest from these and similarly situated waters is available, the effect of these fisheries on lake trout stocks is

believed to be minimal (Pedersen and Hugo 2005). In most cases, the relatively small human populations target other fish species for subsistence, species that can be harvested with higher efficiency and in greater numbers (e.g., whitefish species, Pacific salmon). At present, there is no regulation or limit on the subsistence harvest of lake trout from these remote water bodies.

Sport Fisheries
Lake trout support important recreational fisheries in Alaska. In nearly all areas, the greatest amount of fishing effort directed at lake trout stocks is by local anglers. Sport fishing for lake trout in Alaska is popular throughout the year. Annual sport catch and harvest of lake trout is estimated by the Alaska Statewide Harvest Survey (SWHS), an annual mail survey of licensed anglers (both residents and non-residents). The SWHS also estimates total fishing effort for all fish species for fishing sites but fishing effort directed at individual species is not generally available. The utility of the estimates is strongly dependent on the number of responses for a fishing site.

The sport harvest of lake trout in Alaska statewide has decreased during the last two decades while catches have remained relatively stable. Between 1986 and 1995 harvest averaged about 14,300 lake trout per year compared with about 7,400 per year in the last 10 years. Estimates of total catch did not become available until 1990. Average catch for the most recent period (2001-2005) was 38,300 compared with 33,300 in 1996-2000 and 41,200 during 1991-1995. These results suggest that although the total catch of lake trout in Alaska has not changed substantially, the portion of the catch that is released has increased. The lake trout fishery is primarily conducted by Alaska residents, with residents accounting for approximately 80% of the harvest and 60% of the total catch.

Sport Fish Division's Region III includes the North Slope, the Yukon River drainage including the Tanana drainage, Northwest Alaska, the Kuskokwim drainages and the upper Copper and Upper Susitna drainages (Figure 1). The lake trout fishery within this region accounts for approximately half of the catch and harvest of the species in Alaska. Between 2001 and 2005, approximately 2,800 lake trout were harvested annually while the total catch averaged 16,600. Within the region most catch and harvest of lake trout comes from lakes in the Glenallen area (in lakes near the Upper Copper and Upper Susitna drainages). In the last 5-year period, 61% of the total catch and 57% of the harvest came from this area. The Tanana River portion of the Yukon drainage accounts for the other large portion of the use of lake trout in the region; on average, 27% of the harvest and 21% of the total catch of lake trout is from this area.

Lake Trout Biology
Lake trout in Alaska spawn during the middle or latter part of September. The age at which lake trout mature is variable; the age of maturity for females (AM_{50}) estimated from 11 Alaskan lakes ranged from 5 to 14 years (Burr 1993). Faster growing populations in small lakes generally spawn at younger ages than individuals in larger lakes or in lakes situated at higher latitudes. Lengths of maturity (LM_{50}) for the Alaska populations were less variable, ranging from 16 to 20 inches (360-480 mm FL; Burr 1993). Once mature, lake trout in productive lakes may spawn annually or once every two or more years in more severe habitats (Burr 1991).

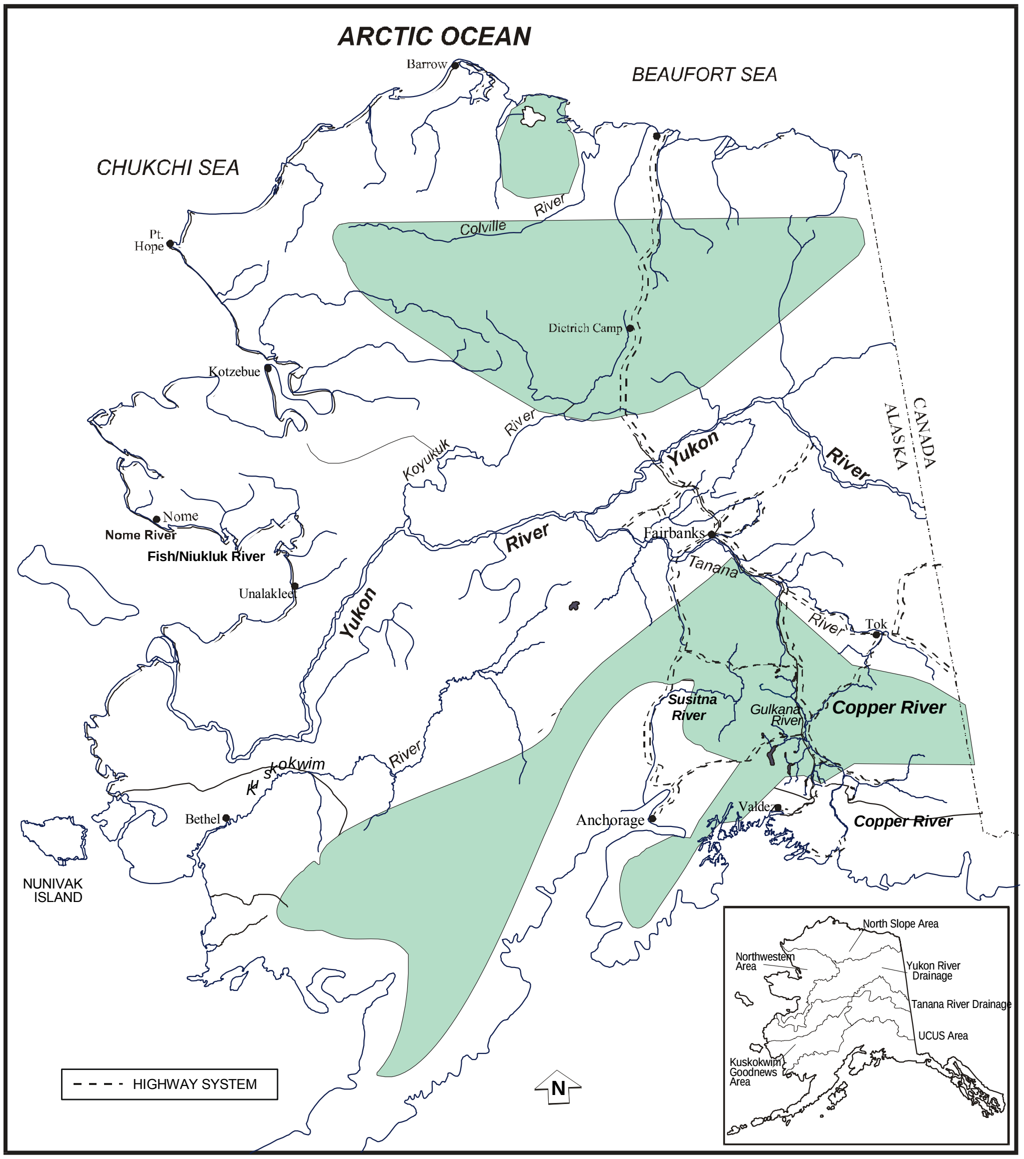

Figure 1.–Distribution of lake trout (*Salvelinus namaycush*) in Alaska indicated by shading.

Growth of lake trout is usually slow. In most Alaska lakes where populations have been studied, lake trout required more than 10 years to reach 400 mm FL (Burr 1997). In other lakes, growth was markedly faster with most fish reaching 400 mm in approximately 5 years. Lake trout can attain old ages and very large sizes. The maximum ages of lake trout sampled from lightly exploited populations in Alaska exceeded 40 years and ages in excess of 30 years were common (Burr 1987). The presence of fish in old age classes indicates low annual natural mortality (Burr 1993). Large lake trout are present in most lakes and a number of trophy size lake trout (> 7 kg) are taken in sport fisheries each year. The current Alaska record is 117 cm and 21 kg. The maximum length that lake trout attain is positively correlated with length at maturity and with lake surface area (Burr 1997).

Estimates of abundance and density from populations in Alaska show that lake trout populations are sparse (Burr 1992, 1997). Density of lake trout of mature size varied from 0.6 fish/ha (1.2 kg/ha) to 32.8 fish/ha (33.5kg/ha). The seven lakes in the data set ranged in size from 33 to 1,600 ha and a significant inverse relationship between lake surface area and adult lake trout density was observed (Burr 1997).

The results from lake trout studies in Alaska including maturity schedules, growth rates and population densities summarized above are within ranges reported for the species from other North American locations (Burr 1993, 1997). Consequently, the information gained from long term, detailed studies of lake trout population dynamics from other areas is generally applicable to lake trout management in Alaska. Carl et al. (1990) reported that mean size, maximum size, and size and age at maturity of lake trout increased with lake size along with the number of predators and competitors. As described in a following section on estimating annual yield, the influence of lake surface area on the growth, mortality, and productivity of lake trout populations can be used in estimating annual yield expectations.

Review of lake trout management in Alaska

Sustainable yields for lake trout are low. In cases where the stock has been depressed, recovery is very slow (Christie 1978; Martin and Olver 1980). Several studies have shown that a small amount of residual fishing pressure may be enough to prevent recovery of the stock (Olver et al. 2004). Because of this, the most effective management strategy of lake trout populations must seek to maintain harvests well within sustainable limits. A key part of effective lake trout management is to manage expectations of anglers.

Estimating Annual Sustainable Yield

Because lake trout inhabit deep water and typically occur in low densities, stock assessment research is difficult and costly, and may result in biased and relatively imprecise estimates, particularly in large or remote lakes. In lieu of stock assessments, researchers and managers in Alaska are increasingly using models to estimate yield potential (YP) of lake trout based upon environmental variables such as lake surface area (LA), thermal habitat volume (THV), and concentration of total dissolved solids. Both THV and LA models have been applied to lakes in Alaska (Szarzi and Bernard 1997; Scanlon 2004)

Christie and Regier (1988) developed the thermal habitat volume (THV) model for estimating harvest potential of lake trout in large lakes (18,900–8,200 ha). THV was defined as the volume of water bounded by the 8°C and 12°C temperature isotherms averaged over the summer (June – September) period. Optimal levels of dissolved oxygen for lake trout occur in this temperature range. Szarzi and Bernard (1997) applied the THV model to lake trout in Paxson Lake and Lake Louise in Alaska, but found that measurements of THV could vary by up to a factor of three from one year to the next, generating wide fluctuations in available habitat and consequentially potential yield estimates. Because of this variability and because many Alaska lakes do not thermally stratify, this model has not been adopted for managing Alaskan lakes.

Payne et al. 1991 and Evans et al. 1991 developed models that described the relationship between lake surface area and observed annual yields of lake trout in Ontario. These lake area models used surface area as a measure of available preferred habitat (Marshall 1996). Lake surface area had a strong association with the growth, mortality, and productivity of lake trout populations (Carl et al. 1990; Payne et al. 1991). Mean size, maximum size, and size and age at maturity of lake trout increased with lake size along with the number of predators and competitors. As a result, lake surface area provided a surrogate factor representing a wide range of environmental and biological factors that affected lake trout populations. These authors demonstrated that lake trout yield varied inversely with lake area. On a per unit area basis, small lakes produced greater yields than large lakes, although total harvests from small lakes are much smaller and small lakes are more vulnerable to overexploitation. The model given by Evans et al. (1991) was based on a larger and more diverse lake data set and was recommended by Olver et al. (1991):

$$\text{Log}_{10}\, H = 0.60 + 0.72\, \text{Log}_{10}\, A$$

where H = annual harvest in kilograms (kg) and,
A = lake surface area in hectares (ha)

The lake area (LA) model described above is currently used to set target harvest levels for Interior Alaska lake trout lakes. This model provides an excellent general guideline but, because the model is based on a large range of lakes and their observed sustainable yields, the predicted annual yields are inherently imprecise. The potential yield given by the LA model is treated as a threshold that should not be exceeded rather than a target level of exploitation.

Estimating Annual Harvest and Yield

The estimates of harvests of lake trout from the SWHS provide an estimate of annual yield of lake trout for each water body. These harvest estimates are compared to the yield potential predicted by the lake area model. Because harvest is estimated as number of fish and the yield from the lake area model is in terms of biomass (kg), the harvest estimate must be converted to biomass (kg) of lake trout. For Alaska lake trout stocks that have been directly studied, information on the size composition of fish present in the stock is used for this conversion. In cases where a minimum length limit regulation is in place, the conversion is based on harvest of legal sized fish only. For lake trout stocks that have not been directly studied, the size of fish harvested is estimated from information from other similarly sized lakes.

Because of the inherent imprecision (variability) in the yield potential from the lake area model and the variability and generally poor precision for lake specific estimates of harvest from the SWHS, it is important to emphasize the limitations of this monitoring scheme. Annual harvests that exceed the estimated annual YP should be used primarily as an indication that the stock may be in danger of excessive exploitation. For high use fisheries where harvest estimates are generally more precise, annual harvest in excess of the LA model target will likely trigger assessment of the population and/or a change in the fishing regulation. For remote, low use fisheries, two or more consecutive years of “excessive” harvest estimates would be needed to trigger research/management actions.

Methods of Controlling Exploitation within Estimated Levels of Yield

The goal of fishery management is to ensure the perpetuation of fish stocks by controlling human-induced mortality of fish. In sport fishery management, the intent is to provide continuing fishing opportunity and to distribute the allowable catch/harvest fairly among participants.

Traditional harvest control measures include daily catch (bag) limits, size-based regulations, gear restrictions and seasons. These measures are effective until they are undermined by large increases in the demand for recreational fishing. Several studies have shown that increases in fishing effort translate roughly into increased fishing mortality (harvest plus unintentional mortality; Goddard et al. 1987; Carl et al. 1990). The management challenge is to balance the desire for increased fishing opportunity with finite annual production. Because of our open access, common property system of resource management, it is very difficult to control high levels of angling effort short of closing lakes to fishing (Christie 1978). Balancing increasing demand with a clearly finite supply is particularly challenging with lake trout. As stated previously, it is critical to manage the expectations of anglers.

Rehabilitation/Stocking

Attempts at enhancing or rehabilitating wild lake trout stocks have generally not been successful, are very expensive, and have resulted in numerous unintended negative consequences. Evans et al. (1991) make a strong case against stocking lake trout for purposes other than for establishing new populations or for re-establishing stocks that have become extinct.

In Alaska, lake trout have been stocked as adults, juveniles, and as eyed eggs in a few lakes that did not previously contain lake trout (Burr 1987, 1994). One of the larger lakes is Harding Lake (1,000 ha) near Fairbanks. This lake currently provides a popular fishery targeting large lake trout. There are no plans for enhancing existing wild lake trout stocks in Alaska.

In recent years Paxson Lake (1987 – 1990, 1,575 ha, Copper River drainage) and Sevenmile Lake (1991-1998, 33 ha) have been used as sources of fertilized lake trout eggs for the AYK stocking program. The egg take from Paxson Lake ended in 1990 because of concerns over disease (IHN virus from sockeye salmon) and genetics (Paxson Lake is not within the Tanana/Yukon drainage). The Sevenmile Lake stock was used only on alternate years because of the small population size (approximately 1,000 adults) and provided about 100,000 eggs each year. Additional sites for obtaining fertilized eggs will be needed if and when lake trout again become part of the stocking program. There are currently no lake trout in any state hatcheries.

History of Sport Fishery Regulation and Management

The daily bag and possession limit for lake trout in most of Alaska until middle 1980s was 10 per day, with only two lake trout larger than 50 cm. Set lines (unattended, baited trot lines) were permitted and the season was open all year. Under these regulations, stocks located in areas near the road system lost large lake trout through high harvest rates, particularly by the indiscriminate set line fishery (targeting lake trout and burbot, *Lota lota*).

In 1988, the regulation for most of Region III was changed to four per day without size limit. In less remote areas (Tanana management area), the general regulation was reduced to two per day with no size limit. Minimum size limits and or reduced daily bag limits were applied to certain high use areas. Within the haul road corridor of the North Slope, a no harvest regulation (catch-and–release only) was instituted in 1995. This regulation was in response to very high harvest rates in the lakes adjacent to the road system.

In 2004, the background regulation for lake trout in Region III was reduced to two per day without size limit. The reason for this change was to provide a uniform regulation throughout the region that was generally consistent with expected annual yields from most lakes. Except for the Tanana and Glenallen management areas, the new regulation combines the daily bag limit for lake trout with the existing two fish limit for lake resident Arctic char, *Salvelinus alpinus*. These closely related species coexist in several lakes in the Yukon and North Slope of the Brooks Range. These species have very similar life history traits and potential yields.

Plan for the Management of Wild Lake Trout Stocks in Alaska

In this section, a plan for the management of sport fisheries on wild lake trout stocks in the Arctic, Yukon, Kuskokwim, and Upper Copper/Upper Susitna management areas of Alaska is proposed. **The overall objective of the plan is to maintain harvests of lake trout below defined MSY thresholds**. Annual harvest levels are estimated from the annual SWHS, and compared to predicted annual yields based on site specific studies or on the lake area model. In addition to maintaining harvests below expected maximum yields, this plan seeks where practical to promote simplicity and uniformity of regulation. Restrictive site-specific regulations often have the effect of simply pushing angler effort and harvest to other nearby waters that are often equally vulnerable to increased harvest.

Description of Management Plan

The **background regulation** will provide a **daily bag and possession limit of two lake trout per day without size limit.** This bag limit was selected because it is likely to provide sustainable levels of harvest across a wide range of populations under moderate levels of angling effort. At this level of regulation, bait is permitted although set lines (unattended trot lines) are not.

If harvest levels increase so that further control is needed, regulations will be applied in the following (increasingly restrictive) fashion.

First, the **bag limit** will be **reduced from two to one fish**. A reduction in bag limit prior to introducing other regulatory controls is preferred for at least two reasons. First, the unintentional mortality associated with the mandatory release of certain size fish is avoided. Second, a reduction in harvest is obtained without unnecessarily reducing the diversity of fishing opportunities (e.g., use of bait, type of lure/hook, reduction in length of season).

If an additional reduction in fishing mortality is needed, the following regulatory actions may be taken alone or in combination: 1) application of a length limit; 2) gear restrictions; and/or 3) seasonal closures.

The use of a **minimum length limit** is recommended when size limits are contemplated. The goal of this type of length limit is to reduce harvest by delaying the entry of year classes into the fishery rather than to manipulate the size composition of the adult standing stock. Given this goal, the use of a length limit regulation should generally be coupled with the elimination of the use of bait (to reduce the incidental mortality of released fish).

Minimum length restrictions should be structured to allow fish to spawn twice prior to recruitment to the fishery. For most lakes larger than 100 ha in interior Alaska, 60 cm (total length) will provide the needed protection (Burr 1991, 1993). For consistency of regulation, the 60 cm minimum length limit should be used unless compelling, site specific data indicate that an alternate minimum size limit is needed. The use of length limits is not recommended for lakes smaller than 100 ha. The lake trout populations in these small lakes are typically composed of small individuals and there is little difference between length of maturity and the maximum size of fish in the population.

Gear Restrictions intended to reduce fishing mortality include elimination of bait and the mandatory use of single hook, artificial lures. Circle hooks also appear to offer a benefit in reduced mortality of released fish and their use may be considered. The use of barbless hooks is widely believed by anglers to facilitate release of fish. However, because there are at present no compelling studies that demonstrate a measurable benefit, it is difficult to justify requiring the use of barbless hooks.

Reducing Open Season. Closing the fishery during periods when the fish are particularly vulnerable to harvest has been shown to be effective at reducing total annual harvest. Seasonal closures that should be considered include spawning closures, closures during spring break-up or closures during the ice covered season. Winter season closures may be especially effective for small lakes located near large communities.

If implementing these regulatory actions fails to control harvests within sustainable levels, a **catch-and-release only regulation** will be implemented. Just as with size-based regulations, catch-and-release regulations require that we consider the unintentional mortality of released fish. To estimate the fishing mortality resulting from catch-and–release fisheries, we will assume that 10% of all released lake trout are killed (harvested).

Finally, if these measures are insufficient to curtail fishing mortality within clearly identified limits, the lake trout fishery will be **completely closed** until assessment of the population indicates that it has recovered to an abundance level that can sustain a harvestable surplus that is sufficiently large to effectively manage. The recovery period is likely to last a decade or more due to the low productivity of the species.

Special Management Waters. In waters where harvests are within biologically sustainable levels, secondary management objectives seeking to achieve publicly supported alternative management goals may be implemented. An example of special management may include shortened open seasons and or catch-and-release only fishing to maintain a higher stock abundance and presumably to provide higher catch rates. An alternative length limits could be used with the goal of maintaining a higher proportion of fish in large size categories. Because special management regulations generally result in less overall fishing opportunity, broad-based public support is emphasized for this type of regulation.

Wild Lake Trout Management Plan

5 AAC (Alaska Administrative Code) Wild Lake Trout Management Plan. (a) The department shall manage wild lake trout populations in the Arctic-Yukon-Kuskokwim Area (Region III) by employing a conservative harvest regime and by maintaining harvests below maximum sustained yield levels. Following sustained yield principles, the department may manage wild lake trout fisheries to provide or maintain fishery qualities that are desired by sport anglers.

(b) In a sport fishery covered by this management plan, the commissioner, by emergency order, may take one or more of the management actions specified in this subsection if there is a conservation or biological concern for the sustainability of the fishery or for a stock harvested by that fishery. The concern must arise from harvest, effort, or catch data for that fishery which has been derived from statewide harvest survey data, on-site creel survey data, stock status data, stock exploitation rates, or from inferential comparisons with other fisheries. The management actions are as follows:

(1) reduce the bag and possession limits;
(2) reduce fishing time;
(3) allow only a catch-and-release fishery;
(4) modify methods and means of harvest.

(c) If the harvest level in the Upper Copper River and Upper Susitna River Area exceeds sustained yield for a two-year time period, the commissioner by emergency order, may close the fishery and immediately reopen a fishery during which one or more of the following restrictions apply:

(1) bag and possession limit of one lake trout;
(2) a minimum size limit applies, the size limit shall be established based on the following considerations:
  (A) length of maturity, with two years of protection from harvest for spawning fish before recruitment to the fishery;
  (B) lake size, with no size limits for a trout population in a lake with a surface area less than 100 hectares;
  (C) uniformity of size limits, with the minimum size limit 24 inches unless the department determines that there is a biological justification for an alternate size limit;
(3) if the reduced bag limit or size limits do not keep harvest below maximum sustained yield levels the commissioner may further restrict harvest opportunity, through:
  (A) seasonal closures;
  (B) spawning closures, winter closures, or both;

(C) allowing single-hook, artificial lures only or no bait, or both;
(D) allowing catch-and-release fishing only; and
(E) a complete closure of the fishery.

(d) Special management waters are waters designated by regulation of the Board of Fisheries, where harvests are within sustained yield levels and where the management objectives include higher stock abundance or a need for a higher percentage of trophy-sized fish. Within special management areas, if the department determines that management objectives will not be met under existing regulatory provisions, the commissioner may, by emergency order, close the fishery and immediately reopen a fishery during which one or more of the following management measures apply:

(1) reduced fishing season;
(2) special gear restrictions;
(3) alternative size limits; and,
(4) catch-and-release fishing only.

(e) The department shall minimize potential conflicts with a subsistence fishery, or other fisheries that overlap the sport fishery, that harvest other fish within the same body of water.

5 AAC 52.022(9). Lake trout: may be taken from January 1 – December 31: bag and possession limit of two fish: no size limit.

5 AAC 52.022(a)(14). The use of set lines is prohibited.

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Chair
James Boraski

Our next speaker is a recent colleague of mine since I have moved into the Western Arctic area. George Low is going to speak to you today on the Northwest Territories and Nunavut populations of lake trout. George started his career with DFO as a technician collecting baseline data used to address the resource impacts of the Mackenzie River Pipeline Project. George wants everyone to be aware that was back in the '70s, the first time round. He has worked as a fisheries management biologist for DFO since 1982. He has also worked extensively with aboriginal organizations in co-management and subsistence, recreational and commercial fisheries along the Mackenzie Valley, Great Slave Lake, Great Bear Lake, as well as Kitikmeot and the Central Arctic. George is also a long-standing member of the Great Slave Lake Advisory Committee and has recently been part of a team which developed the Great Bear Lake Watershed Management Plan.

5.2 Northwest Territories and Nunavut

5.2.1 Distribution, Harvest and Management Concerns of Lake Trout, *Salvelinus namaycush*, in the Northwest Territories and Nunavut

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Distribution
Lake trout, *Salvelinus namaycush*, is widely distributed in the Northwest Territories and Nunavut, including parts of some Arctic islands: Baffin, Southampton, King William, Victoria, and Banks (Scott and Crossman 1973). Lake trout are common in the clear, deep lakes of the Precambrian Shield but also occur in lakes outside the Shield along the Mackenzie Valley to the Arctic coast. Lake trout may also occur in large, clear rivers such as the Coppermine. All lake trout stocks in the Northwest Territories and Nunavut are of natural origin; they have not been stocked in any waters.

Harvest
In Nunavut, Arctic char are the dominant species harvested for subsistence. Lake trout are, nevertheless, important for recreation as well as providing sustenance in communities near these stocks. Spring fishing derbies for trout lakes are very popular in some communities. Eighteen of twenty-seven communities reported trout harvest and the mean total annual harvest from 1996 to 2001 was 22,559 lake trout (Nunavut Wildlife Harvest Study). This species is the backbone of the sports fishing industry on inland lakes in the mainland where several fishing lodges are located. The commercial gillnet fishery is minimal; lake trout are harvested as by-catch, usually during arctic char fisheries.

In the NWT, lake trout is an important species in subsistence fisheries, especially in communities such as Deline, Great Bear Lake, and Lutsel K'e, the east arm of Great Slave Lake. Many other communities have "trout lakes" in close proximity.

In the Inuvialuit Settlement Area (ISR), an average of 5,054 lake trout were harvested annually for subsistence in recent years. However, sports fishing in the area is minimal. There is one lodge in operation.

Lake trout are not regularly fished in the Gwich'n Settlement Area. There are no lodges, outfitters, or commercial fisheries. However, some lake trout are taken in a subsistence net fishery from waters such as Travaillant Lake.

Lake trout is still important to the community of Deline, the only community on the shores of Great Bear Lake. The mean annual harvest for 2000 and 2001 was ~ 3000 lake trout (Sahtu Settlement Harvest Study). Presently, there is no commercial fishery on Great Bear Lake or elsewhere in the Sahtu area. Lake trout is the most important species for the sports fishing industry and the lodges rely on large trophy-sized lake trout to attract guests. Several lodges operate on Great Bear Lake with a total guest capacity of 236 people, although not all lodges are operating at this time. Others are running at reduced capacity. In 1990, when all lodges were operating at full capacity, the harvest was approximately 3,840 lake trout. The harvest was mainly smaller trout taken for shore lunches. Lake trout are harvested to a lesser extent in the other Sahtu communities.

Harvest statistics are not available for the Deh Cho area, but there are several lake trout lakes inland from the communities that are used for subsistence fishing. The community of Trout Lake (Sambaa Ke) fish for subsistence purposes and there is a sport fishing lodge business. A small fishery for local commercial sales was closed on the recommendation of the Sambaa Ke First Nation in 2005. Catch and possession limits for lake trout were reduced to 1 daily and 1 in possession to sustain the high quality sport fishery.

Harvest statistics are also unavailable in the Tlicho Settlement Area and the North Slave region. There are many trout stocks available to the various communities in the area and several lodges rely on lake trout as their main attractant. The eastern Hearne Channel, McLeod Bay, and Christie Bay comprise Area VI (the inner east arm) of Great Slave Lake and are managed for a high quality sports fishery as well as for subsistence fishing by First Nations. There are four lodges that operate in this area with a total guest capacity of 94 people. Catch and possession limits are 1 trout daily and 2 in possession with only one trout allowed over 70 cm. Based on a lodge survey conducted in 2001, the lake trout harvest was ~3,000 fish,and consisted primarily of small trout used for shore-lunches. The only community in the area, Lutsel K'e, reported harvesting 5,183 lake trout in a 2004/05 harvest study. Area V (the outer east arm) is managed for a number of fisheries. The commercial gillnet fishery harvested ~10,000 kg of lake trout in 2004. Itinerant or recreational anglers kept ~1,300 trout, mostly from this area, according to a 1996 study. There is also one lodge and several outfitters who take an unknown number of lake trout from this area. The western basin (Areas IW, IE, II, III, & VI) is not suitable for angling because of high turbidity and sparser lake trout stocks. Although the lake trout stocks in the western basin were fished down in the 1940's and 1950's by the commercial gillnet fishery and continue to be suppressed, 77,000 kg of lake trout were harvested by the gillnet fishery in 2004 as by-catch to the whitefish fishery.

Issues and Concerns

Non-renewable Resource Development: Although development presently occurs in a small portion of the NWT and Nunavut, there is a definite need for fish habitat protection. The NWT has two large diamond mines, continued diamond mine exploration and more mines are on the way. Nunavut has one diamond mine and two metal mines are under development as well as extensive exploration activity. There are many environmental concerns from the mining activities including loss of lake trout habitat, contamination of water and fish, silting and turbidity problems associated with development, and the long-term effects of increased infrastructure such as permanent and winter haul roads. A major natural gas pipeline is planned for the Mackenzie Valley and this has caused increased exploration activity. Fish habitat issues include water withdrawal from lakes, the use of explosives under ice, stream crossings for roads and pipelines, increased potential for spills, contamination problems from drilling muds and sumps, and increased fishing pressure due to increased public access. Although Fisheries & Oceans Canada (DFO) has a "no net loss" policy which applies to mining, oil, and gas development and other activities, it is difficult to truly replace lost lake trout habitat. Cumulative effects of all development activities, whether mining, oil and gas development, or other activities, are a major concern of resource managers and the local communities.

Fisheries Management Issues and Concerns:
Presently, Nunavut has few fishery management concerns for lake trout. Lodges use catch and release fishing and there are no lake trout specific commercial fisheries. Lake trout stocks do not appear to be over-fished in subsistence fisheries. In the NWT, particularly on the two great lakes and near population centres such as Yellowknife, there is potential for stock problems. Lake trout stocks have been fished down in the western basin of Great Slave Lake and in lakes along the Ingraham Trail northeast of Yellowknife. The DFO must continue working with its co-managers to ensure not only sustainable lake trout stocks for subsistence and commercial fisheries where they presently occur, but also must maintain selected stocks at levels which provide large trophy lake trout to the sports fishery. A watershed management plan and research and monitoring plan has been developed for Great Bear Lake which, if implemented, will ensure the sustainability of high quality fisheries on Great Bear Lake. Stock assessments and research studies of lake trout in the eastern arm of Great Slave Lake trout date back to the 1970's and early 1980's. Scientific information on Great Slave Lake stocks is certainly dated and the current status of lake trout stocks is largely unknown. Most lake trout fisheries are managed on a precautionary basis with conservative catch and possession limits and other restrictions. As the human population continues to grow and expand, it will be necessary to know more about our lake trout stocks to manage them wisely.

Highlights since the Whitehorse Symposium in 2002:

- starting in 2004, the use of barbed hooks by sports fishers has been prohibited in the NWT;
- the Great Bear Lake Management Plan has been completed along with a research and monitoring plan;
- catch and possession limits were reduced to one trout daily and two in possession in area VI of Great Slave Lake, and restrictions are being increased on Prelude and Prosperous Lakes, near the city of Yellowknife;
- lake trout research is continuing in the ISR and Gwich'in settlement areas with the approval and support of the Fisheries Joint Management Committee in the ISR and the Gwich'in Renewable Resources Board in their settlement area;

- on recommendation of the Sambaa Ke First Nation, the DFO has closed their small commercial fishery and reduced the sports fishery catch and possession limits from 2 trout daily and 3 in possession to one daily and one in possession.
- an aquatic management program is being developed in the non-claim settled area of the Mackenzie Valley by the DFO and the Deh Cho First Nations; and
- a similar program is being implemented by the Akaitcho Territory Government in partnership with the NWT Metis Nation and three Deh Cho First Nation communities for the collaborative management of the Great Slave Lake watershed.

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Discussion

Unidentified male speaker: With regard to commercial fisheries, when you put a moratorium on them, were there any incentives for the commercial fishermen that were offered?

Low: In this particular case, Trout Lake is a very small community. I believe it has approximately 100 people. They have a lodge business which employs local guides. The commercial fishery was of a very small nature to supply fish for local sales, and they just saw the writing on the wall. They are noticing in their catch that the trout are getting a little smaller and a little less attractive for their sports fishing business. Dennis will be speaking about this later, but we did not have too much problem with closing that fishery. It was basically a community decision.

Chair
James Boraski

Our next speaker was one of the organizers for the Whitehorse event in 2002. Susan Thompson is going to be speaking to us about lake trout in the Yukon area. Susan has worked for the Yukon Department of Environment – Fisheries since 1989 when freshwater fisheries were transferred to the Yukon Government. She is currently a fisheries management biologist and has worked with lake trout on nearly all lakes in the Yukon. Susan was involved, as I said, in planning and hosting the first Lake Trout Symposium, which I understand was a tremendous success and we are glad that the second one is well under way.

5.3 Yukon Territory

5.3.1 Lake Trout Management in Yukon: Science, Rationale and Approaches

SUSAN THOMPSON
Environment Yukon, Fisheries

INTRODUCTION:

The Status of Lake Trout Management in Yukon prior to 1989
Before the transfer of freshwater fish management from the federal government to the Yukon Government in October 1989, there was limited stock assessment and harvest data for lake trout in the Yukon. Lake trout is the dominant freshwater species found in all five major Yukon watersheds and the dominant harvest species, but had a relatively low management priority. Historically, the focus was salmon management. There were generous sport fishing catch and possession limits of 5 lake trout per day and 10 in possession with no size limits and no closed seasons or areas. There were some gear restrictions including prohibitions on the use of downriggers. Angler harvest of lake trout was high (20,000 to 30,000 fish based on 1980 and 1985 national surveys) relative to the estimated harvest of commercial, domestic, and subsistence fisheries.

Anglers were conditioned to harvest large trophy lake trout and had generous catch limits. Commercial netting was allowed on 23 larger lakes with unlimited licencing and no quotas other than standard large lake quotas which were ineffective because of lack of reporting compliance. There was unlimited licensing of domestic netting and harvest. There was a significant level of First Nation subsistence fishing that historically was focused on lake whitefish but it has declined in recent years. Assessment using index netting surveys during the first five years after transfer of responsibility focused on the larger lakes to collect as much species information and population data as possible to learn about the biology and status of lake trout stocks in Yukon.

So what are we doing now?
We are focusing our effort on sport fishing and lake trout harvest management.

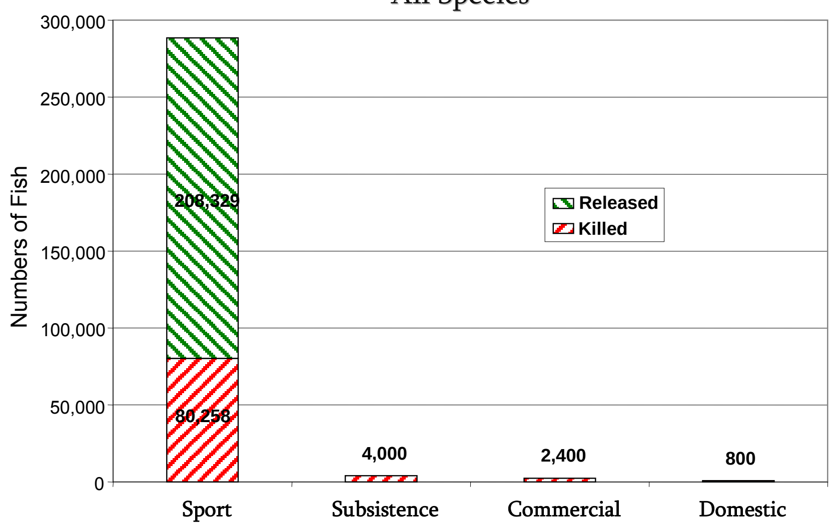
Why is sport fisheries management important?
Approximately 15,000 – 17,000 angling licences are sold annually in Yukon. This is important because the Yukon has a population of only 30,000. In the 2000 Survey of Recreational Fishing in Yukon, there were 94,000 angler days with 263,000 fish caught, 51,000 kept (19%) and 212,000 released (81%). Fourteen million dollars were spent on sport fishing.

DISCUSSION:

We must manage the sport fishery because anglers are by far the heaviest user of the Yukon fishery resource, including lake trout. The objectives and approaches to managing sport fishing are to manage for good quality angling and manage and limit harvest, but not limit angling opportunities. This is done by reduced catch and possession limits, size-selective harvest requiring the live release of all large fish (one trophy-sized fish allowed), special catch and size restrictions on small accessible lakes, no closed seasons or areas, and no gear restrictions that limit angler success other than barbless hooks to facilitate easier live release.

Our focus is on lake trout because they are the most sought-after species by anglers and the most sensitive indicator species for environmental conditions (water quality) and for over-exploitation. They live in deep, cold Yukon lakes with very low productivity. They are slow growing, averaging 120 gm/year (0.25 pounds/year), are late maturing (9-12 years of age), and have low reproductive capacity (do not spawn every year). Lake trout production is generally less than 0.5kg/ha/yr (0.5lb/acre/yr) with a sustained harvest of only 5 – 10% of this for a high quality sport fishery (Figure 1).

Figure 1. Freshwater Fish Harvest Summary (1995)
All Species



How do we manage harvest?

The main regulatory tools are (1) catch and possession limits, and (2) size limits. We found that daily catch and possession limits, which are more social than biological, were ineffective for limiting harvest unless they were very restrictive.

Example - Teslin Lake:

Angler harvest was too high from Teslin Lake with catch limits of 3 and possession limits of 6. These were then dropped to 2 and 4, respectively. After follow-up harvest monitoring and meeting with local Community members and the Renewable Resource Council, we concluded that these limits were still excessive. The catch limit was decreased to 1 per day and the possession limit had a maximum size of 65cm. This was effective to limit angler harvest. Only 15% of lake trout that were caught were released because of the catch limit of 1, while 44% of lake trout that were caught were released because of maximum size limits. Approximately 40% of lake trout caught were released voluntarily which points to the importance of angler education as a management tool.

The lake trout population is slowly increasing in Teslin Lake. For the past three years (2002 – 2005), anglers have been catching more lake trout and they are catching them not only in the areas that were historically good lake trout habitat, but in other areas within the lake where lake trout had not previously occurred.

The most important and effective harvest management tools that we use are slot and maximum size limits:

Slot size limits (release fish between 65cm and 100cm):

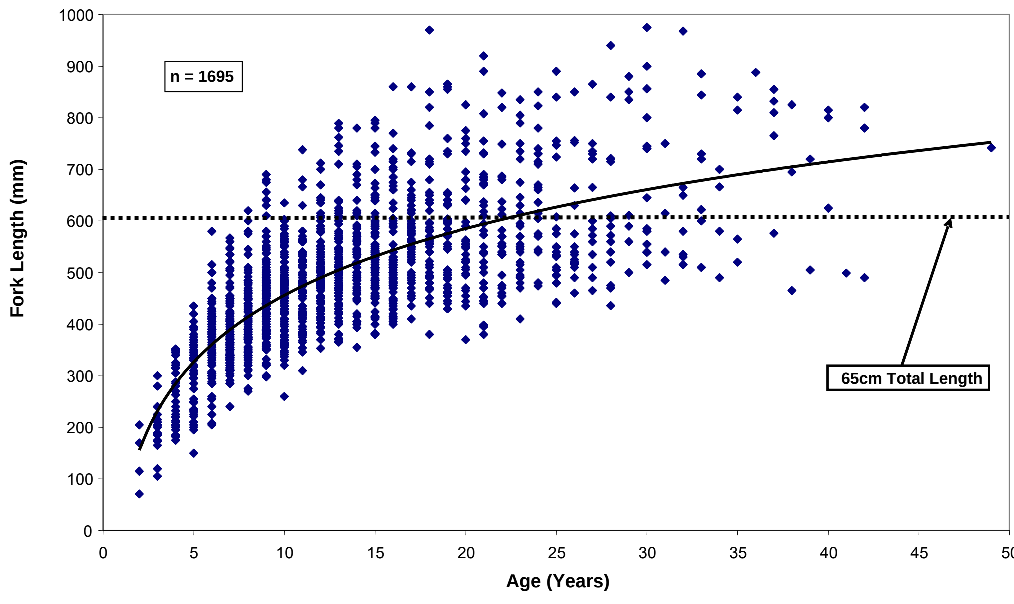
- are effective for maintenance of high quality stocks and angling;
- protects larger spawners but allows harvest of 1 trophy; and
- focuses harvest on smaller/immature fish (most abundant).

Maximum size limits (release fish above 65cm):

- are effective for maintenance of high quality stock and angling quality;
- protects all large, mature fish; and
- restricts harvest to smaller/immature fish.

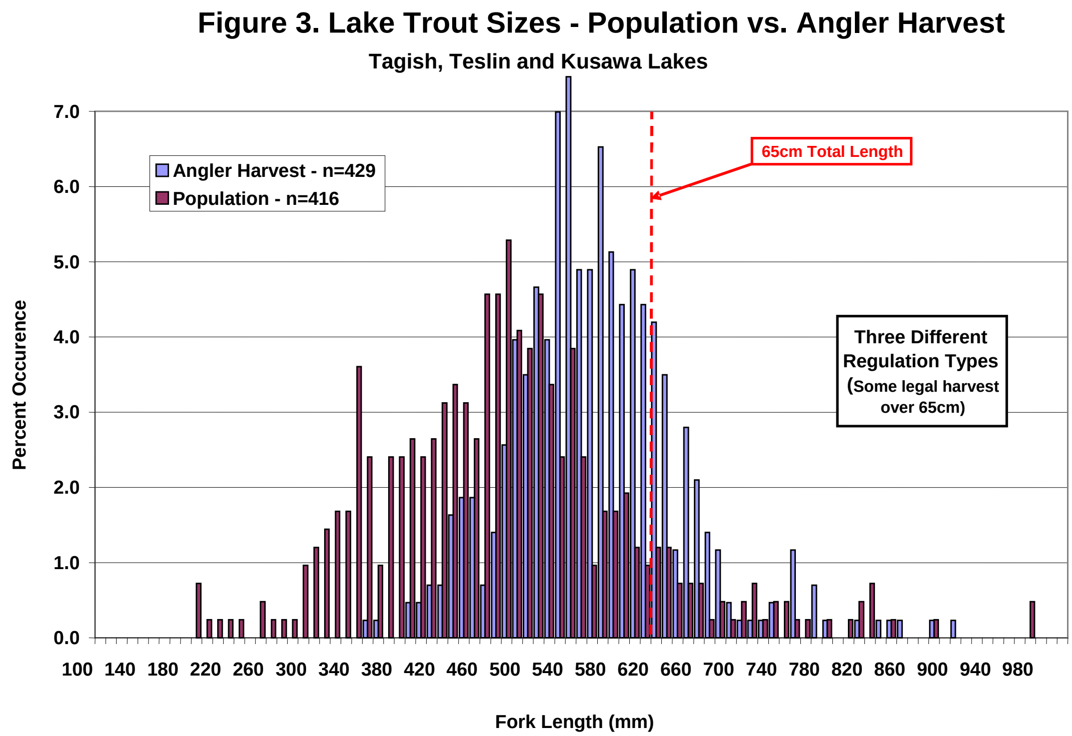
In 1990, when Yukon Fisheries began lake trout stock assessment, the largest lakes in the Yukon were surveyed and we were able to collect a large amount of data, including age and growth data (Figure 2).

Figure 2. Lake Trout Length at Age from Index Netting 15 Yukon Lakes 1990-1994



We established slot limits where all lake trout 65 to 100cm are protected from anglers. Lake trout sexually mature at 9 to 12 years (45 to 50cm) in the Yukon and growth slows as more energy is focused on reproduction. Lake trout greater than 65cm are released which protects large spawners while still allowing anglers access to a high percentage of the stock which consists mainly of smaller, immature fish.

In large Yukon lakes, 85% of the stock is below 65cm (available to anglers) based on index netting while angler harvest is biased towards larger older fish (Figure 3).



These large, old fish may seem disproportionately abundant to anglers because large, sexually mature fish must feed aggressively in summer to produce eggs and milt. Anglers target females more than males (typical angler harvest approximately 60% female) because females must gain approximately 20% of their body weight during summer to produce eggs while males need to gain approximately only 5% of their body weight to produce milt. Thus angler harvest is biased toward mature fish and towards females. There is a special limit for Tagish Bridge. The size limit is in effect and the daily catch limit is one fish because it is difficult to release fish off the bridge and 70% of the fish are over 65cm size limit and of these 70% are females.

EXPECTATIONS:

What have we learned since the first Lake Trout Symposium in 2002 that is important to lake trout management in the Yukon?

- One size does not fit all. Lake trout mature in our small lakes at a smaller size that does not fit into our size restrictions;
- large fish are genetically important to maintaining a healthy population; and
- Tagish Bridge, where maximum size limits are not in effect, anglers are catching mainly large lake trout, and these are mostly females.

Where are we in 2005?
General Regulations – more than 200 lakes (mostly remote or lightly fished):

- daily catch and possession limits - 3 and 6 fish;
- maximum size limit - only one fish over 65cm; and
- barbless hooks proposed Yukon wide for 2007.

Conservation Water Regulations
This affects approximately 50 waters (most road accessible lakes and remote lakes with major fisheries i.e. lodge lakes):

- daily catch and possession limits - 2 fish;
- slot size limit - no fish between 65cm (26") and 100cm (39") in length; and
- barbless hooks - single barbless hooks on some waters.

Small Lakes and Stocks
This affects approximately 20 waters (less than 100 hectares):

- daily catch and possession limits - 1 fish;
- maximum size limit - no fish over 65 cm (26"); and
- barbless hooks.

We do not encourage repeated catch and release of individual fish in Yukon lakes, but do use this as a management tool when fishing effort is moderate in a lake so that repeated catch and release of individual fish is not likely. Most Yukoners have ethical concerns about catching and releasing large numbers of fish (i.e. playing with your food is disrespectful), but they have accepted the necessity of limited live release as a management tool.

Chair
James Boraski

Our next speaker is Ted Down from British Columbia. Dr. Down earned his Ph.D. in Fisheries and Aquatic Sciences form the University of Guelph before moving to British Columbia in 1984 and he joined DFO's West Vancouver laboratory as a post-doctoral fellow. In 1989 he joined the British Columbia fisheries program as the regional fisheries biologist for the Peace Region with responsibility for fisheries management in the northeast quadrant of the province. In 1995, Ted moved to a position in Victoria and is currently the manager of Aquatic Ecosystems Science Section with the Ministry of the Environment. In this position, he coordinates a variety of provincial programs in the areas of stock management and assessment, habitat protection, restoration, fisheries research, and aquatic-species-at-risk.

5.4 British Columbia

5.4.1 Lake Trout in British Columbia – Status, Distribution and Management

N.E. (TED) DOWN, BC Ministry of Environment, PO Box 9338 Stn. Prov. Govt., Victoria, B.C. V8W 9M1. (ted.down@gov.bc.ca)

Introduction
Salmonids are a significant part of the British Columbia fish fauna because of their distribution, diversity, and ecological role. However, relatively little management attention has been focused on char species. Of the three char species native to British Columbia (bull trout, *Salvelinus confluentus;* Dolly varden, *S. malma;* and lake trout, *S. namaycush*), the lake trout has been the least studied. There are several reasons for this situation. First, the majority of lake trout populations are found in relatively remote areas. Second, other salmonids are either commercially important or more fully utilized by anglers and require more intensive management. Third, stream-dependent salmonids are generally more sensitive to habitat perturbations and have required more specific attention. High levels of aquatic biodiversity in B.C. and modest resources have required more extensive approaches to the conservation and management of species like lake trout. In this paper, I report on progress since the lake trout symposium held in Whitehorse in 2002.

Status
Lake trout are a yellow-listed species ("not at risk of extinction") in British Columbia (CDC 2005). However, this status assessment is based on expert opinion because few population data exist for lake trout. The apparently secure current status of lake trout in British Columbia (BC) results from its distribution in less-developed areas with poor road access. Several accessible populations of lake trout are known to be depressed. In contrast, bull trout and Dolly Varden are both blue-listed ("species of special concern").

Distribution
Lake trout are found in the north and central interior parts of BC (Figure 1). Populations are found in watersheds draining to both the Arctic Ocean (via the Peace, Liard, or Yukon rivers) and Pacific Ocean (via the Taku, Stikine, Skeena and Fraser rivers). This distribution likely reflects post-glacial colonization from distinct Beringia and Nahanni refugia (Wilson and Mandrak 2004). Within watersheds, lake trout are predominantly found in one of three biogeoclimatic zones: spruce/willow/birch, sub-boreal spruce, or Engelmann spruce/sub-alpine fir. Lake trout are absent in the boreal white and black spruce zone of the extreme northeast,

likely as a result of summer temperatures and the absence of large, deep lakes. They are also generally absent from the Fraser plateau and Pacific coastal drainages.

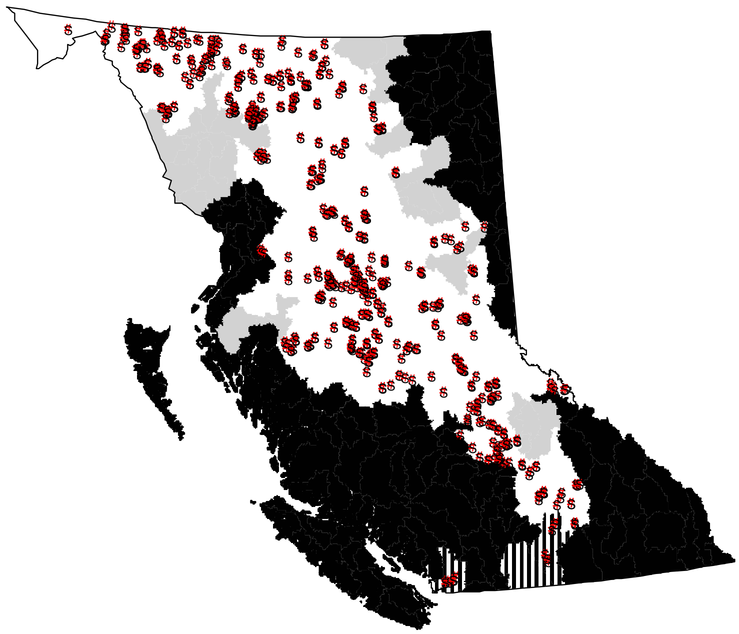


Figure 1. Lake trout range and observations. White areas are core range, gray areas are peripheral range, and black areas are out-of-range. Striped areas contain introduced populations.

Habitat characteristics

Over 70% of lake trout observations in BC are from lakes with a surface area of less than 1,000 ha, and about 65% of these lakes have a mean depth less than 20 m. However, this does not adequately define the lake characteristics of lake trout in BC because larger and cooler lakes also contain lake trout. More than 80% of lakes larger than 1,000 ha that have been sampled contain lake trout. In contrast, lake trout occur in less than 20% of the lakes smaller than 1000 ha. Further, small lakes with cooler watersheds (July air temperature$<10^{o}$C) are more likely to contain lake trout than those in warmer watersheds (July air temperature$>14^{o}$C). For larger lakes, which typically have substantial thermal refugia, the likelihood of observing lake trout is similar in cool and warm watersheds.

Management

Most lakes that contain lake trout populations have been little altered by anthropogenic disturbances. Forestry regulations include lakeshore reserve and management areas to protect “riparian” habitat. In a few areas (e.g., Shuswap Lake), lakeshore development by private landowners may threaten lake trout spawning shoals. The major anthropogenic impact on lake trout appears to be harvest by anglers, particularly in road-accessible lakes. Angling regulations have not adequately considered lake trout population characteristics and there has been little monitoring of exploited populations.

Stocking

Lake trout fisheries in BC are currently fully dependent on natural production. Limited stocking programs occurred in three pulses in the past. Between 1909 and 1916, an average of 21,000 eggs and fry were dispersed annually among 9 lakes in southern BC, utilizing locally obtained brood stocks whose source was not recorded. A second pulse of stocking occurred between 1968 and 1978 when captive brood stock from Manitoba or from the Jasper area of Alberta were used. Six lakes were stocked with a total of 44,000 fingerlings per year. The final period of stocking occurred in 1989-1990 when 3 lakes were stocked with an average of 11,400 fry or fingerlings each year. There are several extant naturalized populations, both within and outside of their natural range, as a result of these programs.

Angling regulations and utilization.

Lake trout account for about 3% of the total harvest by freshwater recreational fisheries in BC (Levey and Williams 2003). There is evidence that anglers may mis-report other salmonids harvested from lakes as lake trout, which causes over-estimate of the harvest. Despite this, lake trout are an important (if sometimes seasonal) fishery for resident anglers.

BC has used aggregate quotas and size limits to regulate sport fisheries for lake trout and other chars. The intent has been to limit the total harvest, irrespective of species, with the side-benefit of minimizing the effects of fish mis-identification. Until the mid-1980s, the trout/char aggregate quota ranged from 5-10 fish per day (depending on administrative region) with only 2 fish allowed over 50 cm. In 1985, the aggregate trout/char quotas were reduced to 4-6 daily with 1 or 2 over 50 cm. These quotas remain in effect today although there are now further restrictions on the aggregate quota to reduce the harvest of char species. Unfortunately, aggregate regulations do not deal well with differences in productivity or life history among these species. Existing aggregate regulations were based on the biology of rainbow trout and have questionable applicability to lake trout.

The first lake trout-specific regulation in BC was introduced in 1980 (a single lake spawning closure). By the mid- to late 1980s, additional location-based spawning closures and reduced bag limits for char were introduced. In 1994, an annual quota for lake trout was put in place on Shuswap Lake in response to declining catch rates, and anglers that were harvesting lake trout were required to purchase a conservation stamp. In 2001, a cooperative management strategy for several trans-boundary lake trout lakes was established with the Yukon territorial government.

These steps recognize the special management needs of char. More of the angling regulations are now based on lake trout biology and lake specific data, yet the effectiveness of regulations has largely not been assessed. Further, there is no consistent regulatory approach among administrative regions, and a provincial char management plan proposed in the early 1990s was not implemented. Because of the relatively low angler effort directed at lake trout, BC will continue to use an extensive approach to manage recreational fisheries for this species. However, any regulatory regime must be based on the best available science, be simple to understand and administer, and be able to support a healthy, sustainable fishery.

Data synthesis and future direction

In 2004, a synthesis and analysis of lake trout inventory and stock assessment data was initiated. The purpose was to estimate demographic parameters, identify useful metrics of stock status, evaluate alternative management strategies, and improve future stock assessment projects. Secondarily, we sought predictive relationships for estimating management parameters from lake characteristics for un-sampled lakes.

Useable data were available for about 90 lake trout lakes. Small sample sizes limited the precision of many of the parameter estimates. Most of the data were gillnet samples and may be biased by size-dependent net selectivity. There was a bimodal distribution of asymptotic size: small-sized populations with asymptotic lengths of about 475 mm and large-bodied populations with asymptotic lengths of about 800 mm. Most populations had moderate growth rates, between 70 and 90 $mm \cdot yr^{-1}$, similar to or perhaps slightly lower than the “average” growth of the Ontario lake trout populations summarized in Shuter et al. (1998). Most BC populations have low instantaneous total mortality rates with the modal values similar to the natural mortality rates that Shuter et al. (1998) presented for un-fished Ontario populations, but the BC mortality estimates are very tenuous. Four broad patterns of growth occurred. Populations had either slow or rapid early growth and combinations of either a small or a large asymptotic size. Most populations were either rapid-small or slow-large types. For a few lakes, both small and large bodied forms existed sympatrically.

We observed a moderately strong positive relationship between lake size and asymptotic fish size (large lakes tended to have large-bodied growth forms) and a weaker positive relationship between growth rate and total dissolved solids (TDS). These two relationships were important because they influenced sustainable yields. Our data conformed to the Ontario relationships (i.e., the exponents were similar to those found for Ontario lake trout), but the growth characteristics of our (more northern) lake trout populations were generally lower than those of Ontario populations with the same lake size or TDS.

Completing this data analysis and evaluating management models will be a priority for next year. BC is also working towards establishing an assessment standard, such that higher quality (but relatively easily obtained) data will be available for future management. We hope to be in a position to propose a revised angling management regime for the 2007 season.

Acknowledgements
Thanks to: Tom Johnston, Eric Parkinson, Paul Giroux, Tom Ovanin, Sue Billings, Vicki Marshall, and Sean Cheeseman for providing the information to support the development of this overview.

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Chair
James Boraski

Our next speaker is George Walker from Alberta. George is currently a district fisheries biologist in Cold Lake, Alberta. He has worked as a fisheries manager for more than 25 years. He started as a technician in 1980 and then as a senior regional technician in 1985. He has been the Cold Lake-Bonneville biologist in the Northeast Region since 1995. Please welcome George Walker from Alberta.

5.5 Alberta

5.5.1 Lake Trout Management in Alberta

GEORGE WALKER
Fisheries Management, Cold Lake, Fish and Wildlife Div., Alberta Sustainable Resource Development.

Introduction
Lake trout play a relatively minor role, compared to other species, in the fisheries of Alberta where cold-water habitats are generally restricted to the Canadian Shield in the northeastern corner of the province and to higher elevations along the mountainous western border. With the exception of Lake Athabasca, Alberta's lake trout lakes are relatively small and located on the fringe of lake trout distribution in North America. Lake Athabasca and Cold Lake cross the Alberta/Saskatchewan border and are jointly managed cooperatively by both provinces. Sixteen lakes in the Mountain National Parks are managed by the Federal government. With the exception of a few fisheries, very little research has been directed towards Alberta's lake trout fisheries.

Alberta Lake Trout Distribution
There are about 70 lake trout water bodies in Alberta (Figure 1). Fifty-five percent (55%) are fly-in-only lakes that are clustered in the Canadian Shield of the province's northeast corner while 30% are in the East Slopes of the Rocky Mountains. The remaining lakes (Cold, Peerless and Grist) are situated in isolated habitats which have allowed lake trout survival.

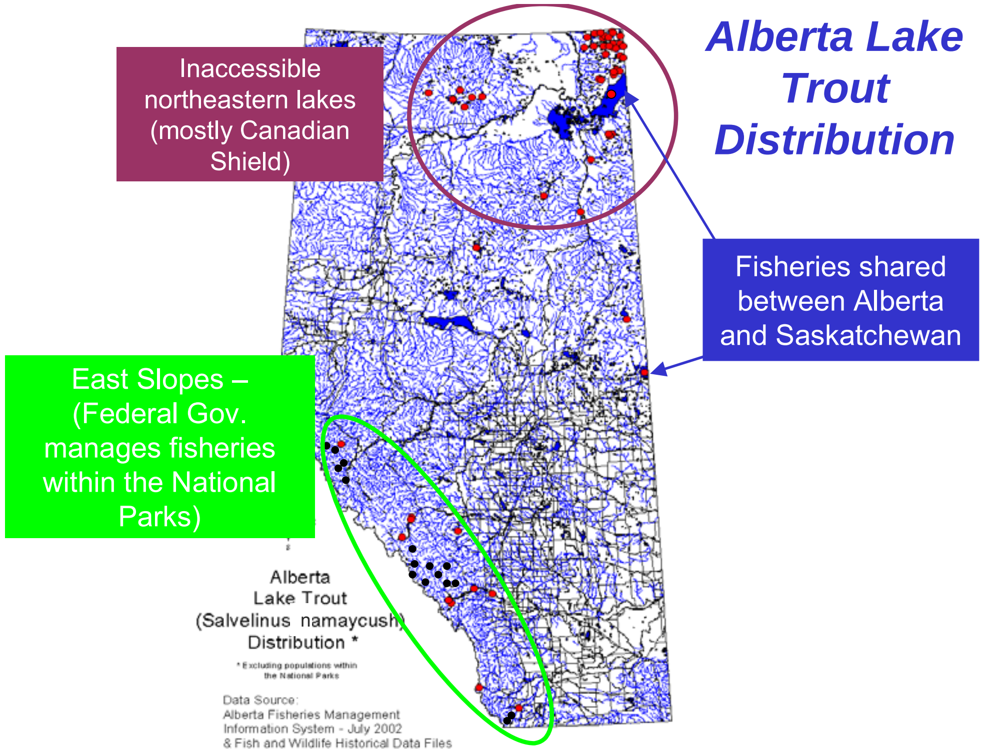

Figure 1. Lake trout distribution in Alberta

Harvest

Alberta lake trout are harvested primarily by the sport fishery and except for Cold Lake, there are poor harvest data. Commercial fisheries harvest lake trout from 3 lakes. The Lake Athabasca commercial fishery has an annual lake trout quota of 10,000 kg but the recent harvest has been only ~2,000 $kg \cdot y^{-1}$. Peerless Lake has a lake trout bi-catch limit of 500 $kg \cdot y^{-1}$ for its lake whitefish gill net fishery. Cold Lake is commercially fished with a commercial trap-net fishery for lake whitefish and lake trout are released if they are caught in the nets. A gill net fishery continues in the Saskatchewan portion of Cold Lake with an annual 1,400 kg lake trout limit. Some domestic fishers harvest lake trout as a bi-catch in their lake whitefish gill-net catches. Harvest data are not available for most lake trout lakes.

Alberta Management Strategies

The main thrust of Alberta's regulation strategy is to maintain levels of lake trout harvest below current productivity. Alberta has a mixture of province-wide and lake-specific sportfishing regulations. However, because of increasing pressures on our fisheries, Alberta is moving toward the lake-specific strategies through:

- minimum size limits that coincide with the size and age at which most of that lake's females have spawned at least twice to limit growth over-fishing and prevent recruitment over-fishing;
- reduced bag limits to reduce and distribute catch on a few highly-exploited lakes;
- season closures during spawning periods on the more highly-exploited lakes; and
- reduced by-catch in commercial fisheries by replacing gill nets with trap nets on Cold Lake and restricting gill-netting on Peerless Lake...

Alberta does not have a comprehensive picture of lake trout productivity, but it does have plans to initiate a Provincial Lake Trout Management Plan.

Alberta's Lake trout Sportfishing Regulations

Province-wide regulations restrict sport fishers to 3 lake trout of any size (Figure 2). However, a number of heavily-exploited accessible lakes require more restrictive regulations and as shown on the map, various reduced-catch and minimum-size limits strategies have been implemented. Most have a closed-season component. Fisheries that are managed federally in the mountain parks have a possession limit of 2 for all species in aggregate.

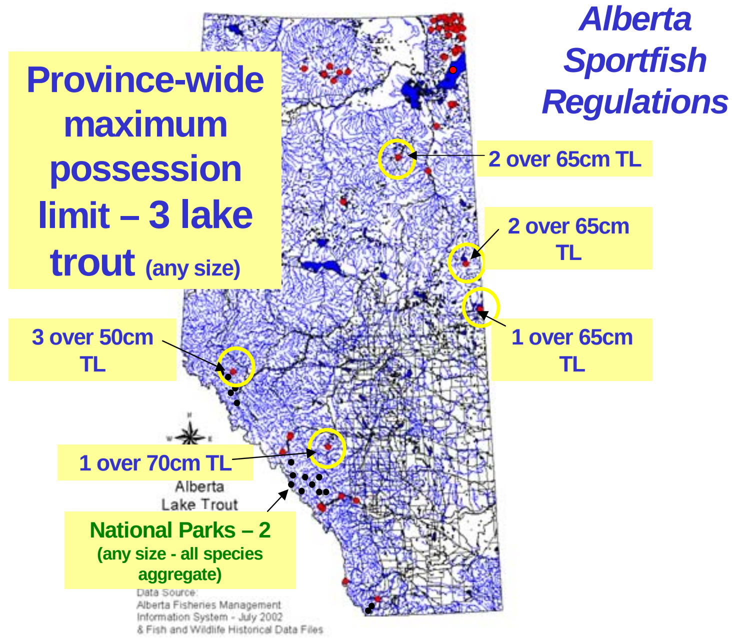

Figure 2. Sport fish regulations in Alberta.

Alberta's Lake trout Management Issues

Alberta's lake trout management capacity has not kept up with explosive economic and population growth since the 1980s. At the same time, fisheries budgets and manpower were severely curtailed, resulting in a twenty year drought in management capability. However, there are signs that this trend is coming to an end. Increased program funding would provide fisheries managers with better information with which to manage fisheries. Current management issues are:

- Poor productivity and harvest estimates when added to increased exploitation have raised serious concerns for our ability to control harvest at sustainable levels. For example, in Cold Lake we are trying to maintain a recovering lake trout population and in the Canadian Shield lakes we are trying to maintain trophy fisheries.
- Poor inventory of Shield lakes – we have no information on the smaller lakes and outdated inventories on most others.
- Monitoring problems - with limited resources, higher profile species have tended to receive the majority of Alberta's fisheries management efforts.
- User Conflicts - two of our most accessible and popular lake trout lakes have commercial gill-net fisheries that create conflict between sport anglers and commercial interests. Conflicts among all user groups are common during allocation processes. These user groups include First Nations, Metis, sport, and commercial fishers.
- Access – Lake trout fisheries, particularly in the north are becoming more accessible to anglers due to oil and gas development.

Chair
James Boraski

Our next speaker is Doug Leroux. Doug will speak on behalf of Manitoba and Saskatchewan. Doug is currently the regional fisheries manager for the Eastern Region with Manitoba Water Stewardship and Fisheries Branch. After graduating in Ecology from Northern Alberta Institute of Technology he continued his studies at the University of Manitoba while employed with the Fisheries Management Section of Fisheries and Oceans Canada. During this time he was involved in a number of lake trout studies in the Northwest Territories. In 1980 he began his career with Manitoba Fisheries Branch and has been involved in managing lake trout fisheries in both northern and southern Manitoba. In addition, there was a short stint, he tells us, in head office as a GIS habitat analyst, but he says that he is trying to forget that period of his career.

5.6 Manitoba and Saskatchewan

5.6.1 Lake Trout Management in Manitoba and Saskatchwan

Doug Leroux
Manitoba Water Resources,

We'll start with lake trout distribution in Manitoba. In Manitoba, lake trout occur frequently in lakes on the Precambrian Shield portions of the province. They are typically found in larger or oligotrophic lakes as well as some rivers, but in the northern part of the province they are found in shallower lakes. Temperature and depth, as you've seen from other speakers, tend to be very limiting factors for lake trout distribution.

The dots on the map (Figure 1) indicate where we have stocked lake trout in Manitoba; some of these have been within their natural geographic range and some are outside this range, such as the Porcupine and Duck Mountains as well as in Riding Mountain National Park. We have had some success in establishing populations outside their normal range and some success within their natural range in establishing or rehabilitating stocks.

Our provincial stocking program averages about 300,000 lake trout annually and this dates back to the late 1920's. Historically, Manitoba has provided lake trout eggs for other jurisdictions, including Alberta. At the present time, we now meet only our own needs and it is a very limited program. Our stocking program is designed to address several objectives: angling diversification, supplemental population stocking, reintroduction, and introduction to new lakes. We have been successful in introducing lake trout into several waters. Some of these populations are now reproducing naturally and our plans include conducting oxytetracycline or OTC marking to evaluate supplemental stocking to some populations. However, that program is presently on hold. We have put all our current OTC effort into walleye for this year.

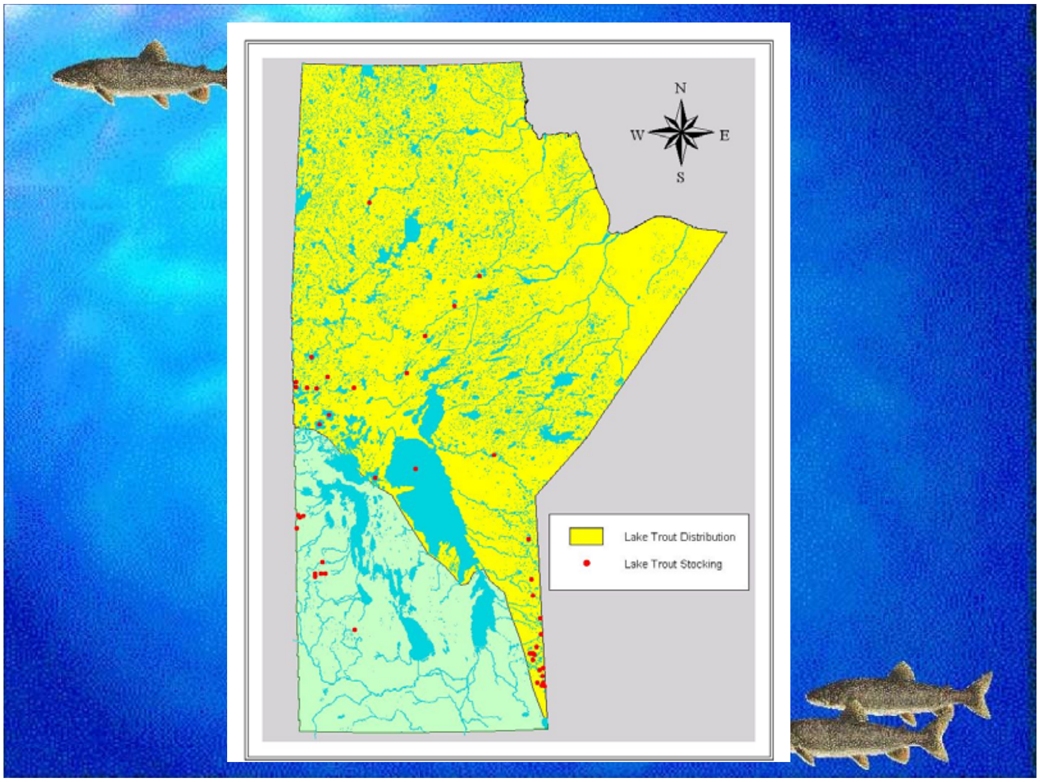

Figure 1. Lake trout distribution and stocking locations in Manitoba.

The Saskatchewan situation is very similar to Manitoba. Lake trout are found primarily in the north on the Precambrian Shield, represented by the dotted curved line in Figure 2. There are 83,200 lakes in the northern part of the province and 10,800 lakes in the southern area. The largest lake is Lake Athabasca and this lake is shared with Alberta and has been covered by a previous speaker.

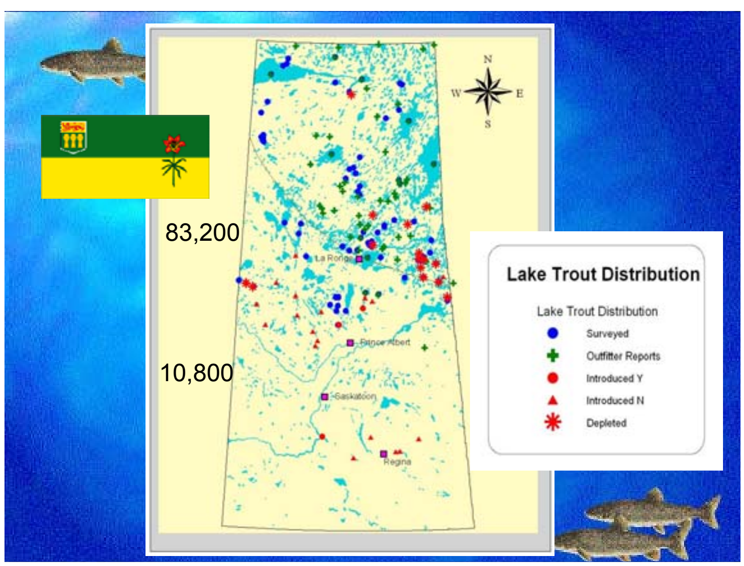

Figure 2. Lake trout distribution and stocking locations in Saskatchewan.

Saskatchewan conducted lake surveys of 350 lakes from 1930 to 1980 and found lake trout present in 70 lakes within the Shield and 10 lakes outside the Shield (Fig. 2). Based on these surveys and looking at limnology and a number of other factors, Saskatchewan estimates that only two percent of their Shield lakes actually contain lake trout. Tourist outfitters in the province report lake trout in another 70 waters. However, one of these un-surveyed lakes now provides their provincial hatchery program with its entire brood stock. Lake trout stocks are considered depleted in 15 of the 70 lakes included in this survey.

Lake trout are harvested by a variety of users in Saskatchewan: First Nation subsistence fishing, commercial net fishing, commercial recreational fishing or the lodge industry, and recreational fishing. The bulk of the harvest occurs in commercial net production and averages about 400,000 kilograms per year from approximately 195 lakes. In contrast, Manitoba produces about 40,000 kilograms per year from five lakes that target lake trout and 6 to 10 where they are incidental catches. Both provinces exhibited a “fishing up” phase as road and aircraft development opened up the north. The decrease in production can be attributed to quota reductions, reallocations, as well as economic and demographic changes.

In Manitoba our experience in commercial fishing is that lake trout stocks are quickly depleted, particularly where they are not the dominant species in the lake. Two examples of this are Cormorant and Gunisao Lakes. In the initial fishing up phase of Cormorant Lake, the lake trout stock was quickly depleted (Fig. 3). The stock has not recovered over a period of 50 years despite management of the commercial fishery. In Gunisao Lake, you will notice from the graphs that lake trout were not the dominant species in the lake. They were an incidental catch in the commercial fishery. They were probably targeted very early in the 1940s, but are now essentially extirpated from the lake (Fig.3).

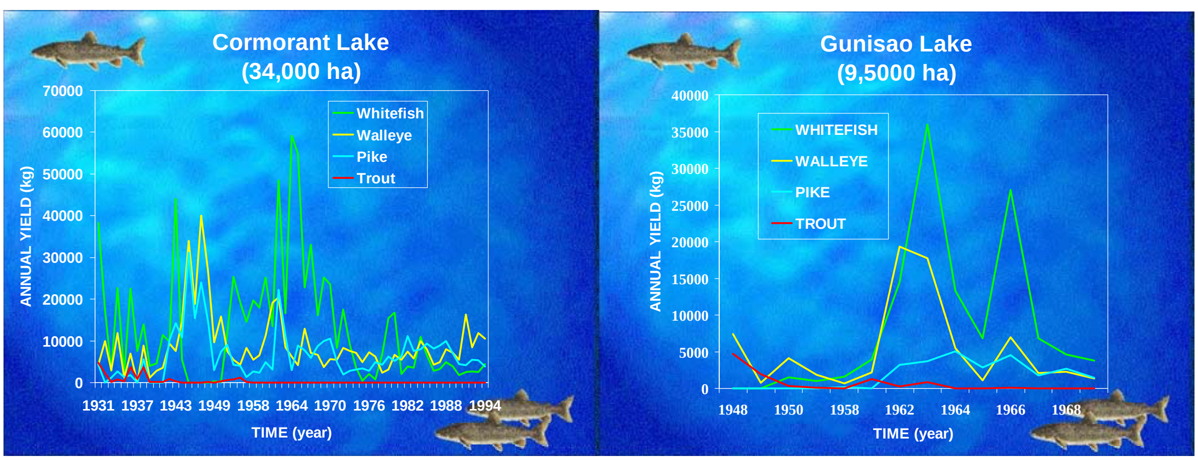

Figure 3. Yield of fishes in two Saskatchewan lakes.

Most of the larger lakes within the lake trout range in Manitoba have well established lodges or outpost cabins. Some offer five-star service and cater to a fairly exclusive clientele. We were not able to determine the actual harvest from creel data. The catch-and-release regulations have significantly reduced the harvest in most of the lodge lakes, but these are included in the creel data. Manitoba and Saskatchewan each have approximately 70 lodges operating in what we consider lake trout country.

Recreational angling is very important in Manitoba and Saskatchewan, as it is in other jurisdictions. It is a high-value fishery and brings substantial dollars into the provinces and caters to a very large clientele. Harvest information is collected every five years through the federal-provincial joint National Angling Survey. In Manitoba, anglers caught approximately 320,000 lake trout in 1980 and that catch has now dropped to 270,000 in 2000, based on surveys conducted from 1980 to 2000. Interestingly, Manitobans retained 128,000 lake trout in 1980 and now only 41,000 in 2000. In Saskatchewan, catches have increased from 222,000 to about 440,000 during the same period. However, although catches have increased, there is a similar drop in the number of lake trout that anglers retain. This is a significant change that we have seen in our lake trout fisheries. Both Manitoba and Saskatchewan have shown a sharp increase in the number of lake trout that are released and we are currently at about 85 percent catch-release for lake trout.

We have very little information about the aboriginal harvest and it is difficult to collect these data. It does occur and it can be an important food source in some areas, but these areas are rather limited in both provinces. Lake trout are likely incidental catches in the aboriginal fishery. I am not aware of many aboriginal fisheries that target lake trout.

Lake trout management in the two provinces occurs for the commercial and recreational fisheries. We have no actual programs targeted at managing the aboriginal subsistence fishery at this time.

In Manitoba, commercial fisheries for lake trout are managed through a combined species quota system. Saskatchewan manages through individual species quotas. Both are based on MSY values of 0.5 kg ha^{-1} y^{-1}. Production is monitored extensively through the Freshwater Fish Marketing Corporation records. Quotas are not normally allocated on lakes less than approximately 400 hectares. At the average current price for lake trout of $1.00 per kg, a fairly low value compared to walleye, lake trout fisheries are not commercially viable for some of the more northern, remote areas. Most of the current lake trout fisheries are only viable when other species are harvested in addition to lake trout.

We have taken a very conservative approach to recreational angling over the years in both Manitoba and Saskatchewan. Prior to 1950, when Manitoba published its first angling guide, the limits for lake trout were 30 daily and 30 in possession. We have now modified this extensively to just two lake trout daily, but most lake trout waters have special limits of one per day. There has been a very strong management trend to reduce limits and protect key segments of our populations through maximum size limits, no harvest regulations, slot-size limits, and spawning area closures. We have also been very proactive in gear restrictions, including barbless hooks in all of Manitoba. In addition, we have single hook regulations on specific waters. There is very limited amount of spear fishing done for lake trout, but we do not allow Scuba-based spear fishing. These management actions have significantly reduced the total lake trout harvest in both provinces. Some lodges have self-imposed restrictions of no harvest (only catch-release) and also have self-imposed area closures in order to protect their fisheries and their investments

To summarize our recreational fisheries management, our primary management focus is to provide high quality angling opportunities. It is a limited resource with limited accessibility to most anglers. Significant consultation occurs with users prior to regulatory changes. Anglers in the tourism industry have strongly supported the regulatory changes over the past 20 years and that has been a big help. In general, we have no harvest of lake trout over 65 centimeters on all major lake trout fisheries in the provinces. Limits are one or two fish, depending on the license type and the waters fished. We have fall season area closures on the two high-use road-accessible waters that occur in Manitoba. The most significant factor in lake trout management is that anglers now, through strong education programs, release 85 percent of the trout that they capture.

Our allocation priorities are similar to most jurisdictions. Our first priority is stock conservation; second to aboriginal subsistence; third to recreational fishing; and our final allocation to commercial outfitting and netting.

In summary, what are the management issues in Manitoba and Saskatchewan? The economics of fisheries for northern communities have been poor for decades and this is a persistent issue with little anticipated change. Pressure for new recreational allocations continues, and recreational fishing has shifted to smaller lakes as most major lakes are heavily exploited already. Road development continues because of further expansion of the mining and forest industries. Allocation policies must be in place to protect fisheries. There are limited resources available for stock monitoring. You have heard very similar problems for other jurisdictions. Aboriginal court cases may extend fishing rights to an increased segment of the population. We have significant genetic issues if we become reliant on stocking programs in the future. Our major management success has been the protection of larger trout and the trophy fishery, due primarily to the buy-in by the general public and the lodge industry.

* * * * *

Discussion

Unidentified Male speaker: Doug, when you said you do not have a commercial quota for lakes under 400 hectares, did you mean that there is simply no commercial fishing on these lakes?

Leroux: Yes, we would not even consider opening up a commercial quota on a lake under 400 hectares.

Unidentified male speaker: But there would be recreational fishing allowed on these lakes?

Leroux: Yes, but no commercial gillnetting.

Unidentified male speaker: Will Canadian regulations include a barbless restriction or barb restriction?

Leroux: Manitoba is barbless completely for all fishing. You cannot use a barbed hook anywhere in the province. Saskatchewan has barbless regulations on some waters in some areas.

Unidentified Male Speaker: I've read a few reports and I do not remember any of them saying that barbless hooks reduce fish mortality. Is that information out there somewhere?

Leroux: Manitoba struggled with that question for a long time. We started this campaign years ago. There may not be any definitive studies to back it up, and the results in these studies vary greatly depending on species methods and other factors. I doubt anyone would say that there is not at least some reduction in handling time, which must lead to some reduction in mortality, but we just did it as a broad conservation measure. We firmly believe that this does reduce mortality caused by handling time.

Mr. Holland: I'm Ross Holland with DFO. A few years ago I started to look at the statistics for Lake Athabasca because I was interested in comparing these with the statistics for Great Slave and Great Bear Lakes. What I found was the fishery went through spectacular ups and downs. What I would like to know is whether these were caused by economic factors or because the stocks were depleted.

Leroux: It's very difficult to draw conclusions looking at production information from any commercial fishery. You need a very in-depth knowledge of the whole history of the fishery and of the markets and demographics. Just looking at the raw data and drawing conclusions is pretty difficult.

Chair
James Boraski

Our next speaker, Dr. Nigel Lester, is a research scientist with the Ontario Ministry of Natural Resources in Peterborough, Ontario. He is also an adjunct professor at the University of Toronto. He obtained his B.A. and M.Sc. at Queen's University in Kingston, Ontario and his Ph.D. at University of Sussex in England. He began his career with the Ontario Ministry of Natural Resources in 1983 as a systems analyst and was responsible for the development of the Ontario Fisheries Information System, or OFIS. As coordinator of that program Nigel developed Fishnet, which is a computerized system for managing Ontario fisheries data and he worked with the Ontario Fisheries Assessment Network to develop standards for assessing fish populations. I first met Nigel during a meeting of one of the fisheries assessment groups. In 1992, he joined the Fisheries Research Section as a research scientist and his research is currently focused on the development of standard methods for monitoring the abundance of lake trout and walleye populations in Ontario lakes. He is also developing biological reference points for evaluating the status of these populations. Results of this research are being used to develop a state of the resource monitoring program for Ontario lakes and Nigel is playing a key role in the design of that program.

5.7 Ontario

5.7.1 Lake Trout across the Range – Ontario

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Lake trout lakes in Ontario
Lake trout inhabit approximately 2,200 inland lakes in Ontario (Fig. 1) in addition to the Laurentian Great Lakes. Many of these lakes are small (median surface area = 192 ha), but relatively deep (median maximum depth = 30 m), clear (median Secchi depth = 4.9 m), and nutrient poor (median Total Phosphorus = 6 ug/L). These conditions are necessary to provide a well-oxygenated hypolimnetic volume during the summer when surface temperatures of most lakes are too warm for lake trout. The geographic distribution of lake trout lakes largely tracks the Canadian Shield. Clear water makes these lakes popular locations for cottages and, because this species is the largest member of the fish community in most shield lakes, lake trout is a popular recreational fishing target.

The State of the Resource
The lake trout resource has suffered in areas of high-population density (notably southern Ontario). The extent of the damage is not known because comprehensive surveys of lakes have not been conducted, but there are several indicators of change. Angling catch rates have declined and many lakes have been stocked in an attempt to manage dwindling stocks. In the south, 60% of lake trout populations have been supplemented by stocking. In the less populated northwest section of the province, only 4% of lakes have been stocked. Excessive exploitation has undeniably played a key role in the decline of lake trout, but anthropogenic

changes in habitat and the aquatic community have also had detrimental effects (Evans et al. 1996; Dillon et al. 2004; Steedman et al. 2004; Vander Zanden et al. 2004; Wilton 1985).

Protection of the Resource
Protection of the lake trout resource in Ontario requires a multi-faceted approach. Lake trout habitat is being protected through measures that use a hypolimnetic dissolved oxygen criterion to establish limits to shoreline development. Lake trout lakes are protected from the potential impacts of timber harvesting and water level fluctuations through the appropriate application of various guidelines established for timber and waterpower management planning and operations. Industrial emission regulations have led to reductions in acid deposition and subsequent water quality recovery of historically acid damaged lakes and efforts are currently underway to re-establish viable lake trout populations in these systems. Species invasions and unauthorized species introductions have also occurred. However, action has been focussed, for the most part, on public education efforts to limit the problem of invasive species.

We have recognized that levels of angling effort and harvest often exceed sustainable exploitation levels. A lake trout exploitation model (Shuter et al. 1998) indicates that sustainable levels of angling effort are in the range of 4 – 7 angler-hours/ha when there are no restrictions on the size of fish harvested. Values exceeding 20 angler-hours/ha are not unusual in the south. To address these levels of exploitation, fishing regulations have become more restrictive in recent years. Reduced fishing seasons (winter closures on some small lakes) and reduced daily catch limits (from 3 to 2) have been implemented in many parts of the province. In addition, size-based regulations (such as protective slot limits) have been introduced to reduce harvest while minimizing impacts on fishing opportunities.

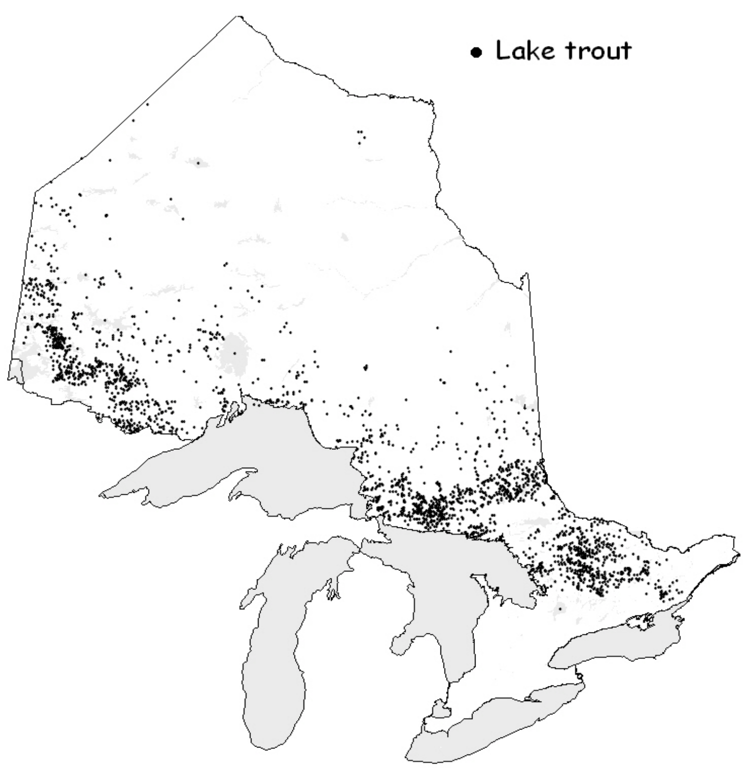

Figure 1. The distribution of lake trout lakes in the province of Ontario.

The provincial fishing regulations have grown increasingly complex as a result of a management approach that has focused on individual lakes. A larger spatial and temporal scale of management is needed to effectively manage a resource like lake trout which is widely dispersed across the province (Lester et al. 2003).

As part of a new Recreational Fisheries Management Framework, Ontario is currently moving toward a broad-scale landscape approach to fisheries management. This approach will reduce the number of Fisheries Management Zones, rationalize their boundaries based on ecological and social factors (such as the province's climate zones, watersheds, patterns of angling pressure, and road networks), and apply regulatory controls that are more consistent across the zones. In addition, regulatory "tool kits" that recommend standardized regulations are being developed for each major sport fish species, including lake trout.

Monitoring the Resource

Historically, monitoring activities for the lake trout resource in Ontario have relied heavily on creel survey programs to obtain angling catch rate data (CPUE) to use as an index of lake trout abundance. One problem with this approach is that angling CPUE is not a sensitive indicator of true lake trout abundance (Shuter et al. 1998). To address this problem, the Ontario Fisheries Assessment Unit network has been developing calibrated index netting standards for lake trout (and other species in Ontario lakes). In addition, an acoustic survey methodology for estimating lake trout abundance is being tested.

Another change in direction is the design of a provincial scale monitoring program as part of the new Management Framework. Historically, most of the data obtained on lake trout lakes was in response to a perceived problem on individual lakes. Consequently, our data offer a biased view of the state of the resource. Stratified random sampling of lakes has been proposed to alleviate this problem (Lester and Dunlop 2004). The proposed program would sample 10% of the provincial lake trout resource every 5 years in order to determine if broad-scale fisheries management objectives are being met. Measures reported would include lake trout abundance, mortality rate, and angling effort, as well as other indicators for monitoring changes in habitat and the aquatic community.

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Chair
James Boraski

Our last speaker for this morning's session is Dr. Brian Lantry. Dr. Lantry is presenting both the U.S. and the Canadian perspective on lake trout in the Laurentian Great Lakes. Dr. Lantry received his Ph.D. from the state university of New York College of Environmental Science and Forestry. He has worked previously as a fisheries biologist for the New York State Department of Environmental Conservation where he worked on restoration and management of lake trout in Lake Ontario. His current position is the research fisheries biologist for the U.S. Biological Resources Division and he is responsible for the assessment of the progress towards lake trout restoration in Lake Ontario.

5.8 Great Lakes

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JAMES L. MARKHAM, New York Department of Economic Conservation, Dunkirk Fisheries Station, New York
DAVID M. REID, Ontario Ministry of Natural Resources, Owen Sound, Ontario
SHAWN P. SITAR, Michigan Department of Natural Resources, Lansing, Michigan
ARRON P. WOLDT, US Fish and Wildlife Service, Alpena, Michigan

We have really benefited from a rich history of science and assessment on the Laurentian Great lakes over 50 years of restoration. Most of my experience is from Lake Ontario, but I have noticed that there are several people in the audience today with more experience in the Upper Great Lakes than I and if I can not handle your questions, I'm sure these other researchers can.

I'm going to split this talk up into three areas. First, I want to talk about some historical background, and then spend a little more time on the current situation.

The commercial yield of lean lake trout in the Great Lakes has varied extensively through the years and we benefit from the commercial records of these fisheries (Figure 1).

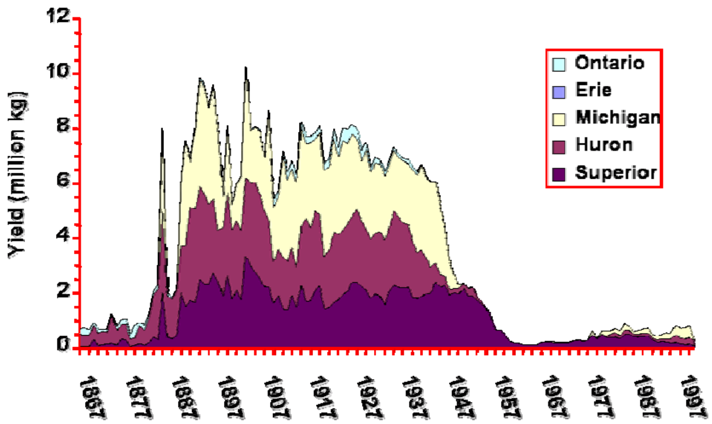

Figure 1. Commercial yield of lake trout from the Great Lakes

Like one of the previous authors said, it is tough to get good information from commercial catch records. Although, I do not think it is too hard to see the trend in this slide. There was a long period of high exploitation in the Great Lakes, probably characterized by "fishing-up" the stocks, followed by a sharp decline of the lake trout stocks in all the lakes in a relatively short period of time that coincided with the establishment of sea lampreys in each lake. It was really a one-two punch of high exploitation rates and then the establishment of this exotic invader that caused the crashes. In most cases, the lake trout populations were driven to extinction except for Lake Superior and a small area of Lake Huron. Currently there is a small commercial fishery, but it really pales in size to the historic fishery.

Much of the genetic diversity of lake trout in the Great Lakes was lost during the population crashes. There are three remaining morphological types (Figure 2). Each of these exist as self-reproducing populations in Lake Superior, and can be distinguished by both their fat composition and distribution within this lake.

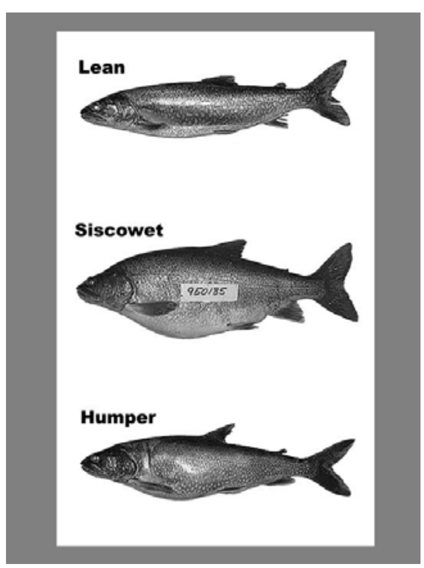

Figure 2. Remaining native morphotypes of lake trout in the Great Lakes.

The lean form is lowest in fat and the siscowet have the highest proportion of fat. The leans occupy relatively shallow water near shore and the siscowets are found in deep water throughout Lake Superior. The humper form is intermediate in fat content and found near off-shore reefs that rise from deep water. Their depth distribution is somewhat similar to the leans but humpers are not found along the shores of the lake. Because of their location they are probably reproductively isolated from the other two morphological types.

The diets of each form reflect what is available in each habitat type, and the spawning period is fairly similar between the lean and humper forms, but a little more protracted for the humpers. Mature siscowets appear throughout most of the ice-free period in Lake Superior. We are not quite sure when they spawn and their spawning habitat is closely related to their depth distribution. Figure 3 shows a quick snapshot of the depth distribution of the leans and siscowets to show that their distributions are very different, but also that the siscowets are far more abundant than the leans in Lake Superior and account for a large share of the lake trout biomass in that lake. This is very important because we really have not made full use of this morphological type in stocking programs in the other Laurentian Great Lakes and there is some anecdotal evidence from the past commercial fisheries that they did exist in the other lakes.

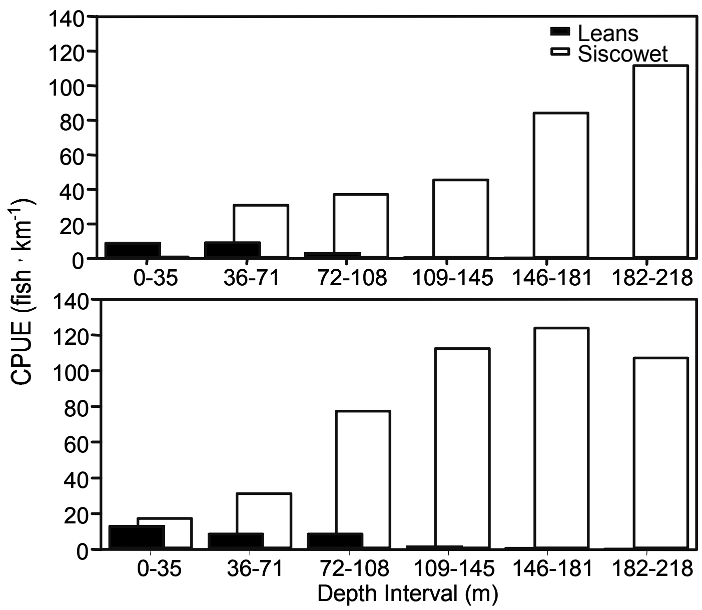

Figure 3. Depth distribution of two morphotypes in Lake Superior

There has been a tremendous amount of stocking effort of lake trout in the Laurentian Great Lakes, peaking at about 12 million spring yearlings stocked per year. We know that younger fish have been stocked, but these younger fish have high mortality. The mortality information is used to estimate how many of these very young fish survive to spring yearling stage. We usually divide the total number of younger fish that are stocked by about two and a half to get the yearling equivalent number. Lake trout restoration in the Laurentian Great Lakes accelerated when sea lamprey control was instituted. This control program is very important in the Great Lakes and first started in the late1950s in Lake Superior and was finally instituted in Lake Erie by the mid 1980s.

Using the early data from Lake Superior as a guide, the goal for stocking to restore the lake trout stocks corresponds to one to one and half fish per acre, or about 240 to 260 per square kilometer. Stocking approached or exceeded this goal in only two lakes: Lake Superior, where lake trout are now restored, and Lake Ontario, where we are continuing to have a lot of problems restoring the lake trout stocks. Stocking in Lake Huron and Michigan never reached the stocking objective and that is in large part due to the logistical constraints of the hatchery system. The habitat available for lean lake trout in these lakes is immense. In fact, it is larger than that available in Lake Superior. The hatcheries just could not produce enough lake trout to flood that habitat. Lake Erie is a different situation. It is being managed for a commercial smelt fishery, and it has a relatively small area of suitable lake trout habitat. Quotas set for stocking lake trout in Lake Erie take into account the demand for smelt both by lake trout and the commercial fishery. Currently, only U.S. waters of Lake Erie are being stocked with lake trout.

Several strains have been used for stocking the Great Lakes through the years. There has been some stocking of splake and some back crosses of splake and lake trout, but these programs are largely discontinued at the present time. Just recently, humper lake trout have been brought into the hatchery off the Klondike Reef, but only a few humper lake trout have been stocked for a couple of years into Lake Erie. We do not know yet how they will adapt to Lake Erie. Most of the restoration efforts to date used the lean lake trout form and a lot of this has involved remnant Lake Superior stocks. These have been used in all the lakes. There are a couple of remnant Lake Michigan strains used that were preserved before the crash of lake trout in that lake by stocking them in inland lakes. A couple of native Lake Huron strains have been used and a Lake Ontario strain was derived from feral stocked fish that survived to maturity in that lake. Importantly, the Seneca Lake strain has been used quite widely in the Great Lakes due to their resistance to both lamprey wounding and their better survival of attacks compared to other lean strains of lake trout.

The good news from the Great Lakes is that the Lake Superior lake trout community is restored. This occurred by the mid-1980s when production of wild fish overtook hatchery fish and in the modern time period stocking has been reduced to a small area on the far eastern end of the lake. Siscowets played a large role on their own in fostering rehabilitation of this lake and now they account for a large proportion of the lake trout biomass. This is in direct relation to the proportion of available habitat for this species in the lake. There is much more habitat for the siscowets than the other two lake trout morphs in Lake Superior.

Except for some isolated areas in Lake Huron and Lake Michigan, lake trout exploitation is no longer a large problem in the Great Lakes. There is an expanding commercial and recreational fishing in Lake Huron, but it is also spreading to larger portions of the lake. The northern part of Lake Huron is where they were having problems with high lake trout mortality from commercial fishing, but this is now under control and since 2000 adult survival rates and the number of age classes in the population is increasing throughout the open waters of the lake.

The harvest of lake trout from Lake Ontario has changed through the years. Initially there was a large commercial fishery. There has been a switch from a commercial to a sport fishery during the modern period of restoration, and the extent of that sport fishery in the 1980s and early 1990s rivaled some of the catch rates in the commercial fishery that just predated the collapse of the stock. The managers believed that this level of harvest was excessive and were able to put in some fairly severe angling restrictions. They put a 25 to 30 inch protected slot limit in the U.S. waters which reduced fishing effort on lake trout, and diverted effort toward other fish species. They achieved about a 60 percent reduction in harvest due to this limit.

Pacific salmonids are stocked and co-exist with lake trout in all the Great lakes, and anglers tend to target the Pacific salmonids over the lake trout, and this is pretty consistent in all the Great Lakes. It is a similar situation in Lake Erie with walleye. Walleye is targeted over the cold water fishes in the eastern basin of Lake Erie and when anglers target salmonids, they tend to target steelhead. But recently, there is a fishery developing in the extreme eastern end for lake trout now that the anglers have noticed that there are a lot of big, old lake trout present. In fact, last year, the new New York State record lake trout came from Lake Erie weighing about 40 pounds.

What do we think are the current impediments to lake trout restoration in the lower Great Lakes and in Lakes Huron and Michigan? Natural reproduction is occurring in a lot of areas in the Great Lakes including Lake Superior, many areas of Lake Huron and at least along the US shore of Lake Ontario. Lake Superior, of course, has been declared restored, but if you look at all the areas that are considered restored in the Great Lakes, it is just Lake Superior and the relatively small area in northern Lake Huron in Parry Sound.

We are continuing to experience some pretty severe impediments to lake trout restoration in the Great Lakes. There have been many workshops and meetings where impediments to restoration have been discussed. Here is a shortlist of some of the more important impediments. Certainly lamprey predation is a problem. It has been a problem in the recent past and a continuing problem on many of the Great Lakes that requires continued vigilance and high input of effort both in terms of dollars and manpower. This will probably be a major problem into the foreseeable future in the Great lakes. Insufficient spawning stock size, due to management for other species and logistical constraints in the hatchery system, has been a problem for Lakes Huron, Michigan, and Erie. Thiamine deficiency and early mortality syndrome has been a real problem in lakes with abundant populations of alewives, mainly Lake Michigan and Lake Ontario, but it is thought to be a problem in Lake Huron as well. The invasion of the round goby that occurred recently in the Great Lakes may be an important impediment as local impacts from their densest populations are becoming fairly severe. The lack of native forage communities might be leading to lower asymptotic sizes of the lake trout in the lower lakes, but this also impairs resistance of the lake communities to invasive species.

Lamprey control based on Great Lakes Fish Commission records is shown in Figure 4. This is an index based on the number of wounds per hundred lake trout caught in index gillnetting. It's a combination of fresh wounds through almost completely healed wounds on larger fish. You can see at certain points in time in all the lakes that lamprey wounding has been much higher than the five wounds per hundred goal set by GLFC. In fact, in Lake Superior and Michigan it has been an increasing problem recently due to lamprey colonizing new habitats. In Lake Huron, it has historically been a very large problem until the St. Mary's river system, the large connecting river between Superior and Lake Huron, was treated recently. We have had recent further colonization by lamprey in Lake Erie although there is very little spawning habitat for lampreys in this lake. On the U.S. side, it is almost entirely restricted to one stream system. Lampreys colonized the headwaters of that stream recently and caused wounding rates to increase based on recent gillnet assessments. In Lake Ontario, we have been lucky that there is a long history of good lamprey control since the mid-1980s. We have had really good control measures in place in this lake.

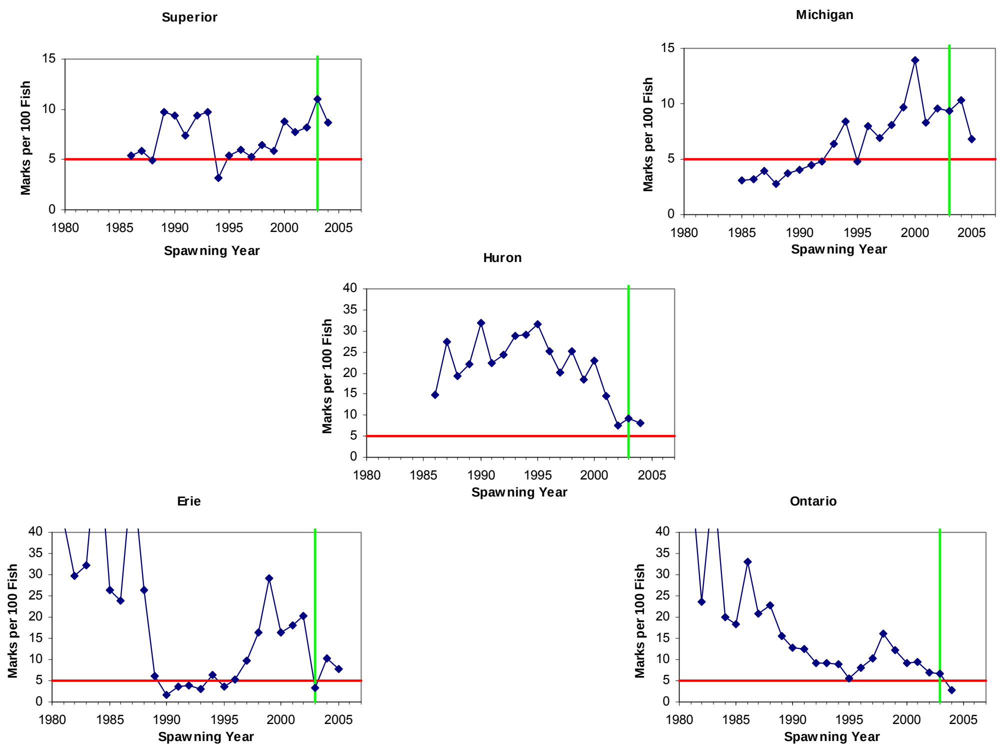

Figure 4. Lamprey wounding rates per 100 lake trout.

One of the impediments we highlighted was low spawner abundance. High spawner abundance was one of the major objectives for each of the lakes recovery plans, and it was to be accomplished through extensive stocking. The idea was to create a high density of hatchery fish so there was a high likelihood that some would find a good spawning habitat to start natural reproduction in each lake again. It looks as if this contributed somewhat to the Lake Superior situation, but we still have low spawner abundance in Lakes Michigan, Huron, and Erie. There are many problems that impact spawner abundance. Lamprey predation has been a problem at times in each lake. The numbers that were stocked in each lake was another problem. A further problem was also where the stocked lake trout have been released and what kind of densities were achieved in the past. Stocked fish were spread among different management jurisdictions and part of the stocking effort was to sometimes produce a population that could be fished rather than create a seed stock to rehabilitate the population. Recently, objectives have changed, and fish are being stocked in good habitat and better stocking success has been achieved in Lakes Michigan and Huron. High exploitation is mostly under control now, but that has been a problem in Lakes Michigan and Huron. Recently, we reduced stocking in the early 1990s in response to differences in the productivity of these systems. In Lake Ontario, the decline of the alewife stocks and managing for Chinook salmon motivated an early 1990s stocking reduction of lake trout.

Coupled with these changes, we have had diffuse aggregations of lake trout spawners and those spawners have deposited their eggs in some pretty bad locations. The spawners do not have any experience in selecting appropriate habitat. The Great Lakes are large lakes and lake trout spawners tend to return to the areas where they were stocked. In the past, stocking often occurred in high energy zones along shore where there is a lot of wave scouring and ice scouring in the winter time, and this is really bad for lake trout eggs. Also, part of the problem may be due to the hatchery environment where the stocked fish were raised. The light conditions were often too high and fish may have been raised to sizes that were probably too large to effectively imprint fish on suitable spawning locations. Larger fish may obtain higher survival post-stocking, but the larger stocked fish probably have poorer success finding their way to good habitat for spawning. Stocked spawners lack a lot of the imprinting and olfactory cues of the past that the native populations had as fry coming out of the gravel. Recently, attempts to address this problem have been made by stocking eggs and fry in Lake Michigan, but we do not think they have observed any success from these stocking practices. There is also the issue of low genetic diversity. Not only have we lost a lot of our genetic diversity, but we do not currently make use of all the lake trout forms available for restoration.

We have problems also with poor fry survivorship. In the past, habitat degradation and contaminants were thought to be responsible for poor survival. Nutrient abatement has occurred in each of the lakes and limits on contaminant releases into the lakes were put into place. These problems are no longer deemed an issue. Both types of contaminants have been reduced in each of the lakes. The habitat quality has improved and the contaminant burdens in adult lake trout have come down substantially through time, so they are no longer viewed as an impediment. However, with the invasion of the lakes by exotic mussels causing increased water clarity and the infilling of interstitial spaces in the spawning reefs with mussels, this habitat degradation is likely becoming a problem again. We are also observing benthic mats of algae appearing in areas that are now receiving light penetration to the bottom. In addition, several other exotic species continue to impact fry survival through a variety of mechanisms.

In spite of the legislation and controls in the Great Lakes to stop the introduction of exotic species, they continue to be introduced at a high rate. In fact, the introduction rate is accelerating. The most important recent invaders are the zebra and quagga mussels and the round goby.

A lot of research on alewives has occurred during recent years. We know they create a pretty severe recruitment bottleneck for lake trout in the Great Lakes. Not only do they directly consume the lake trout fry, but they also consume the fry of the prey that lake trout eat and there is evidence that they can cause the collapse of prey fish stocks in the lakes. By doing this, the exotics dominate the community in a lake and limit prey choices and asymptotic size of lake trout. Alewives can reduce energy efficiency by not filling in all the niches and reduce energy transfer in the summer time between the cold water and the warm water in the lakes because they are confined in a large part to the warm water. Also, they directly prey on the lake trout larvae and recently there has been a lot of research into their role in causing thiamine deficiency.

The efficiency of a lake can change between an earlier alewife-dominated community and a recovering prey fish community that includes some of the native prey fishes. In Lake Michigan, the bloater, a deep water coregonid, and deep water sculpin are present in greater abundance in recent times. The total fish biomass is quite a bit higher now than when it was an alewife dominated community.

Thiaminase is an enzyme that breaks down thiamine. Alewives are rich in thiamine. Where alewives exist in the Great Lakes, all the salmonids include a disproportionate number of this species in their diets. When a predatory fish eats an alewive, the thiaminase in the prey gut is released. The thiaminase breaks down the thiamine in the alewife in the predatory fish stomach, and the resulting meal is very poor in thiamine. This causes thiamine deficiency in the predatory fish, and their gametes have very low levels of thiamine which is very important to successful reproduction. Not only is thiamine thought to be produced in the guts of the alewife through a thiamalitic bacteria, but it has also recently been found in high abundance in the phytoplankton and algae and there is some speculation that the exotic mussels, are exacerbating this problem through fostering and production of blue-green algal blooms. There is also some speculation that the thiamine may be getting into the food chain through this compartment.

There is a progression of the impacts from the thiamine deficiency. Beginning with a diet that is disproportionately high in number of alewives, the predators receive a low level of thiamine in their diet. Lake trout and Atlantic salmon seem to be especially susceptible to this in the Great Lakes and it is thought that that the reason for failure of the restoration attempts of Atlantic salmon in Lake Ontario since the 1800s is largely due to Atlantic salmon adults consuming alewives. A diet that is rich in thiaminase leads to metabolic stress and neurological lesions along with behavioural changes such as reduced swimming performance and reduced migratory ability. It's been observed in the New York State Finger Lakes that rainbow trout that were low in thiamine weren't able to migrate to spawning grounds and those that had high thiamine levels were. Also, a couple years ago a mass mortality of coho salmon occurred in Lake Michigan and when the dead fish were examined, they were found to be very low in thiamine. Then adults pass this problem to their progeny. The direct result is early mortality syndrome. There are several indirect results in addition to this mortality which include reduced growth, foraging ability, and predator avoidance. These probably indirectly add to the elevated mortality for the fry. The mortality seems to persist to the juvenile stage. This occurs in juvenile Pacific salmon who seem to exhibit some of the adult-like symptoms of thiamine deficiency and who then perpetuate the problem to their progeny when they reach sexual maturity. Ultimately, this culminates in population level lowered productivity, and possibly reduced resistance to other stressors as well.

An interesting situation has developed in Lake Huron where alewife abundance has crashed. Alewives were fairly abundant in Lake Huron until the recent assessment survey. They disappeared, more or less, from the survey in 2004.

Before 2004, few naturally reproduced lake trout were observed in assessment surveys. Wild lake trout were captured at almost all the survey sites on a lake-wide basis in 2004 and 2005, but they are still a small but significant proportion of the lake trout in the catches. So, the lake-wide collapse of alewives was followed by a lake-wide burst of lake trout natural reproduction. The increase might be associated with reduced alewife predation on lake trout larvae or reduced thiaminase in adult lake trout diet. We can use this as a good indicator of what might be needed in Lakes Michigan and Ontario, where very dense populations of alewives presently exist in comparison to past alewife numbers in Lake Huron.

The invasive species, round goby, is the most recent major problem that is occurring in the Great Lakes and gobies like sculpins and crayfish are egg and fry predators. They really exert a large impact through their ability to achieve enormous densities. Some of the data from Lake Ontario showed that sculpins in the past existed at about a maximum of 20 per square meter while gobies now can exceed 100 per square meter. This is probably the result of their ability to produce multiple broods in a year, and that they are aggressive nest guarders and have a readily available prey supply in the form of the dreissenid mussels that blanket much of the Great Lakes now.

When you add increased fry mortality from goby predation, the picture becomes much graver. Just to give you a benchmark of where we were before the goby invasion, in Lake Superior about 12 to 16 fry per 100 eggs were captured on the reefs when restoration was occurring. Before the goby invasion at Port Weller about two to three fry per 100 eggs occurred in Lake Ontario. When gobies came in, even at relatively low levels of abundance, lake trout fry production essentially went to zero.

The objective of Great Lakes lake trout management in recent years was to produce a large population of spawning age adult lake trout with an extended population age-class structure. This objective may need rethinking to include a goal of rehabilitating the lake trout prey fish community. Using Lake Huron as an example, the recent crash of alewives was followed by a lake-wide burst in reproduction of lake trout, and recovery of some of the native prey fish stocks is beginning. Just to highlight this again, remember that alewives came into the upper Great Lakes in the 1940s and 1950s, but their abundance was at a relatively low level through that time period and they did not explode to high abundances until the 1960s after lake trout abundance had collapsed and released alewives from predatory control. So the idea is that our goals should be to rehabilitate the native prey fish as well as lake trout and then we would expect to see several changes that would lead to self-regulating populations of lake trout, and also create some resistance in the community to the current exotics that are in the lake, and also some resistance to the further introduction of exotics that seem inevitable.

I think we can take away some lessons from our recent experiences. The first is, it is not clear that just using the lean form of lake trout will be sufficent to restore lake trout throughout the Great Lakes. However, although the siscowet form accounted for a large portion of the restoration that occurred in Lake Superior, it has been an extremely hard sell to both the managers and anglers to introduce this form into the other lakes despite a lot of anecdotal evidence from the commercial fishery that suggested they were present historically.

Not achieving high spawner densities has certainly been a problem. This, coupled with exploitation and a relatively abbreviated age class structure for some of the lakes, has been a continuing problem. But, even when you are able to achieve very high spawner density, as occurred in Lake Ontario during the most recent ten years, a high density of alewives may preclude lake trout restoration. In contrast, when a Lake Huron lake-wide crash in the alewife population occurred, it was followed by a burst in natural reproduction of lake trout even at spawner densities below the target number. This certainly seems to send a signal that we need to suppress alewife abundance more aggressively in the other Great Lakes.

Management plans for the Great Lakes are being redeveloped, and these will reflect realigning expectations for management with the current ecosystem parameters, and Lake Superior will be used as a guideline. We know from experiences in Lake Superior that they needed to control both lake trout exploitation and lamprey predation to achieve restoration and certainly they benefited from a community that still had many of its native prey fish components intact. One of the major conclusions from the Great Lakes story is the impacts of exotics on lake communities. The introduction of exotics continues in the Great Lakes and they are not only suppressing lake trout rehabilitation through a variety of mechanisms, they are also derailing some of the ecosystem objectives for the whole lake communities. I think if we work the idea into our management plans that we need to rehabilitate both the predator and the prey populations we will get some resistance towards the impacts of the present exotics and resistance towards future invasions.

6 Fisher’s Panel

6.1 Fisher’s Panel Biographies:

This panel of local experts will provid insight into concerns and issues from the perspective of the user of the lake trout resource in the NWT. They have a broad background of experience over the range of NWT fisheries: subsistence, commercial and recreational. They have played a role in the co-management process of managing aquatic resources with DFO. Many are decision makers on boards and committees and are leaders in their communities. They share the goal of supporting conservation efforts for sustainable fisheries in the NWT.

Panel Members

George Low is the panel chairman and has been a Fishery Management Biologist with DFO in the Western Arctic Area since 1982. Based in the community of Hay River, his area stretches across trout country from the Arctic Circle southward including Great Bear and Great Slave lakes. He is a long-standing non-voting member of the Great Slave Lake Advisory Committee.

Mr. Max Kotokak is a long-serving member of the Fisheries Joint Management Committee (FJMC), established under the Inuvialuit Final Agreement. The FJMC advises the Minister of Fisheries and Oceans on matters relating to fish and fish habitat and harvesting in the Inuvialuit Settlement Region. Max is also an avid fisherman in the Husky Lakes area and a businessman in his home community of Tuktoyaktuk.

Mr. Robert Charlie was born and raised in Fort Mcpherson, NT. He attended elementary/junior high school in Fort McPherson and attended junior/senior High school in Inuvik. After high school, Robert attended the Adult Vocational Training Center in Fort Smith and began working for CN Telecommunications/Northwestel as an Electronics Technician. Robert has been the Chairperson of the Gwich’in Renewable Resource Board since 1995 and works with the Government Agencies and Renewable Resource Councils to manage the wildlife and fish resources in the Gwich’in Settlement Area. Robert is also active in various capacities within the Gwich’in organizations.

Arthur Beck, as well as being an active subsistence fisherman, operates a sports fishing lodge on Great Slave Lake and for a time was a commercial gill-netter. Arthur continues to be active on the land: hunting, fishing, and dog-mushing. He brings a wealth of practical experience and local knowledge to the table. He is a longstanding member of the Great Slave Lake Advisory Committee and vice-president of the Fort Resolution Métis Council.

Mr. Jerry Morin has commercially fished on Great Slave Lake since the 1970s. He often fished in the outer part of the “East Arm” of the lake – trout country. He has a wealth of local knowledge on Great Slave Lake trout stocks.

Ms Diane Giroux is the Akaitcho Territory Government’s representative on the Great Slave Lake Advisory Committee and Sub-chief of the Deninu Kue First Nation in Fort Resolution. She is also the Chairperson of the Fort Resolution Environmental Working Committee and a member of the First Nation Forestry Management Program Committee. Obviously a very active person in the Akaitcho community at large, she brings a wealth of information on traditional fisheries.

Chair
George Low

Good afternoon. We have brought together a panel of local experts from across the Northwest Territories. They have a broad experience of being on the land, on the water and also fishing for lake trout. They're leaders in their communities and most of them serve on resource management boards or committees or have other co-management roles.

Max Kotokak is going to speak first. Max is a long-serving member of the Fisheries Joint Management Committee, FJMC. The FJMC advises the Minister of Fisheries and Oceans on matters relating to fish and fish habitat and harvesting in the Inuvialuit Settlement Region. Max is an avid fisherman in the Husky Lakes area and is also a businessman in his home community of Tuktoyaktuk.

6.2 Inuvialuit

Max Kotokak
Fisheries Joint Management Committee

Good afternoon, ladies and gentlemen. On behalf of the Fisheries Joint Management Committee and the students here today, I would like to thank the organizers of this meeting, the meeting's sponsors and the special person, Lois, thank you.

I am from the Western Canadian Arctic. We call ourselves Inuvialuit. Inuit is a more general term that is applied in Greenland, Canada, Alaska and a small area in northeastern Russia. Our close neighbours in Alaska still are referred to as Eskimos.

I work at a regular job driving a truck in my home of Tuktoyaktuk. I am also a hunter and a fisherman. Fish and marine mammal resources of the western Arctic in Canada are managed co-operatively by the Canada/Inuvialuit Fisheries Joint Management Committee, FJMC, with its partners the Federal Department of Fisheries and Oceans, the hunters and trappers committees in each community, and the Inuvialuit Game Council. The FJMC was established as a result of the land claims treaty between my people and Canada in 1984.

Here is the Inuvialuit Settlement Region (ISR) in relation to North America. Here is a blown up map of the ISR. Many of the lakes in the area are used for lake trout fishing by the people of Tuktoyaktuk. Many of the lakes in the ISR have lake trout, including Banks Island and Victoria Island.

One of the most important lakes for lake trout fishing is Husky Lakes. Lois Harwood will be discussing Husky Lake and Sitidgi Lake in a presentation later in the symposium.

Many of the people from Tuk have fishing camps on different parts of the lake. Archaeological digs have shown the importance of this area for fishing of my Inuvialuit ancestors for hundreds of years. I remember the first time my parents took me fishing to Husky Lakes. I was five or six years old. We traveled by dog team for about 40 kilometres from Tuk to Husky Lakes in April or May. Because there was plenty of snow on the land and a lot of sunlight, which made traveling easier, we would camp for a week or so and fish by jigging through the ice. We would catch enough lake trout for food, but we were mainly there for the enjoyment of being out on the land. I can remember one time catching a big fish that would not fit through the ice hole. I thought it was going to be the biggest trout ever caught. It turned out to be the biggest flounder ever caught in the lake.

When I was young I used to fish mainly using nets in the summer and jigging in the winter. Most of the people still use nets, but mainly fishing using the fishing rod with the lures that we have today. Personally I would not use something like this lure. It has no barbs on it.

I fish for subsistence, not for sport. My father used to make fishing hooks using caribou bone and old nails. Lake trout are important for recreational use and subsistence in the ISR. Several recent issues have caused growing concerns for both the FJMC and the people in the ISR.

This is a map of the past seismic exploration in the Delta and the near shore of the Beaufort Sea for oil and gas. This development might potentially damage some of the Inuvialuit lakes in the area. Also, we are concerned that all the people coming in from the south to work in the industry might want to go fishing, increasing pressure of fishing populations. Four wheel vehicles driving along pipeline are a potential problem as well. There are also concerns with possible road construction from Tuk to Inuvik. Such a road would go past critical lakes and may mean increased access to the lakes and overfishing.

Climate warming might change lakes in the area. Will the permafrost melt and cause problems with contaminants? We are a long way away from pollution sources in the south, but the Arctic is a sink for pollution from the south. Will it get worse? Will rising sea levels cause changes in the lakes?

In conclusion, I will tell a little story here. There was a manager from the co-op who wanted to go out lake trout fishing. This was the time people were still using dog teams. The only transportation was the dog, so he had to go around trying to buy dogs. He managed to round up maybe five or six, but he needed a lead dog. So again, he was wandering around town and he runs into a guy with a lead dog that he was not using. He talked and talked and tried to get this dog, and the guy told him the dog was no good. He don't look good. You can't sell him. But in desperation he kept going back to this guy and finally he sold it to him. He had to do a training run with the dogs, so this was in late May, when there was water on the ice and cracks were opening up. So he did a training run with the dogs and as he was traveling he can see a crack up ahead. He tried to stop the dogs, but the dogs kept going and finally the lead dog fell in. He went out, fished the dog out and then went a little ways. He was heading back to the community and the same thing happened. He ran into a crack that was open. Again the lead dog fell in. He went back to the community – oh, while he was there he was looking at the dog wondering what was going on. He waved his hand in front of the dog; the dog was blind.

He didn't like it so he went back to the guy in the community and he said, "you sold me a blind dog." And the guy told him, "I tried to tell you the dog don't look good." Thank you.

Chair
George Low

Robert Charlie is chairman of the Gwich'in Renewable Resource Board. Originally from Fort McPherson, he now lives in Inuvik and I've been told he is an avid fisherman and hunter.

6.3 Gwich'in Renewable Resource Board

Robert Charlie

Just to give you some perspective I will talk a little bit about the organization that I represent. I will talk about some of the past activities of the Gwich'in and their harvest activities in the past. I will talk about some of the things that are happening today, and then I will talk about some of the issues.

The Gwich'in Renewable Resource Board is a co-management board established under the Gwich'in Comprehensive Land Claim Agreement that was settled in 1992. Under the terms of that agreement the Gwich'in Renewable Resource Board was established to deal with wildlife, fish, and forest management. Along with that, some of the principles that guided that board were that they would develop management plans that would conserve the resources for people today and for future generations of people that live within the Gwich'in Settlement Area.

Also, one of the activities that we conducted between 1995 and 2000 was a harvest study. Now looking at the harvest study numbers on average during that five year period, Gwich'in people harvested on average only about 200 trout a year. One of the reasons for that is that in the past the Gwich'in lived a subsistence lifestyle, but during the summer they did a lot of fishing along the river systems and there are not too many trout in the river, so as a result of that the harvest numbers are quite low. Basically, the species that they depended on were whitefish and inconnu rather than trout. Now in the fall and the winters a lot of people, because of their lifestyle, lived out on the land and traveled to a lot of the big lakes and I think Tsiigehtchic is one of the communities that did a lot of harvesting on a major lake around their community, which is the Traviallant Lake.

Today, a subsistence lifestyle is not followed as much by Gwich'in people. They spend a lot of time in the communities. They do periodically go out hunting and trapping and fishing, but times have changed. People are not so dependent on living on the land any more and, I guess, following a wage-based economy. Nevertheless, there are people dependent on living on the land following a subsistence lifestyle. So as I mentioned, the GRRB mandate is to try and conserve those resources for the people.

Earlier we heard some presentations that talked about some of the issues; one of the major projects that is happening in our area, as you know, is the Mackenzie Gas Project. Along with that comes a lot of the engineering and research. A lot of winter geotechnical work looking at the gravel resources that is going to be required to build the pipeline and with that comes the access roads and our fear is that a lot of these access roads are going to give easier access to people. One of the things that we will be doing in the near future is start looking at developing a trout management plan and along with that we will be looking at the population of trout within the Gwich'in Settlement Area, looking at the habitat, the water quality, water quantity, and also looking at some of the potential impacts that are going to come along with the pipeline. There is going to be a 40 or 50 metre wide right-of-way for the pipeline, so again, access to a lot of the resources.

Also there is interest in the communities now for sport hunting and potentially setting up lodges along some of the lakes in the area. Again, how do you find a balance between the needs of those people and the needs of the Gwich'in people as they carry out that subsistence lifestyle?

Fisher's Panel

Chair
George Low

Our next speaker is Arthur Beck. Arthur, as well as being an active subsistence fisherman, operates a sport fishing lodge on Great Slave Lake and at one time even worked in a commercial fishery. Arthur continues to be active on the land: fishing, hunting, and dog mushing. He brings a wealth of practical experience and knowledge. He is also a member of the Great Slave Lake Advisory Committee.

6.4 Great Slave Lake Advisory Committee – Sports and Traditional Fisheries

Arthur Beck

I do not have this fancy stuff on slides or other things to show you, but I have a lot of experience. I grew up on the Talston River. My father is Ray Beck. My mother was a Chipewyan Indian. My father was German. We grew up on the land on the Talston River from the time we were little guys and I learned to speak the native language, plus English. I have had very little schooling, but lots of knowledge out on the land.

I also commercial fished, and I grew up in a fishing environment. My father was a trapper and fisherman and I got to speak to a lot of the Elders in the community because I spoke the language. When I was young I heard a lot of stories. I am 48 years old now, but I heard a lot of stories about how the trout fishing was great in the bay of Fort Resolution, the community where I live now. It is 100 miles south of here. But there have not been any trout caught since the 1950s until the last couple of years. This summer alone I caught 25 trout.

There were commercial fishermen on this lake, plus at the time there were a lot of hunters and trappers. There were no snow machines, so everybody was using fish for their dogs. There were a lot of dogs, but the dogs kind of faded away except for us. We still race with them. There are a couple of us that still trap using them. But we do not put as much fish away as we used to for the dogs, and the fishing, well, the high cost of equipment and gas and whatnot. A lot of the fishermen faded. There used to be 300 fishermen on this lake at one time. Now there are probably 30 active fishermen and a few others, the sport fishermen. Subsistent fishermen - there are a few of us left. There are not too many of us that do it. And we find that the trout are coming back.

But what we are worried about now is that we have the East Arm of Great Slave Lake closed to netting since 1980 or around there. That is about 15 to 17 years ago and we have trout all over Great Slave Lake now, and nice trout, which we have not had for a long time. But what we are worried about now with all the mines coming up, especially here in Yellowknife with the arsenic seeping into the lake and also we are concerned about the dam that they are talking about putting up in the Lockhart River where they back-up the water. That is where the mercury level comes into the lake. When they hold the water back, the water and mercury goes back up into the plants and brings the mercury down. So we are concerned right now about the water - make sure the water is clean - in Fort Smith and Fort Resolution, Hay River, all around Great Slave Lake. And they say it is a nice beautiful filter, but if you go down, especially around Fort Resolution, there is bedrock just about a foot underground. And the water table, it flows right into Great Slave Lake. So that's the things we have to watch. Thank you.

Chair
George Low

I have known Jerry Morin for many years. He claims to have commercially fished in the East Arm of Great Slave Lake long before I came to Hay River in 1975. Jerry has the experience on the lake, and in particular the East Arm of the lake, which is a long span of time. He also represents the fisherman's federation and brings valuable experience from the commercial fishery to the panel.

6.5 Great Slave Lake Advisory Committee – Fishermen's Federation

Jerry Morin

I have commercially fished on this lake for the last 38 years. I came into the fishery just after the lake started to be heavily exploited and there were up to nine million pounds of fish taken in one year at that time. I started fishing shortly after that. Fishing was pretty hard then. If you caught a box of fish from one net, you were doing really well. But when I started they had reduced the quota and it was down to where it is now at 3.4 million pounds per year. It is very well managed now. Even though the fish were quite scarce when I started I noticed an increase every year. Now, just two years ago, I had been in the East Arm, every year I go there and I set a net and I kept it down for two and a half hours and we had two and half boxes of fish out of it. This is in the same area where you were lucky to get a box of fish even two nights down a number of years ago. Then last summer I went there in the same area and it was three hours down and we got three and a half boxes. So there are a lot of fish. And I notice in areas there where we never ever caught trout before, there are trout all over now. It does not matter where you go on the lake now, there are trout. There are trout on the big part of the lake, not just the East Arm, even those stocks are up. And they have increased apart from what they used to be.

The thing I noticed over the years here, I been born and raised here in the Territories, is I look at lakes, where there has been hardly any fishing, and you see the fish have big heads and small bodies - like they are out of balance. To me, where you use the fish, where you're fishing and the people are fishing, the fish are healthier. They are in better shape. I think that is the way the Lord created this for man to use the resources He has given us. You can see the difference in that. All we have to do is manage. I know the Great Slave Lake fishery is very well managed and the quota has not been taken from the lake because, like Arthur said, there are hardly any fishermen left on the lake and the stocks are increasing. This is my observation over the years. Thank you.

* * * * *

Discussion

> Bert: Can you clarify the regulations for whitefish versus lake trout on Great Slave Lake? Is it closed completely for commercial fishing of all kinds of fish in the East Arm?
>
> Arthur Beck: The lake trout fishery is closed in the East Arm area - Great Slave Lake is broken into six areas and area six is McKinley Point in the East Arm - that has been closed from McKinley Point, Blanchette and the East Arm has been closed since 1988. But whitefish is open, although area six is closed to all gillnet fishing. But there are fishing seasons for areas one to five. We have certain areas closed for certain species.

Like inconnu, that is closed on the south shores where their spawning area is, but there is not really any place closed for whitefish.

Bert: And do I understand now that you are saying that lake trout are starting to appear more in areas one to five, is that right?

Arthur Beck: Yes, lake trout are appearing all over Great Slave Lake now. For a while you could only catch lake trout in the North and East Arm, but now they are all over Great Slave Lake. They are moving south and southeast. In Talston River, where I grew up, there were no lake trout there when I was a kid. The Elders said there was once a lot of lake trout there. They used to use hooks to catch them. They would go out and set ten hooks and they would catch, say, eight beautiful 20-pound lake trout before. Then after the commercial fishing for a few years, then there was no lake trout at all. We could not even catch them with nets. But now, since East Arm has been closed since 1988, the lake trout are all over Great Slave Lake, and there are lots of beautiful big ones.

George Low: Thanks Arthur. I will just add that the Simpson Island Fish Plant has been closed since 1992, so it is very hard to deliver whitefish or trout from the outer East Arm. So that is a factor as well.

Unidentified female speaker: I was just wondering what the time period was between when you were no longer seeing trout and when you started to see them again. How many years did it take for them to start showing up?

Arthur Beck: You could notice the difference in about eight to ten years, but it was about 15 years when you could notice a big difference in every area.

Unidentified male speaker: What about the subsistence fishery on Great Slave Lake? Is it declining as well?

Arthur Beck: There is no fishery declining. Subsistence fishing is still going strong. There are a lot of people in communities catching and using a lot of fish. We are hunters and trappers and fishermen, so that is part of our diet. There is a lot of fishing on Great Slave Lake, and a lot of gillnets. Not so much sport fishing, but a lot of gillnet fishing by aboriginal people.

Unidentified male speaker: I just wanted to start off, Max, at the beginning you mentioned the barbless hook and you would not use a barbless hook and I guess I can appreciate that for subsistence fishery, but I was wondering in general what your thoughts are on the sport fishery and the use of barbless hooks and the increasing catch-and-release that sport fishermen are exercising to try to maintain the resource. Is that an activity you support?

Max Kotokak: I would say that I do not mind that. If it works, then it works. But personally, like I said, I would not use barbless hooks.

Jerry Morin: I have been operating Talston River Outfitters since 1990 and before this regulation was in place we were already practicing catch-and-release and barbless hooks. We had a few of our guys who got barbs stuck in them and it was not cool. We had some guests get caught in the barbed hooks too. We have been practicing catch-and-release since before the regulation was in place. We started this a long time ago. Maybe we have 30 guests in the camp and we have maybe 10 or 15 boats. We only keep enough fish for shore lunch and we hardly handle the fish. Our guests do not take any fish home. They come there. If they catch a fish what they have to do is they weigh it, then measure it, take pictures and then we put the fish back so somebody else can catch it.

John: There was reference to global warming. Do you have any observations that nature might be responding to any temperature change you are seeing?

Arthur Beck: Well, global warming and there is also what they call the pineapple effect. We do not notice it so much in Great Slave Lake because we have a lot of deep water, so the water is a lot cooler. But on the southern shores the water is shallower here it is warmer. In the hot summer, trout do not come into the south shores too much, but they stay in the deep. So we do not really have that problem yet.

Jerry Morin: I just want to answer in that when I first started fishing for the first five to eight years in the winters, we would have about a three-month cold snap and when you would get up in the morning; if it was 30 below you were happy. That is how cold it was. Now you do not see that at all any more. You might get a week of weather like that. So it has really gotten a lot warmer. I notice a difference over the years because when you are out there and you are fishing every day, you sure notice the weather. Like I said, it was three months practically every year for about the first eight years of my fishing career. So I see a big difference.

Chair
George Low

Diane Giroux is the Akaitcho Territorial Government's representative on the Great Slave Lake Advisory Committee. She is also sub-chief of the Deninu Kue First Nation in Fort Resolution. She is chairperson of the Fort Resolution Environmental Working Committee, a member of the First National Forestry Management Program, and a member in other organizations. She has a wealth of information for us.

6.6 Great Slave Lake Advisory Committee – Traditional Fisheries

Diane Giroux

As George said, my name is Diane Giroux. I am from the community of Fort Resolution, which is just across the lake here on the southeast shore. Fort Resolution is located on the north shore of Resolution Bay. But as George has stated, I am here currently in the capacity of a representative of the Great Slave Lake Advisory Committee as an Akaitcho Territory Government representative. The Akaitcho Territory Government is an organization that is comprised of six member First Nations which were signatory to the Treaty No. 8 Adhesion of 1900 here in the North. Two of the First Nations, Smith's Landing and Salt River First Nation, are both located along the Slave River. The other four First Nations of Lutselk'e, N'Dilo, Dettah and Deninu Kue are situated on the shores of Great Slave Lake itself.

My community of Fort Resolution are Deninu Kue, as it is known in the Chipewyan language. It is one of the oldest or is the oldest settlement in the Northwest Territories. Currently it is home to approximately 550 people. It is comprised of predominantly aboriginal peoples of Chipewyan, Dene and descendant Metis, with a small number of non-aboriginal residents.

As a community the people in Deninu Kue have experienced many changes over time. We were one of the areas with very early European contact. We had a lot of active development and involvement in the fur trade in this area. We also were impacted by being situated along the early river transportation corridor of goods that came to the North. We also have a history of sawmills in our area. I was told it was roughly since the 1930s that there have been different levels of milling going on and logging. We also had the impact of residential schools, having one of the earlier mission schools in our community. We also have been impacted to some degree by commercial fishing and other influences, including near my community major non-renewable resource extraction with the lead-zinc operation in the Pine Point area.

Despite these many challenges the lifestyle of the Dene is today in many ways still very traditional as a community. The cultural aspects, such as the language, as Arthur stated earlier, is still quite strong and the traditions of our people with the use of our land continues today and we have many active users of the land, the waters, that involve hunting, trapping, fishing, and overall clearly shows that the lifestyle of our people as Dene is still surviving. We are still utilizing and practicing our traditions on our traditional lands.

My presentation today is actually based on my community of Deninu Kue. It reflects interviews and surveys that were done to collect information from current active harvesters relating to fishing and also interviews of past Elder harvesters. The rationale for this was that with both groups involved, they collectively represent the living history of our Dene traditional activities and with the information collected it is considered traditional knowledge. I wanted to bring this point up because although we did conduct the surveys I cannot speak to specifics. That deals with concerns that our people have in our community when information is disclosed and how it is used. But I will get back to that a little bit later. With traditional knowledge, as I stated, it requires specific handling in the collection of the materials. Also, the use of the materials is always considered. There is storage of information collected. One of the outstanding issues in that area has always been intellectual property rights. Because there is no legal premise, I guess, for how collective information is gathered and used, there have been concerns raised there.

Moving on to the interview survey, the way this was developed was that it was done in two parts. The first part of our survey was to determine fishing in general. When I speak of fishing in general we asked general questions in the surveys as to what species of fish were caught, what areas they were caught in, what seasons and time of the year that they were harvested, and we expanded on that area with concerns that individuals may have had. We also questioned their perception of the quality of fish that were harvested and allowed them an opportunity to raise any additional issues or add comments about any of our questions.

So, we proceeded with that first part of the survey in that area and we also followed with the second component which focused specifically on trout. Over a few days we had two individuals doing the interviews within our community. For the current harvesters we had the interviews conducted in English and with the Elders we had a surveyor who was fluent in the Chipewyan language, so all interviews with the Elders were done in the Chipewyan language.

I will speak generally to the first part of the survey that we conducted. Most of the fish that were harvested were used for sustenance or for eating. We identified that the gathering and harvesting of that fish was not only for immediate family needs, but also for sharing with the other Elders in the community and with others. In some cases that included relatives outside of the community and friends and their families. So fish are very actively used in this way. The harvest also included some feedback on the history of commercial activity by the peoples of the community.

Historically there was a fish plant in the Simpson Islands of Great Slave Lake, which is very near or within our traditional land use area, and it ran until 1992. The majority of the people who were involved with the commercial fishery at that time were not large-scale operations, but most used small skiffs and the fishermen for the most part were individuals who also were very active trappers. So this was a seasonal activity and it very much reflected the lifestyle of the people in my area.

To move on to the Elders, I separated my presentation into the Elders and the harvesters and very active harvesters in different areas. So I am just speaking generally here. With the Elders, collectively, those that were interviewed, many of them identified changes that they had noted within their lifetimes and also made direct reference to areas of concern about those changes. The predominant response of change was that the fish population had decreased dramatically on the lake over their lifetimes. The majority of Elders directly attributed this change to the introduction of commercial fishing that was established in the 1950s. During this period of heavy harvests, many Elders felt that the stocks were all affected by the newly introduced resource extraction, which seemed to have been large scale and I believe has been well documented in the history of commercial fisheries on the lake, and quotas having been met for a long time on the lake. But I also have to note that most recently, since my involvement with the Great Slave Lake Advisory Committee, I know that the quotas themselves over the last several years have not been met and there is actually a decline in numbers of commercial fishers on Great Slave Lake at this point. There is potential for that to have a huge impact on the industry as a whole.

The Elders also raised the issue or concern that locally we do have fewer people that are fishermen. We also have fewer nets among our people in the community, so that activity locally has decreased. Among the harvesters, there is still a feeling that there are still enough current harvesters that tradition can continue. Again, going back to the Elders, the other area that they felt was reflected by the decrease in fishermen and fishing activity was the decline in the use of dog teams. Historically, that has been the main way for our people to travel until the introduction of snow machines. That necessity is no longer there. There are still people that have dog teams. Some may still travel using dog teams, but it is not at the same level as it was historically. I say that from personal experience because my late father and my brothers were all trappers and when I was quite young just about everybody used dog teams and I'm not that old.

Also, the other area the Elders made reference to was fish having been harvested to be used as part of the bait for trapping. Again, this was another industry that once thrived, but because of various reasons it has declined. Mainly it is to do with market prices of furs. As Arthur stated earlier, it is still a current active practice of our people. It is not as lucrative financially, but it still continues today.

Going on with the other part of the Elders' survey, they raised a few other issues. I will not go into the details because I am going to make reference to them later with the current harvesters as well. But many of the Elders, despite their concerns, still felt overall that the quality of the fish is still very good. But they do have some concerns with things like parasites, cysts and also skinny fish. I wanted to get a little bit more information on the skinny fish, but I was told by a couple of Elders that it is a natural incident. You do not have huge numbers of skinny fish, but you do catch the occasional skinny fish.

A direct quote from one of the Elders was, "in numbers, the fish, it's way down; the quality, it is still good." And that was consistently stated by all of the Elders that were interviewed.

The Elders consistently said that major population declines had occurred in the case of trout due to commercial fishing and that the quality of the trout was still very good. Among the other changes were noted, there seemed to be increased numbers in trout and a lot of them felt that they are slowly coming back. The concerns here were that we should ensure that the increased number of trout be allowed to continue to rise.

There were domestic zone issues and other issues with commercial fishing, but it was also noted by an Elder that another concern was sport fishing. They did acknowledge that the problems were not with established lodges or tourism outfits, but his concern lay with the number of people who are going out onto the lake, onto the tributaries, and harvesting without any monitoring. There is increased activity on the land and one of the Elders noted that it had to do with GPS systems. They are saying that at one time, people, because they were not familiar with the lands, with the waterways in our area, were required to either go to an establishment or have a local guide to provide their safe passage, but that is no longer the case. We have more and more people going out onto the waters who are not coming through the community and their activities are not being monitored. I thought it was a very significant point. What I would say additionally is that I know through my involvement with GSLAC that lodge outfitters are very involved in monitoring the catch and harvest of fish that are caught in conjunction with their facilities. This is very reassuring, but as I said, the concern is with those who are not going through these types of commercial operations. The other minor point I would add is that they were questioning what kind of permitting was in place that allowed people to go out on the land without going through commercial establishments. I will leave this issue with that final comment.

In the survey of the current active harvesters, they also identify all of the species very much the same as the Elders, with the exceptions of the additional species cisco and goldeye. I'm not sure if there was a miss in the survey, but I'll check into that. They also spoke about what the best time was to harvest fish and also the areas that were being utilized for harvest. Unfortunately, due to the traditional knowledge aspects, I am unable to go into specific detail. There is much concern about potential abuse of traditional knowledge. So I do have to apologize. But I can speak to some of the issues.

Despite this, I can say that the current harvesters also echoed the concerns of the Elders and also confirmed that the fish was still of good quality. They also noted increased numbers of trout in the harvest throughout the whole lake. Additionally, current harvesters continued to use the areas used previously by the Elders and are continuing to collectively use the whole lake and river systems as was done in the past. For me, that was very good to hear. Another part of that I would say is that we do have a lot of youth who are becoming more active on the land as well. So I think that is very positive to say that level of interest is still there.

The other note I would say is that in some cases, the harvesting of some species occurred year round. Some of the harvest for other species was done on a seasonal basis. Traditional knowledge was also very consistent among the Elders and between the Elders and the current harvesters. It was interesting to note that one of the harvesters mentioned that in some cases one of the changes he had noted was that to access a certain species of fish they had to go into deeper waters. I wanted to raise that point because I am going to make reference to climate change a little bit later on in my presentation.

So in conclusion to this component of my report, I would say that the Elders and the current harvesters both have noted changes to populations and also to recent increases for some fish species. In this case, I will state that changes have occurred for trout and inconnu. But there were issues with all fish in general with parasites, cysts and with commercial aspects as well as tourism. Also, both groups agreed for the most part the quality of the fish is still very good, but there are concerns for a small percentage. Both agreed that there is a need to ensure that they are managed properly. They believe that the current stocks are increasing and that this should be monitored. Also, there was a need to establish addtional fish studies.

I would say the people of Deninu Kue today and in the future want to ensure that they are able to continue with the traditional fishing activity that has been occurring since time immemorial. A large part of that has to do with the value to the Dene people of the land. We do believe we have a stewardship obligation with the land. We take care of the land; it takes care of us. It is one of our values. Also, when we speak to the land, we also speak to the water because there is land under the water and as an environment we do approach it from a holistic manner. We do need to have a healthy environment to have healthy people and in the case of fish we need to have a healthy habitat to have healthy populations.

To move on to the second part of my interview, I would like to speak generally to some of the areas that the community has also been working on with the environment committee and issues that have been raised in different forums such as workshops.

Most recently, our community held a climate change workshop that involved the whole community. There were a lot of concerns raised about climate change because we know it does not affect just ourselves, but is very much a global issue. It has the potential to have a huge impact on our lifestyle. We have always had the ability to adapt to these changes, but with the nature of climate change happening at such a rapid rate – and I say rapid rate because we also worked with a group called Meg's GWEX. They were doing actual studies related directly to climate change and they undertook a several years study over waters, rivers and whether changes were related in our area to increased number of forest fires from increased lightning strikes. So we do have some information to substantiate that this is occurring.

There was concern raised with climate change because this is happening so rapidly. Elders noted the weather is very, very different now. The seasons are almost out of sequence in some cases. This has occurred recently; we have had a very cool summer. We have had a lot of rain, and this definitely impacts things. In some ways, this is good because this year we have more berries. In past years, again going back to climate change, the weather was too hot so berries were not maturing. They were drying up very quickly and berries are an important part of our diet. It also affects the natural vegetation that is in this area.

One of the concerns that were raised by, I think, the majority of the conference participants was new species coming into the North such as southern plants. Fish, as well, were identified as a problem and I think most recently there was a Pacific salmon caught up the Mackenzie River. So it is very interesting; it was believed that it had to do with increasing water temperatures. But there is also new wildlife. There are new plants, there are new birds, and there are new insects. You have all of these new species coming into this environment where they are not native species. So there are going to be changes and the concerns are going to be with what happens with our current wildlife, our current birds, and our current vegetation. Those are things we have to be aware of and we are going to have to deal with these at some point.

The other area that was of major concern recently in our community is water quality. This does have direct impact to fish populations and other species.

Historically Great Slave Lake has been considered a very cold lake, but with global warming and climate change there are increased temperatures in the lake and it is bound to have an impact on the ecosystem.

Locally, some of the concerns with water quality had to do with seepage regarding lagoons, sewage facilities, those types of things, and also contaminants. Historically, legislation has not always been in place to address environmental issues within the communities. Our people have always been very aware of this problem. We tied this into the health of the land and the health of the people, which are directly related.

There were also concerns raised recently regarding pollution and in our case we are very aware of the downstream effects where we are located. Years ago, there was a focus on pulp mills upstream, but there was also concern with human settlements because of waste treatment and the concerns that pollutants are getting into the water, in some cases with untreated sewage going directly into the water systems that flow into the Great Slave Lake.

Additionally, industrial development was raised as an ongoing issue. In our case, I made reference earlier to our community being across the bay from the lead-zinc mining facility at Pine Point. It was a major non-renewable resource development project that continued for quite a few decades. There have always been concerns by the people in our communities with pollutants from that development, and from the tailings ponds. Again, going back to that period of time, legislation was not in place to address pollutant issues, the handling, reclamation issues, and restoration issues. There are always concerns when you deal with monitoring these types of developments and that scale of development, but the community is basically saying that with the re-interest in the zinc in that area recently, they do not want to repeat history. In the case of Pine Point, the majority of the community felt that when the resource extraction occurred, the land was left in a very sad state. There were no initiatives to address reclamation or restoration of the lands, and it had a huge impact on the wildlife and also the peoples of our community - the environmental aspects, but also social and economic.

Another area of development that has been raised recently in our area is hydro development. Again, our community has directly felt the impact of hydro development upstream. In our case, the major development is the Bennett Dam. It drastically altered water levels along our river system and on the lake itself. It is still a contentious issue to our people from the forums that I have recently attended. There are a lot of outstanding issues. Unfortunately, I believe that there are really no provisions for end-of-the-line impacts. But there is opportunity, I think, to address these at some point. I think people are more aware that there are downstream impacts of hydro development and you need to look at a minimum of 30 miles downstream to evaluate total impacts.

Additionally, we also are looking at the potential expansion of the Talston hydro facility, as well as a new facility on the Lockhart River.

There are also commercial aspects to this development for traditional fisheries of our people. The majority of the fishing is for domestic purposes and there are concerns because fish are part of our traditional diet, a very large part of it. To go the store right now and buy whitefish or trout is very expensive.

Other commercial concerns come again with commercial over-harvest, and again I will make reference to the quotas that were met previously, a long time ago, and the issues of management that come from addressing issues such as those relating to stock assessment. Also I know one of the contentious points in our community with commercial fishing deals with mesh size because it has been reduced. Elders always have a lot to say about this because you use nets that can catch smaller fish these not being allowed to mature and it will affect populations.

With co-management of resources, our area is actually in an unsettled region. So right now when we talk about co-management we are not fully engaged, but we do work with government and industry and with other Dene in the North.

The primary economic factor to be considered here is the cost of the fish in stores. This has impacts on each individual. Commercial fishing was done by people in our area. It did support the trapping lifestyle and most recently there has been re-interest by people in the community to look at a fish processing plant in our area.

Also in relation to the NWT and tourism with sport fishing, there is no objection to barbless hooks and the catch-and-release program. That is very much supported, but as I said earlier, there is increased concern with the numbers of sport fishers on the lake that are not going through lodges or tourist outfitters, and these people are basically unmonitored and this is escalating.

In closing, I just wanted to speak briefly to an initiative with the Akaitcho Territory Government. This fiscal year we accessed funding through the Aboriginal Aquatic Resource Oceans Management Program. These monies are designed for unsettled regions to become more fully engaged in resource management. In our case some of the areas we are considering for use of these funds are to support traditional knowledge studies and to support monitoring programs. It is an opportunity for us to develop capacity. One of the potential outcomes of this process is possibly the establishment of a management board to address issues. I think this is important because as I said earlier, in our case we are in an unsettled land claims area. We are still in negotiations with the Government of Canada, but we are very mindful, despite that, that there are legal obligations relating to treaties. There has been case law established and at the end of the day fish is part of our diet. It is part of our traditions. It is part of our culture. As I said earlier, we need the land; it encompasses the fish, the water, the wildlife, and it is part of our identity as Dene. Thank you.

7 Special Guest Presentation

Introduction
Ron Allen

At this time I am very pleased to introduce to you our Member of Parliament for this part of the world, the Honorable Ethel Blondin-Andrew, Minister of State. But that is not her real claim to fame. You had heard earlier that we are in the center of lake trout country. Her real claim to fame is that she has cleaned more lake trout than any other single person in this room. We are very pleased to have you here today and we know you have a busy schedule and the fact you have taken the time to come and speak to us today tells us a lot about the importance of lake trout to this part of the world. If there is anybody in Ottawa that knows something about lake trout, our MP does.

7.1 Address by Honourable Ethel Blondin-Andrew

MP Western Arctic and Minister of State (Northern Development)

I did actually say I have cleaned more lake trout than probably everyone else except Paul Modeste, if he is here. I am not sure he is here, but he worked at the lodge in Great Bear Lake and he has been a guide for many years. I think he is one of the people that used to check our nets. My job in the summer was not as interesting as my colleagues' when I was a teenager. I went to school in Fort Smith to a leadership school, but in the summertime I did not get to work at the lodges and take jobs in Norman Wells. I had to stay home and look after my grandmother and we had to clean fish. Someone visited our nets because my dad worked for NTCL. I cleaned tubs and tubs of fish. It is a very flattering thing for a 16 year old in a miniskirt to be cleaning tubs of fish hoping for a date. I did not mean that. I did that and the other job I had was to take the remains, the guts, and boil them. Then we combined them with tallow, a quarter pound of tallow and rolled oats, and fed that to the dogs. Now that is a summer job that I have never seen when I worked for HRDC for 11 years; I never saw that job on the website.

We have unique backgrounds up here in the Northwest Territories. I am really pleased to be here. I am just here on the heels of coming out of that place I lived on Great Bear Lake, Deline. I have had successive tours there lately. I was there with Minister Dion, the Minister of Environment, when we expanded the – of course I am off topic already. You cannot trust those politicians; you want them to talk about trout and they talk about something else. But anyway, I should say that I was up there and Minister Dion caught a 20 pound trout. Minister Alcott was there yesterday; he is the man that handles the money for the government, Reg is the president of the Treasury Board. His son caught a 20 pound trout and I caught a trout. I was determined that I was not going to leave Deline if I did not catch a trout. So I am glad I did and I am here today.

Before that, my assistant Jackie and I were in a meeting in Whitehorse on a climate change meeting. So I was trying to think of linkages between that and here and I had a very interesting trip to the Yukon because I was the head of the delegation for Canada hosting Senator John McCain from Arizona. He is a big supporter of the International Polar Year initiatives that probably some of you know about that. We are supporting that as well. We also had Senator Hilary Clinton, who is huge on the environment, and we also had Senator Susan Collins, who is from a place originally called Caribou in North Carolina, I believe. She lives in Maine now. It was called Caribou because they had caribou there and then the white-tailed deer contracted a disease and there are no longer caribou there. So these things do happen in the ecosystem.

We went to the Yukon to look at the glacial icecaps that are shrinking and to look at the environment. We were in a place called Klukshu, and it is a very isolated place, we went there and we saw sheep and we flew in helicopters and the interesting thing about Klukshu is the real change in the climate. That has enormous implications for the animal species, as you well know. I know those of you who are here from the Arctic. I think Frank Pokiak is here. In the Arctic Regions the weights of polar bears are highly implicated in their reproductive capacity. Now, they are not trout, but I am actually getting towards trout through polar bears. We also saw fish that were a very traditional fish that is used still in Klukshu and we left with the impression that things are changing. They now have a huge Spruce Bark Beetle infestation. It was unbelievable how climate change has had an impact. I think they have lost 800,000 hectares of trees to the Spruce Bark larvae. You need two cold years of -60° to kill the larvae, and obviously we have not had that because the problem is increasing.

Now I am really happy to say that coming here today I was speaking to some of the people that organized this meeting and they said that all reports from the different regions were that lake trout populations are still healthy and abundant. I can tell you on Great Bear Lake I think they are okay. I think there are many trout and I think the water is still cold. The Arctic Ocean is warming. I think the Arctic Climate Impact Assessment Report indicates that reflection of the sun off the snow and the ice actually heats up the ocean. That has implications for the seals, and henceforth to the reproductive weight that is needed for polar bears. Reproduction occurs when females weigh at 280 kilograms, but at 240 the number of cubs is reduced to one, and at 180 kilograms most of them will quit reproducing. And that is the impact that climate change has for polar bears.

So I better get on with my speech. I am here on behalf of Minister Regan. He bids you well and he sends his regards and his regrets that he was unable to attend. He is going to make a visit to the North though. I am especially pleased to have this opportunity to meet with representatives from such a wide cross-section of interest from Canada and the U.S., the mining industry, oil and gas producers, recreational fishers, scientists, land claim organizations, and other government officials. Each of you has a vested interest in lake trout and its habitat.

I want to point out that I work with the fishermen from the NWT Fishermen's Federation. I see Mr. Morin over there. I have been working very closely with them. I think it is one of the industries that are much stressed. It has really high infrastructural needs. Almost everything is cash intensive. You have to pay your workers. The issue of marketing and competition is a really big issue for them and how government plays a facilitating role is also important. So I want to say I am happy that they are here and we'll continue to work with them.

Through your presence each of you is demonstrating your commitment to protecting this key northern resource in years to come. You are here this week because you recognize that cooperation on this issue is essential. As Minister of State for Northern Development, I am well acquainted with the wide range of activities in Canada's northern areas, especially here in the Northwest Territories.

At this symposium each of you has the opportunity to demonstrate your expertise and how it can be applied to reach our common goal of conserving lake trout and their habitat for generations to come. In many ways this symposium is about balancing the many activities here in the North. It is about finding ways for all activities to thrive while protecting what makes northern Canada so very special in the first place – its unique environment and natural resources. Lake trout are one sign of this for the environment.

I have fished trout all the way up to Husky Lakes, I never did catch a trout there, but I did go to Drum Lake where they have dolly varden and I fished quite extensively with my relatives who live there and got some really good fish, and I have caught lake trout in Great Bear Lake, as well, and also in Great Slave Lake. So I am really happy that there is an abundance of trout, and they are not an endangered species.

Here in Yellowknife we are surrounded by the best lake trout habitat in the world. People come from around the globe to discover what people from this territory have known for years, that there is simply no better place to fish for lake trout.

All this attention and all this activity make managing this resource in a sustainable way an absolute necessity. That is why the first lake trout symposium organized by the Yukon Territorial Government in 2002 was so important. It brought together the many groups interested in preserving this territory's, and indeed this continent's proud lake trout heritage and finding ways to cooperate to meet this goal. This year's conference continues this tradition.

Your four themes speak to the many challenges faced by lake trout and what you are doing to meet those challenges: industrial development, lake trout biology, ecology and habitat, co-management regimes and lake trout harvesting, and stock and habitat assessments. I understand that many productive discussions have taken place on each of these topics with more discussions to come. This kind of dialogue is essential. It opens up new avenues for cooperation and serves as a forum for sharing ideas, science and how you can build a sustainable future for lake trout by working together.

Over the years the Government of Canada has taken a much more cooperative approach to managing not only Canada's fisheries, but protecting habitat as well. This is especially key here in the North. With the renewed interest in the North and its resources the time for dialogue, the time for cooperation, is now.

I was really glad to hear that Diane Giroux did a traditional knowledge presentation. I think that this is so critical. When I spoke at the forum with the senators the other night I wanted to emphasize the absolutely critical role that traditional knowledge plays along with contemporary science in dealing with the habitat, the environment and all the complex ecosystems, and with the animal species as well and how that ties into climate change. I am pleased to hear that happened. I am sure there were others who spoke to that as well.

With this symposium you are establishing a model; one that others can follow as we find new and innovative ways to balance northern development with the need to protect this beautiful place and its resources for the future. At times we are faced with tough decisions. With more information, the kind of information being discussed at this meeting, these decisions become easier to make. I am here today to tell you that the Government of Canada supports you in this endeavor and we look forward to working with you in the years ahead to protect lake trout and its habitat for future generations.

Once again, maybe I will give you your Dene lessons, if you have not had it today. I do not know if Diane told you the word for lake trout, but in my dialect, which is Northern Dene, lake trout is S'ahbah. I don't know how you say it in Inuktitut; Frank but can you tell us what the word for lake trout is? You want to say it here? What do you say?

Frank Pokiak: It is called Iqaluaqtuk for fish.

Thank you very much, I just want to say that once again, on behalf of Minister Regan and his Department, I wish you a pleasant and productive conference. As Groucho Marx said, you can tune a piano, but you cannot tun-a fish. Thank you.

8 Plenary Sessions

Chair
George Low

8.1 Plenary Session Biographies

Dr. David Evans is employed as a Research Scientist, Applied Research and Development Branch, Ontario Ministry of Natural Resources, Peterborough, Ontario. Since 1997 Dr. Evans has held the position of Adjunct Professor, Watershed Ecosystem Graduate Program, Trent University, Peterborough, Ontario and from 1987-2000 was Adjunct Professor, Department of Biology, York University, Toronto. Dr. Evans obtained his B.Sc. in marine biology at the University of Victoria in Victoria, British Columbia and his M.Sc. and Ph.D. degrees in zoology at the University of Toronto. His research spans fish physiology, population biology, aquatic ecology and watershed science with particular interest in the ecology of salmonid fishes. He currently supervises three graduate students studying land use impacts on brook trout populations in small headwater tributaries; use of GIS tools and topographic indices to predict the location of coldwater streams and seeps on Precambrian Shield landscapes; and the impact of water level regulation on the production of littoral zone fishes in Shield lakes. Dr. Evans has studied the biology, habitat use, population ecology and management of lake trout in Ontario lakes for the past 15 years. His current research includes thermal and dissolved oxygen requirements of lake trout, the effectiveness of slot-size fishing regulations and stocking of native stocks for sustainable management of lake trout populations, effects of management practices and water level regulation on diet, growth rate and Hg accumulation of lake trout, and the impacts of climate change on lake trout habitat, production and fishery yields. Dr. Evans has been an active member of the American Fisheries Society and is a past president of the Canadian Aquatic Resources Section, of AFS.

Dr. Lyle Lockhart joined the Freshwater Institute of DFO as a Research Scientist in 1971. He remained there for 30 years and was a member of or head of several different research sections. His work there centered on the presence or biological effects of chemical contaminants in fish or marine mammals or their habitat. When he retired, he was head of the "Arctic Contaminants Research" Section. He has contributed to the publication of over 100 scientific reports. Most of his work relevant to the North consisted of the lethal and sub-lethal toxicology of crude and refined petroleum oils, tainting of fish by oils, mercury in fish and beluga whales, and the use of sediment cores to reconstruct aspects of environmental history. He was also an adjunct professor at the University of Manitoba. He retired from DFO in 2001, and has been working part-time with North/South Consultants in Winnipeg. Recently he submitted manuscripts describing mercury in northern Canadian fish and in beluga whales, and is presently working on a contribution to the chapter on hydrocarbons for the Arctic Monitoring and Assessment Program report.

Dr. Brian Shuter earned his undergraduate and graduate degrees at the University of Toronto and received his Ph.D. in 1975. He joined the fisheries research section of the Ontario Ministry of Natural Resources in 1977 as a Research Scientist and continues to hold that position. He has been an Adjunct Professor at the University of Toronto since 1996. He has published extensively on the population biology of freshwater fish, particularly small mouth bass and lake trout, with a strong emphasis on thermal ecology and impacts of climate change.

Dr. Michael J. Hansen is an expert in fish population dynamics, with a special interest in restoration of lake trout in the Great Lakes and state-tribal co-management of walleye in northern Wisconsin inland lakes. He earned his B.S. degree from the University of Wisconsin – Stevens Point (Water Resources-Fisheries), his M.S. degree from Cornell University (Natural Resources – Fishery Science) and his Ph.D. degree from Michigan State University (Fisheries and Wildlife). He joined the faculty of the UWSP College of Natural Resources in fall 1996 as an Assistant Professor of Fisheries. He spent 4 years prior to college as a sonar technician with the U.S. Navy in San Diego, California (1972-1976), 3 years as an Associate Scientist with EA Engineering, Science & Technology in Lincoln, Nebraska (1981-1984), 6 years as the Great Lakes Sport Fishery Specialist with Wisconsin Department of Natural Resources in Madison, Wisconsin (1984-1990; during the last 3 years, he also served as Treaty Fishery Specialist) and 6 years as Chief of the Section of Resource Assessment and Fish Community Dynamics with the U.S. Department of the Interior's Great Lakes Science Center in Ann Arbor, Michigan (1990-1996).

Dr. Hansen has served as Co-Editor of the North American Journal of Fisheries Management since 1997, published numerous scientific publications, presented the results of his research at numerous state, regional, and national scientific conferences, received numerous grants for research, and trained many students, who now work for state, tribal, and federal agencies or are pursuing further training at academic institutions. Much of his research is in collaboration with the State of Wisconsin, on walleye stock assessment and fishery management of inland lakes, or through the University of Wisconsin's Sea Grant Institute, on lake trout stock assessment and fishery management in Lake Superior. He presently teaches introductory, advanced, and graduate courses on fishery science, fishery research, fishery management, and wildlife and fish population dynamics. His work with the Great Lakes Fishery Commission began with the Lake Superior Technical Committee, for which he served as Chair for 10 years, the Sterile-Male Sea Lamprey Task Force, for which he served as a member, the Larval Sea Lamprey Assessment Program Review team, for which he served as Chair, and the Board of Technical Experts, for which he presently serves as a member.

Dr. Michael Papst's research interests include Arctic Char ecology, resource co-management and marine larval fish ecology. He has a long term interest in the management of Arctic aquatic resources. Dr. Papst has worked for the Department of Fisheries and Oceans for twenty-seven years and is currently Division Manager of the Arctic Research Division of the Central and Arctic Region. He has a Honours B.Sc. from the University of Waterloo, a M.Sc. from York University and a Ph.D. (Zoology) from the University of Manitoba. He was appointed and served as a member of the Fisheries Joint Management Committee (FJMC) of the Inuvialuit Settlement Region by the Privy Council of Canada from 1990 to 1997. His current research efforts are focused on the study of marine larval fish communities along the Beaufort Sea shelf.

Dr. John Casselman is an Adjunct Professor in the Department of Biology at Queen's University, Kingston and Research Scientist Emeritus with the Applied Aquatic Research Branch, Ontario Ministry of Natural Resources, at the Glenora Fisheries Station, where he supervised the Lake Ontario Research Unit. He is also a Conjunct Professor at Trent University, Peterborough, in the Ecosystems Graduate Student Program. His graduate student colleagues work on projects across Canada, including the north.

Most recently John is collaborating in studies of the effects of impoundment on northern lake trout stocks and is a co-investigator on a U.S. National Science Foundation study of accurate age and growth determination of northern lake trout and population demographics. These studies are in Labrador, northern Quebec, and the Northern Territories.

John is particularly interested in the effects of climate and climate change on year-class strength, growth, and production of northern fish and also in their influence on invading species and the effects of invaders. He considers the management of trophy fisheries to be especially challenging and sees, in the assessment and management of northern lake trout, parallels with muskellunge. Catch-and-release mortality must be measured and minimized, and all forms of exploitation must be especially conservative. Education, communication, and collaboration are critical if the quality of northern fisheries is to be sustained. Northern lake trout are a unique and precious resource, presenting special management challenges, since they are very slow-growing, old-growth, climax populations.

From left to right: John Casselman, Brian Shuter, Dave Evans and Nigel Lester

8.2 Theme 1: Lake Trout Biology and Habitat

8.2.1 Thermal Niche and Dissolved Oxygen Requirements of Lake Trout with Reference to Fishery Yields in Changing Environments

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Introduction

Lake trout, *Salvelinus namaycush*, is a stenothermal species that inhabits relatively deep, cold lakes spanning the North American continent. Throughout its geographic range and especially in the more southern extensions lake trout are affected by climate change and the threat of hypoxia, both naturally occurring and associated with watershed disturbances caused by human activities. Southern populations have been identified as highly vulnerable to climate warming due to changing thermal and water chemistry regimes of lakes and associated loss of summer habitat and productive capacity (Magnuson et al. 1990, Schindler 1998, Schindler et al. 1996, Schindler and Gunn 2004). These factors are now poised to affect lake trout distribution and production across its entire range (Magnuson et al. 1997, Stefan et al. 2001, Shuter and Lester 2004). Forecasts of climatic change and impacts of human activity on the future sustainability of lake trout are driving the need for improved understanding of the thermal ecology and dissolved oxygen requirements of this species.

This paper describes the directive, limiting and controlling effects of temperature and dissolved oxygen on the biology of lake trout and demonstrates the influence of these factors on lake trout angling harvests. The objectives are to review and update the thermal niche and dissolved oxygen requirements of lake trout; to describe the effects of hypoxia on metabolism and power capacity of juvenile lake trout; to address the effects of hypoxia on recruitment of lake trout; and to assess the potential impact of climate change on lake trout summer habitat and angling fisheries.

Comparison of the fundamental and realized thermal niche reveals discrepancies that are central to understanding the habitat requirements, environmental constraints on productivity and critical conservation needs of this species. Preferred temperatures of yearling lake trout in the laboratory, 8-16 °C, correspond closely with the field distribution of adult lake trout, but not with the colder realized thermal niche of wild juveniles (Fig. 1).

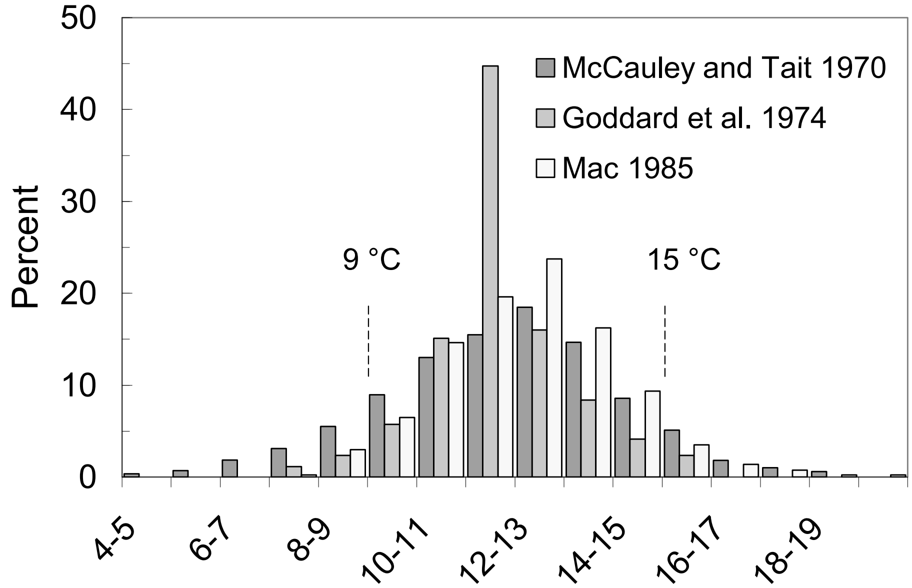

Figure 1. Thermal distribution of juvenile lake trout in laboratory experiments from the primary literature.

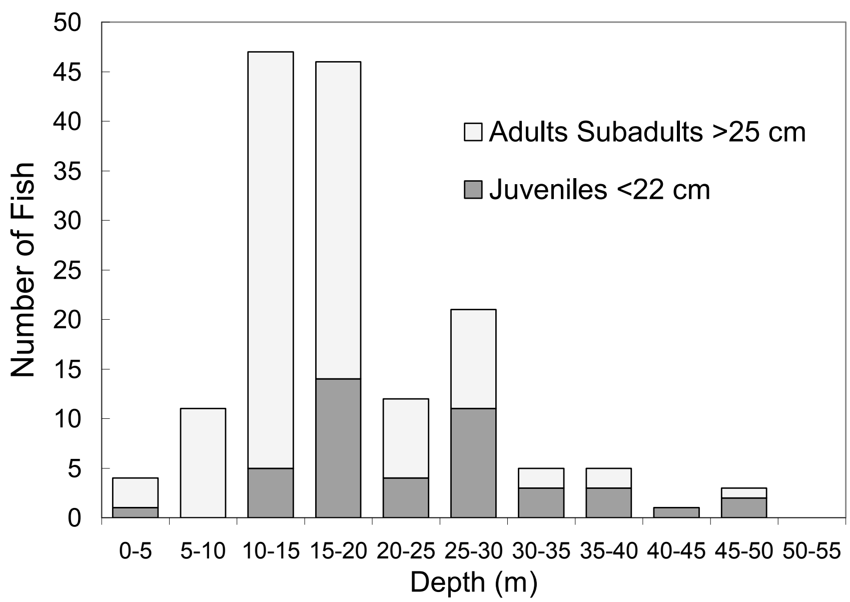

Figure 2. Depth of juvenile and adult lake trout captured in gill nets during July 7- August 24, 1947 in Louisa Lake, Ontario (from Martin 1952).

Early field studies (Martin 1952) suggested that juvenile lake trout segregate from adults during summer stratification (Fig. 2) and this has subsequently been confirmed (Fig. 3). ROV observations have provided direct visual confirmation of the deep distribution of juvenile lake trout during summer in Source and Victoria Lakes in south-central Ontario and Squeers Lake in north-western Ontario (Davis et al. 1997).

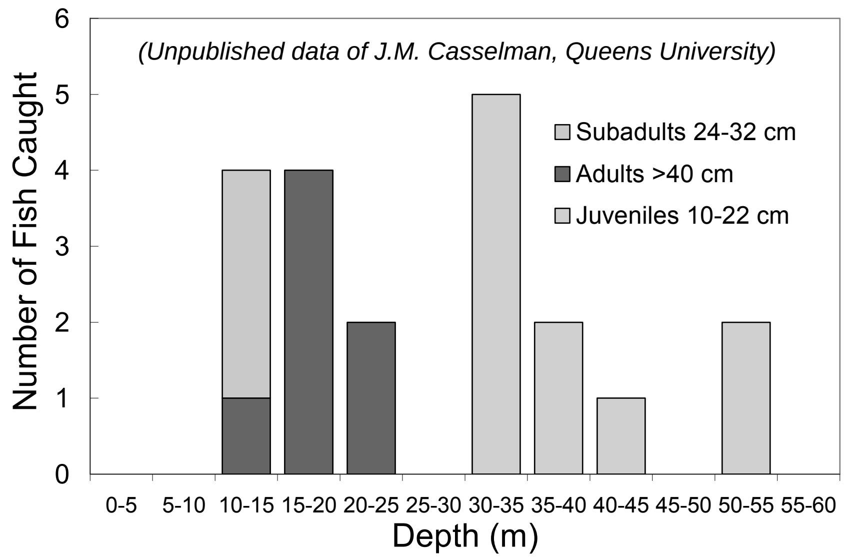

Figure 3. Depth of juvenile and adult lake trout in gill nets set at 5m depth intervals in South Wildcat Lake, Ontario during mid-summer (unpublished data, J.M. Casselman, Queens University, Kingston, ON).

In these lakes, juvenile lake trout were observed at a mean daytime depth of 23.4 m (mean range, 12.9 - 33.4 m) and mean temperature of 6.8 °C, (range 6.4 - 7.4, Davis 1997). Juvenile and young-of-the-year lake trout were always observed near the lake bottom and were most often encountered resting directly on the substrate (Davis 1997). Habitation of the deep water zone, low light conditions and close proximity to the profundal substrates would tend to minimize predation mortality by adults. In one lake juvenile lake trout moved upslope at night possibly to take advantage of marginally warmer temperatures (Davis 1997). Adult lake trout are more pelagic and generally distributed near the base of the thermocline (Fig. 4), but make excursions into water as warm as 20°C at night (Sellers et al. 1998), presumably to feed on cool- and warm-water prey (Fig. 5).

Dissolved oxygen also directs the vertical movements of lake trout, but observations of changes in distribution in response to low dissolved oxygen are relatively rare. The dissolved oxygen avoidance threshold in Lac la Ronge was about 3.6 - 4.3 mg L^{-1} (Martin and Olver 1980) and in Lake Simcoe was about 4 mg L^{-1} (Evans et al. 1996). In small lakes in northwestern Ontario 75-90% of lake trout were found at >6 mg L^{-1} and the daytime avoidance threshold appeared to be 2- 4 mg L^{-1} (Sellers et al. 1998). Dissolved oxygen concentrations of 1.4 - 2.9 mg L^{-1} were observed to be lethal in Swan Lake, Alberta (Martin and Olver 1980). Benthic habitation renders juvenile lake trout especially vulnerable to oxygen depletion within the hypolimnion. The mean dissolved oxygen concentration based on individual fish observations in three lakes was 7.4 mg L^{-1} (mean range 6.6 - 7.9 mg L^{-1}). In Squeers Lake juvenile trout opted to remain in sub-optimal dissolved oxygen conditions during the day (4.7 mg L^{-1}, varying from 3.2 - 5.2 mg L^{-1}) presumably to avoid predation under the highly transparent water conditions. In Source and Victoria lakes, under the cover of darkness, juvenile lake trout moved to depths that were 1-5 m shallower and about 1 °C warmer than day-time distributions, again suggesting the importance of light intensity to predator avoidance.

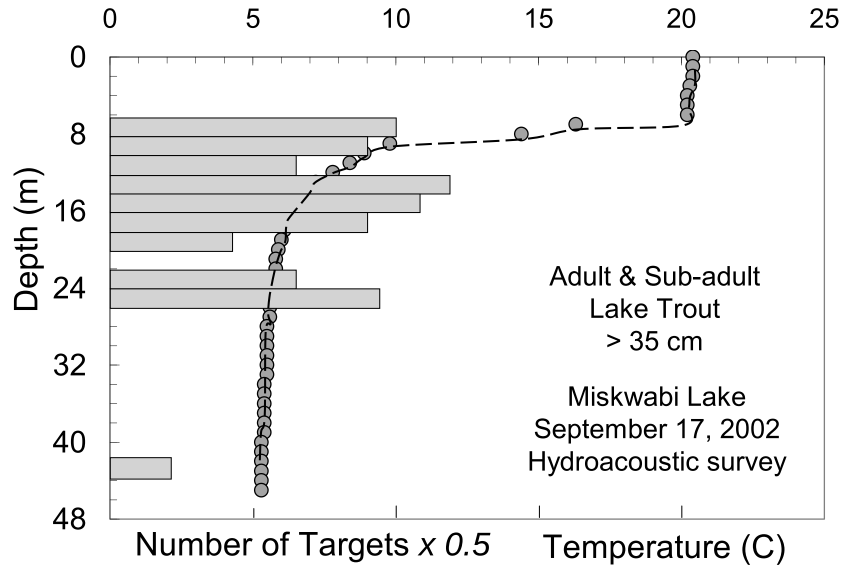

Figure 4. Depth distribution of adult and sub-adult lake trout in Miskwabi Lake, Ontario during mid-day in late summer 2002, based on systematic hydro-acoustic survey, with cross-lake transects perpendicular to the long axis of the lake and spaced at 100m intervals.

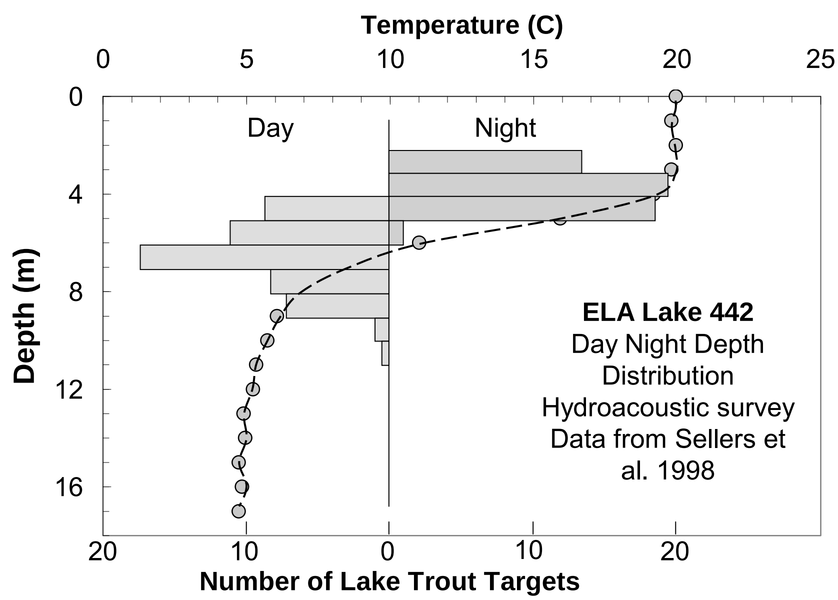

Figure 5. Temperature distribution of adult lake trout during the day and night In Lake 442, Experimental Lakes Area in northwestern Ontario (Sellers et al. 1998).

Lake trout appear to actively select the highest dissolved oxygen levels available and levels below 7 mg L^{-1} are generally avoided, although voluntary excursions into hypoxic waters < 4 mg L^{-1} do apparently occur at a low frequency (Fig.6).

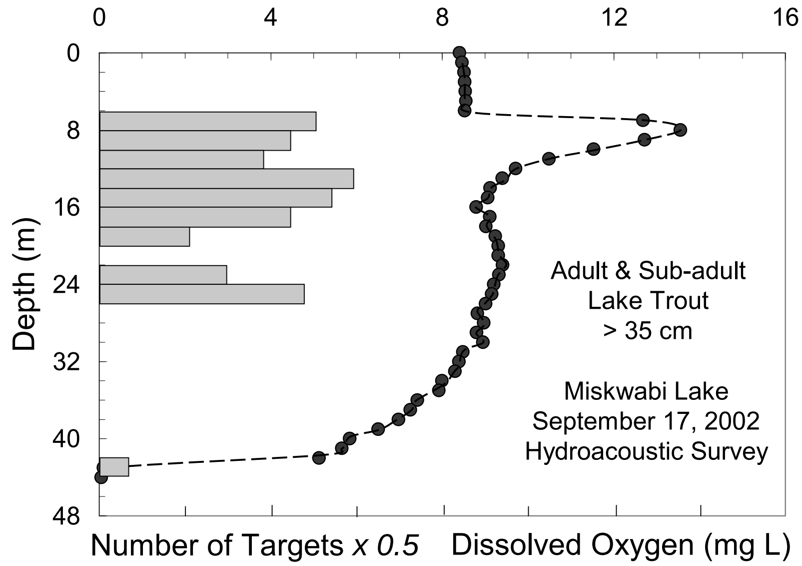

Figure 6. Distribution of adult and sub-adult lake trout targets in Miskwabi Lake in relation to dissolved oxygen during mid-day in late summer 2002, based on systematic hydro-acoustic survey.

Juvenile lake trout generally experience lower dissolved oxygen conditions than adults in southern lakes because of their habitation of greater depths. Segregation of juveniles from the adults is probably maintained by adult predation pressure (Evans et al. 1991; Evans and Willox 1991). The adult habitat is much less subject to hypoxia because it is near the base of the thermocline and is usually well oxygenated. The juveniles however are at high risk to hypoxia, being confined entirely to the hypolimnion in southern waters during summer months. This habitat routinely presents hypoxic conditions (Molot et al. 1992) and consequently is a potential bottleneck for lake trout recruitment because of the limiting and lethal effects of low dissolved oxygen on young-of-year and juvenile lake trout. At dissolved oxygen <7 mg·L^{-1} growth impairment would be expected (British Columbia Water Quality Guidelines 1997) and growth impairment and extent of recruitment failure would increase as dissolved oxygen conditions approach the incipient lethal concentration, which is 3 ± 0.2.mg L^{-1} at 4-12 °C (Evans 2005). At concentrations <3 mg·L^{-1} acute mortality and extinction would be expected.

Metabolic scope-for-activity, i.e., the difference between standard and active metabolic rates, defines the range of power capacity available for lake trout to perform work, i.e. to swim, capture prey, digest and assimilate food, and avoid predators. Maximum power capacity is attained at 12-20 °C and PO2 >120 mm Hg (Fig. 7). At ambient dissolved oxygen concentrations of 7, 5, and 3 mg·L-1 power capacity of juvenile lake trout at 4-8 °C was reduced by about 33, 67 and 100%, respectively.

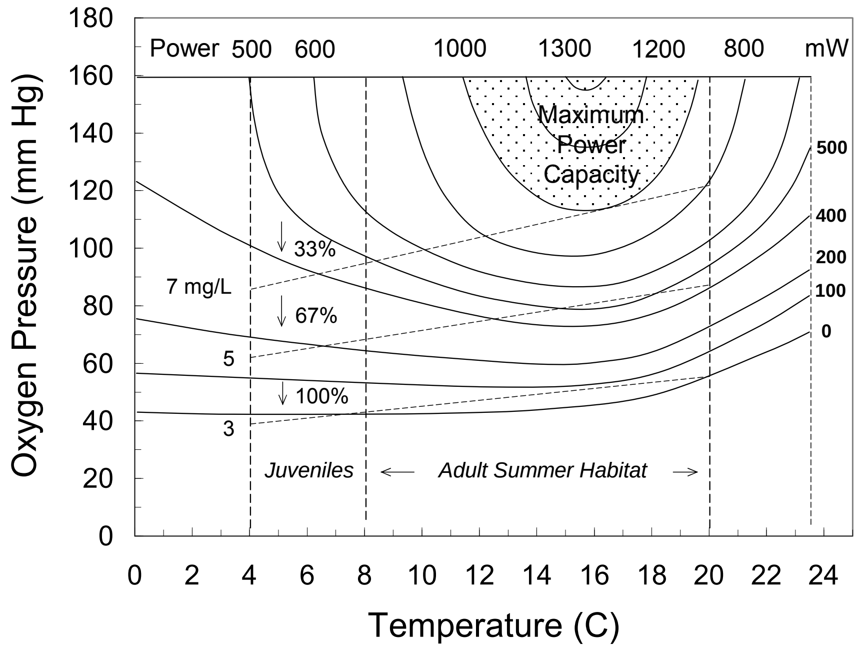

Figure 7. Power capacity of juvenile lake trout over the range of temperatures and partial pressures of oxygen potentially encountered in lakes across the species range.

An environment that provides for attainment of ¾ power capacity at dissolved oxygen concentrations >7 mg·L^{-1} appears to accommodate most daily life-support activities of lake trout, including maximal feeding and growth, and therefore should ensure the sustainability of lake trout populations with no net loss of productive capacity (Evans 2005 MS in review). The updated thermal ecology of lake trout, provided here, clearly reveals the critical importance of the juvenile habitat and the metabolic analysis (Fig. 7) illustrates the primary importance of hypoxia in the ecology of this species. Comparisons among lakes has confirmed the strong link between the degree of hypoxia and lake trout recruitment success, where excellent to good recruitment occurs at MVWHDO >7 mg·L^{-1} (Fig. 8).

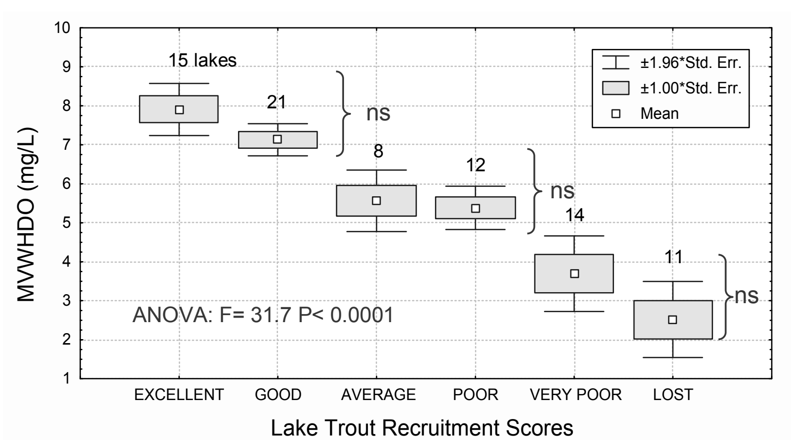

Figure 8. Mean volume-weighted hypolimnetic dissolved oxygen (MVWHDO) versus lake trout recruitment status of lake trout in Minden, Bancroft, and Mazinaw areas of south-central Ontario.

Assessment of climate trends in Ontario revealed that temperatures are rising, especially in winter and spring; winters have become shorter; snow pack is declining; duration of ice cover is shorter, especially on smaller lakes; and duration of thermal stratification of inland lakes is increasing. These climate changes affect the volume and hypolimnetic oxygen depletion rates of stratified lakes, especially near the southern limits of the lake trout range. Empirical evidence of a climate effect was evident in Harp Lake, Ontario where April air temperatures were weakly, negatively correlated with MVWHDO (Fig. 9).

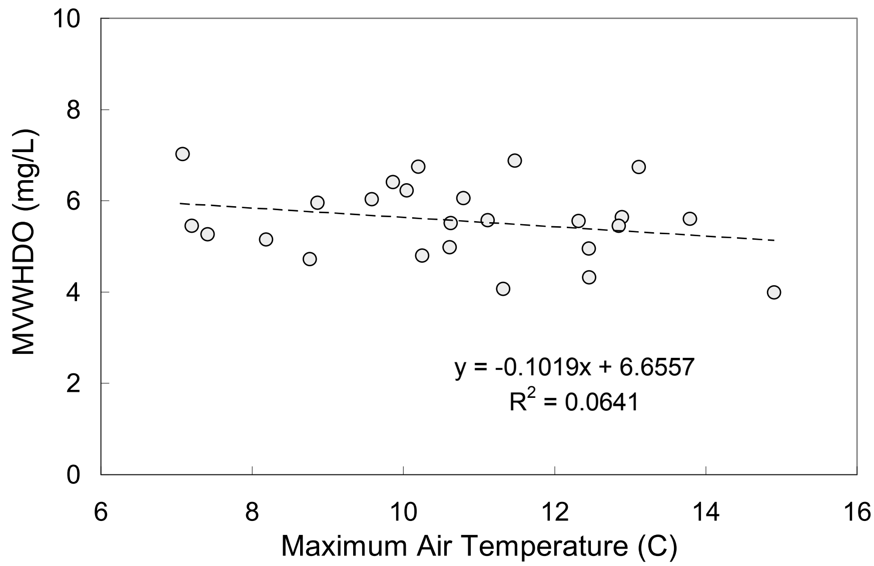

Figure 9. MVWHDO in Harp Lake, Ontario adjusted to August 31 and 6 ug/L phosphorus versus April mean, daily-maximum air temperature.

Comparisons among Ontario lakes revealed that sport fishery yields of lake trout during the 1970s and 80s were strongly correlated with hypolimnetic volume and oxygen content (Fig. 10), although the majority of the variation was explained by hypolimnetic volume. Based on Fig. 10, relatively small changes in hypolimnetic volume and availability of dissolved oxygen caused by climate change and/or other anthropogenic factors such as water level regulation would be expected to result in significant reductions in lake trout harvests (Table1).

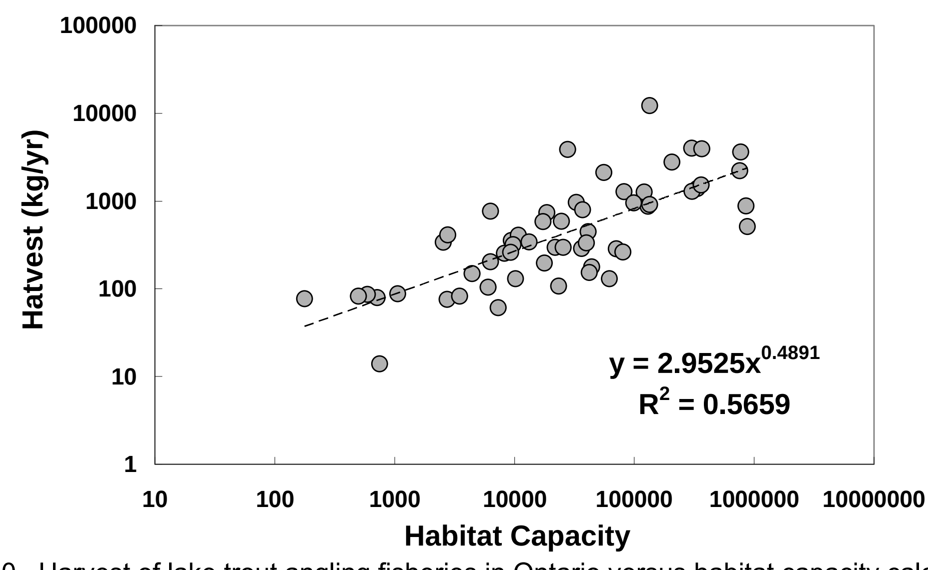

Figure 10. Harvest of lake trout angling fisheries in Ontario versus habitat capacity calculated as the product of hypolimnetic volume and late summer MVWHDO.

Table 1. Estimated loss of angling harvest of lake trout caused by a 25 percent reduction in summer habitat and a 1.5 mg L^{-1} loss of hypolimnetic dissolved oxygen in Ontario lakes. Observed Harvest1 = 6.5371 Area0.6535 is based on the actual harvest data (Fig. 10). Estimated Harvest2 = 4.7053 Area0.6653 is based on the equation from Fig, 10 and the simulated changes in habitat volume and dissolved oxygen ("anthropogenic effect").

Lake size (ha)	Obs. Harvest1 1970 and 1980's (kg yr^{-1})	Est. Harvest2 "Anthropogenic effect" (kg yr^{-1})	Lost Harvest (kg yr^{-1})	Estimated % Loss of harvest
100	132.6	100.7	31.9	24.1
250	241.2	185.3	55.9	23.2
500	379.5	293.9	85.6	22.6
1000	596.9	466.1	130.8	21.9

Climate change has the potential to directly affect the heat content, thermal structure and water chemistry of lakes, including the flux of phosphorus and dissolved organic carbon (Schindler 1998, Schindler and Gunn 2004). These factors together can have a significant negative impact on the quantity and quality of lake trout habitats (Dillon et al. 2003) and on their productive capacity through effects on lake trout recruitment, growth, and survival. Other factors including water withdrawal and water level regulation, removal of riparian forests and wetland disturbance will operate additively with climate impacts to further stress lake trout resources, especially near the southern boundaries of the species range.

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* * * * *

Discussion

David Evans: It seems that Arctic populations of lake trout behave differently than southern populations in the juveniles' use of the littoral zone. In the south they use the hypolimnion. At some point across the landscape there is a transition from littoral zone to hypolimnion.

That transition point is going to change, I think, and that will be a very interesting thing to track for those of you that have an opportunity. Northern populations seem to grow much more rapidly than southern populations, presumably one of the reasons being that the juveniles live in the very productive epilimnion in the North, have access to abundant food, whereas southern populations are very much confined to an impoverished hypolimnetic environment during summer, which is when their growth primarily occurs, and suboptimal temperature and oxygen conditions. So some very intriguing things here that I think are going to be quite important to explore further and will be important in understanding how lake trout populations respond in the North and the South.

Unidentified male speaker: Have you looked at the implications of that shorter winter on the biology of lake trout?

David Evans: No, I have not. Again, I think there are a number of energetic questions related to these kinds of changes that we are actually seeing now and, in fact, the natural experiments have been done. The inter-annual variation in mean annual temperatures, for example, at Muskoga Airport in the heart of southern Ontario is about eight degrees, which is a greater range of temperature variation inter-annually than we would expect to see with two-times-CO2. So the natural experiment is there to be able to try to put times series together to explore responses of different parts of the system; winter ecology energetics, summer ecology energetics.

So I think while we have been looking at the thermal ecology of lake trout for 50 or 60 years there are some very interesting questions emerging that we simply still do not have answers for and that I think are really critically important if we are going to have the rigorous science that will be able to present the case for adaptive actions in response to climate change and other stressors.

The data that I presented was data in a very old paper that was published by Gibson and Fry, Fred Fry. It was work that was done at Maple, which I think you will probably remember as the fisheries research lab there, and it was oxygen consumption measurements in typical standard respiration chambers of the day and an annualar swimming chamber of the day. I am working up that paper now; it is in revision for CJFAS.

Unidentified male speaker: Based on the results of your work, do you have any suggestions of where, when, and how we could be stocking lake trout, particularly to maximize survival?

David Evans: You are asking the wrong person this question. I am not a real fan of stocking, especially on top of wild stocks. I think this is not a good approach. One of the things we have tended to do in the past is stock on spawning shoals. It seemed like a good idea to put yearling lake trout on spawning shoals in the spring and quite possibly what has been happening is that they will be preying on the emerging fry. So that is not a good idea to do that, even though it seemed like a good idea at the time to put them on a shoal which they would hopefully come back to as adults and spawn on. It probably does not make that much difference where they are stocked as long as it is strategic in the sense that I have just been discussing, not on top of where you may have emerging young. But in general, the interaction between hatchery fish and wild fish is negative and the wild fish lose out, especially if there is high exploitation. I have a poster in the other room which is looking at the effect of stocking on wild stocks and we are seeing some very interesting, very rapid switches in the structure of those populations and the hypothesis is that the stocked fish actually have a direct effect on the recruitment of wild fish, a negative effect.

Unidentified Male speaker: You mentioned in one of your last slides that you were facing work on or looking at shoreline development. I was just wondering what direction that is taking?

David Evans: That is mainly related to the issue of cottage development and resort development in southern Ontario and the impacts of phosphorous loading on these systems. So I have been working on the habitat requirements of lake trout and the link to phosphorous inputs, the connection between phosphorous, chlorophyll and oxygen.

Chair
Ron Allen

Our next speaker is Dr. Lyle Lockhart. Dr. Lockhart is certainly no stranger to this part of the world – known across the Canadian territories for his work on contaminants. If anybody wants to know anything about mercury that is the first name that is going to come up. So it was quite a change for us when Dr. Lockhart retired from the DFO and we are glad to see he is still in the contaminant business and still active and able to be here and speak to us because he does have a wealth of experience and expertise.

8.3 Theme 2: Contaminants in Lake Trout

8.3.1 Mercury in Edible Muscle of Lake Trout from Sites in Northern Canada

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Introduction
Subsistence fishing has been an important source of food for Native People in northern Canada since prehistoric time. Measurements of the levels of mercury in edible muscle of northern fish have been undertaken for over three decades in efforts to evaluate the risks of consuming northern fish. This report summarizes the data obtained from lake trout (*Salvelinus namaycush*) from sites distributed from the Yukon to northern Quebec. The question being asked was essentially "Are the fish safe to eat?" The results have been used frequently to support decisions on fishing and consumption of fish. The results were sorted in several ways, into concentration ranges corresponding to human consumption guidelines, into political jurisdictions and into types of bedrock geology. Overall muscle tissue of lake trout, usually exceeded the subsistence consumption guideline of 0.2 μg g^{-1} total mercury and often exceeded the higher guideline of 0.5 μg g^{-1} total mercury for commercial sales of fish.

Several studies of mercury in northern fish have been conducted, usually with the objective of describing the levels in fish from a particular location of interest (e.g. Trout Lake, NT, Swiripa et al 1993; Hay and Slave rivers, NT, Grey et al. 1995; Yukon, Atkins Baker 1977;). Some of the accumulated results from these studies have been summarized in government reports (e.g. Desai-Greenaway and Price 1976; Muir et al. 1986; Environment Canada, 1979), but few of the results have appeared in the scientific literature.

Data were compiled for this presentation on lake trout from a larger set of data describing levels of mercury in several species. The more complete data are presented by Lockhart et al., 2005. In order to comment on levels in concentration ranges established for the protection of human health, the data were sorted into three ranges on figure 1 (Health and Welfare Canada 1979):

- Below 0.2 μg/g (unrestricted consumption),
- Between 0.2 and 0.5 μg/g (for subsistence consumption), and
- Above 0.5 μg/g. (for commercial sales)

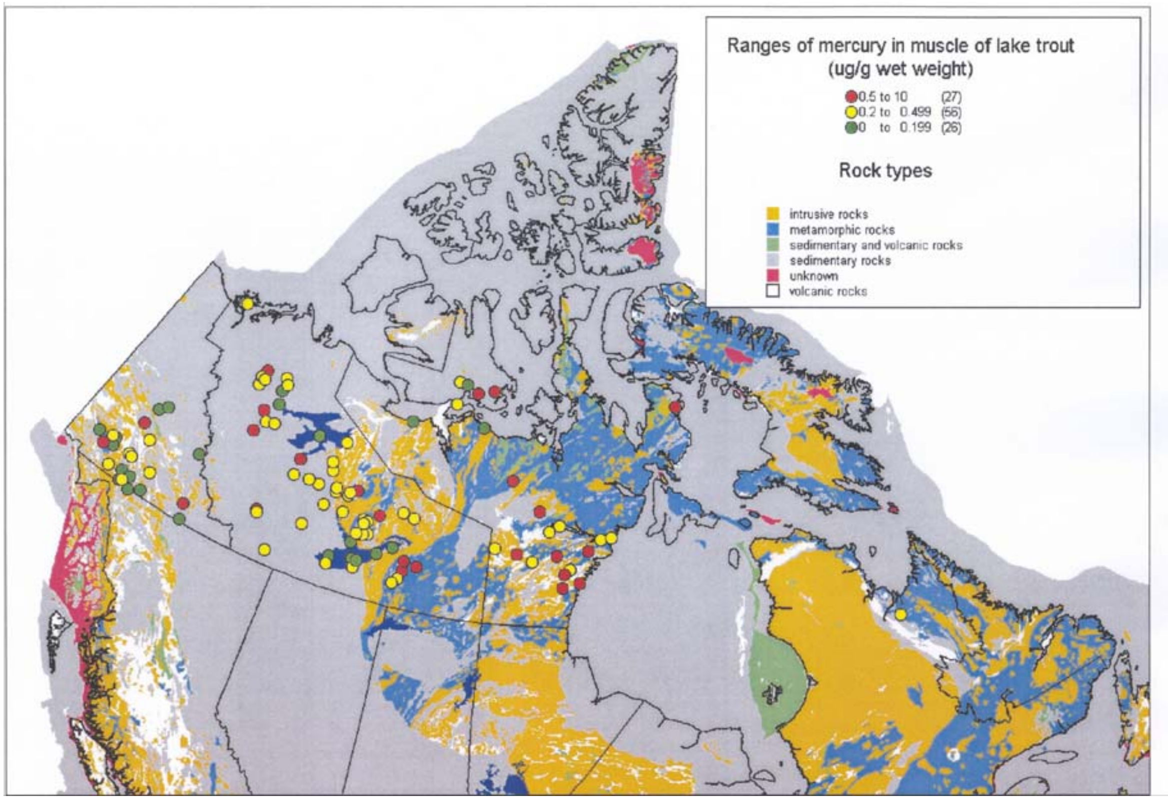

Figure 1. Map representation of mean levels of mercury in muscle of lake trout (µg g-1 wet weight). Green dots, mercury in the range below 0.2 µg g-1; yellow dots, mercury in the range between 0.2 and 0.5 µg g-1; red dots, mercury greater than 0.5 µg g-1.

Methods

Fish were usually obtained by gill netting and biological measurements recorded at the collection site. Usually a sub-sample of dorsal muscle was taken and frozen at the time of collection. On some occasions, whole fish were frozen and sent to the laboratory for sub-sampling there. Mercury was determined by wet digestion and cold vapour atomic absorption spectrophotometry using internal and external quality assurance procedures. Summary statistics and comparisons of means were calculated using SAS software on a personal computer. Since fish length was almost always correlated with mercury level an attempt was made to adjust the levels for differences in fish length. The natural logarithm of mercury was taken as the dependent variable and regressed on length as the independent variable. The regression line so calculated was used to calculate the expected level of mercury in a fish of approximately the average length of all the fish.

Results

Information on levels in muscle of lake trout was derived from the analysis of 1855 individual fish with an overall average level of 0.38 µg/g. Of the species sampled, only walleye (*Sander vitreus*) had had a higher average level of mercury. The results indicate a widespread problem with mercury in subsistence lake trout fisheries with the problem being most evident in Nunavut.

The questions explored were those of site-to-site variation within and among different political units, and the same using geological boundaries instead of territorial boundaries. Some sites had been sampled on more than one occasion and those offered opportunities to test for temporal changes.

Geographic variation by political boundaries

Initially the data were sorted into ranges corresponding to levels recommended for the protection of human health for locations in different territories. Table 1 shows the results of this type of sorting. For example, the overall mean level for the Yukon sites was 0.26 μg/g, the lowest among the political units. There were 22 sites represented from the Yukon and of these, 10 had mean levels in the lowest range of unrestricted consumption, 10 had mean levels in the middle range of limited subsistence consumption and only 2 had mean levels in the high range above limits for commercial sales. Figures for the Northwest Territory were slightly higher with a mean of 0.35 μg/g and a more even spread among the concentration ranges. Forty-nine sites were represented and 14 of these fell in the low range with 25 and 10 in the middle and high ranges respectively. The figures for Nunavut were the most ominous with the highest overall average of 0.47 μg/g, just below the limit for commercial sales. Only 5 of 22 from Nunavut fell in the low range with 10 in the middle range and 7 in the high range. With one collection only from Quebec, little can be said about the levels there. In terms of political boundaries then, the levels in lake trout appear to be highest in Nunavut.

Table 1. Numbers of length-adjusted means of levels of mercury in muscle found in each geographic region together with the averages of the means (± S.D.). (Giauque Lake excluded)

Species	Geographic region	Number of sites and mean ± S.D. in low range (green) (<0.2 ug g-1)	Number of sites and mean ± S.D in medium range (yellow) (between 0.2 and 0.5 ug g-1)	Number of sites and mean ± S.D in high range (red) (>0.5 ug g-1)	Total	Mean for all collections in geographic area ± S.D.
Lake trout	YT	10 (0.13 ± 0.03)	10 (0.32 ± 0.08)	2 (0.59)	22	0.26 ± 0.15
Lake trout	NT	14 (0.13 ± 0.04)	25 (0.29 ± 0.09)	10 (0.79 ± 0.36)	49	0.35 ± 0.29
Lake trout	NU	5 (0.15 ± 0.06)	10(0.37 ± 0.08)	7 (0.85 ± 0.23)	22	0.47 ± 0.31
Lake trout	QU	0	1 (0.37)	0	1	0.37
Total		29	46	19	94	

Giauque Lake was excluded because of very high levels in the fish as a result of historical use of mercury for extraction of gold from the Discovery mine there.

Geographic variation by geological boundaries

Geological maps are readily available and we used one published in CD format by the Geological Survey of Canada. The latitude and longitude coordinates of the collection sites were used to overlay the points on a geological map using MapInfo software on a personal computer. An example of this type of overlay is shown in Figure 1 in which the geological variable shown is the type of bedrock and the colours of the points indicate means in the three ranges: green for the low range, yellow for the middle range, and red for the high range. Of the 94 sites described, 68 were in sedimentary rock, 9 were in metamorphic rock, 11 were in intrusive rock and the remaining 6 were in volcanic rock (Table 2). The site means tended to be lowest in the sedimentary rock where the average of the means was 0.32 μg/g, as compared with 0.44 μg/g in metamorphic rock, 0.41 μg/g in intrusive rock and 0.59 μg/g in volcanic rock (Table 2). The distribution of means within each type showed a tendency to more sites in the high mercury range in the metamorphic, intrusive and volcanic rocks. The proportions of sites in the middle and high ranges were slightly higher in those rock types than in sedimentary rocks. This sort of distribution cannot be taken as evidence that the bedrock of a lake basin is responsible for the level of mercury found in the fish because the numbers of sites in 3 of the 4 rock types is so small. However, these data do serve as a starting point for future sampling to test such a hypothesis more rigorously. For example, future sampling might seek intentionally to include sites in different types of bedrock. If the bedrock type does play a role in regulating mercury in the fish, then questions of mechanisms will have to be tested.

Table 2. Numbers of length-adjusted means of levels of mercury in muscle found in concentration range within each type of bedrock with averages of the means and standard deviations in parentheses. (Giauque Lake excluded)					
Species	Bedrock type	Total sites in rock type	Sites with mean Hg <0.2 µg g-1	Sites with mean Hg between 0.2 and 0.5 µg g-1	Sites with mean Hg >0.5µg g-1
Lake trout	Sedimentary	68 (0.32 ± 0.25)	24 (0.14 ± 0.04)	33 (0.30 ± 0.09)	11 (0.77 ± 0.28)
Lake trout	Metamorphic	9 (0.44 ± 0.20)	1 (0.08)	5 (0.38 ± 0.07)	3 (0.65 ± 0.07)
Lake trout	Intrusive	11 (0.41 ± 0.22)	3 (0.14 ± 0.04)	5 (0.40 ± 0.08)	3 (0.68 ± 0.11)
Lake trout	Volcanic	6 (0.59 ± 0.56)	1 (0.16)	3 (0.28 ± 0.11)	2 (1.26 ± 0.44)
Totals		94 (0.36 ± 0.27)	29 (0.14 ± 0.04)	46 (0.32 ± 0.09)	19 (0.79 ± 0.29)

Temporal variation considered site by site

In view of differences among sites, temporal comparisons were attempted only in cases where samples were available from the same site on more than one occasion. The comparisons were made two at a time so that a site sampled on three occasions might provide two comparisons, the second against the first and the third against the second. The third possible comparison, the third against the first, was not made. Comparisons were made by analysis of covariance taking length as a covariate of mercury using the LSMEANS option of PROC GLM of SAS software. Over all the species analyzed, there were 167 instances in which two mean values for mercury could been compared for the same location. Of these, 34 indicated higher levels of mercury, 111 indicated no change, and 22 indicated lower levels. Considering lake trout only, 31comparisons were made with 4 suggesting increases, 4 suggesting decreases and 23 suggesting no change.

Lac Belot represents one the most convincing cases for increasing levels; good numbers of lake trout were obtained (19 in 1993 and 54 in 1999). The arithmetic mean levels of mercury were 0.135 ± 0.049 and 0.212 ± 0.075 µg g^{-1} in 1993 and 1999, respectively, and the fish lengths were almost exactly the same. The slopes of the two regressions did not differ and the effect of year was highly significant ($F=26.05$, $p<0.0001$). The length-adjusted least square means calculated by SAS were –0.905 (antilog 0.124 µg g^{-1}) in 1993 and –0.702 (antilog 0.199 µg g^{-1}) in 1999. The levels of mercury in lake trout from this lake were significantly higher in 1999 than in 1993.

Nonacho Lake, in contrast, represents a convincing case for declining levels. Lake trout obtained from Nonacho Lake in 1975 (N=8) had an arithmetic mean level of 1.06 µg $g^{-1}$and those sampled in 1986 (N=51) had a significantly lower mean level of 0.54 µg g^{-1}. The fish in 1986 were somewhat shorter than those in 1975 but the difference in length did not account for the decline in levels of mercury.

While there are many limitations on the use of these data for temporal trend analysis, they do not suggest a consistent regional trend of increasing or decreasing levels, although individual sites do sometimes suggest changes. Age data would improve the ability of the analysis to detect changes in levels of mercury and many of the more recent collections include information on fish ages. However, most of the older samples lack ages and the structures are no longer available from which ages could be determined. Future sampling, particularly of greater ranges in size classes and with ages determined, will improve the ability to discern any temporal trends at sites.

Summary

Mercury contamination remains a serious problem for lake trout throughout most of their range in northern Canada. Less than one third of lake trout collections had length-adjusted mean values for mercury less than 0.2 ug g^{-1}. The problem with mercury in lake trout was somewhat more severe within Nunavut where only 5 of 22 means fell in the lowest range. The problem in walleye is probably even more severe than it is in lake trout. There are suggestions, although not definitive evidence, that the bedrock setting of a lake may have an association with the levels of mercury in the fish. Lake trout from lakes in sedimentary rock tended to have somewhat lower levels of mercury than those from lakes in other types of rock.

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Discussion

<u>Unidentified male speaker</u>: Do you know what the half-life of mercury is? How it turns over?

<u>Lyle Lockhart</u>: It is about two years. We deliberately tried to do this experimentally a few years ago, like, about 30 years ago, by moving fish from a high mercury lake in north-western Ontario called Clay Lake to a low mercury lake in northern Manitoba called Hemming Lake, an experiment that was probably highly illegal. Then measuring the rate at which the level declined back to that in the new lake. If you plot the level on a log scale and it turned out to have a half-life of about two years; that was using northern pike.

<u>Dr. Evans</u>: Do you know if there is a systematic difference in the mercury content of the cheek muscle versus the dorsal muscle?

Lyle Lockhart: I cannot remember that, but I think all these data are dorsal muscle. When we have done previous experiments we have done a lot of dissection and measured it in all the different body organs. It seems to me that liver and kidney were high and, of course, those analyses are not done on most samples because the analyses are designed to answer the question whether the edible product on the shelf of a store is okay. So it is all done on muscle. We just standardized all our analyses using muscle. If I were going after a project to define levels of mercury maybe in a more scientific rather than a trade way, I probably would look at liver. As to cheek muscle, I cannot remember. I imagine we have that, but I cannot remember what it is. I do not think they would differ greatly, but I do not know.

Dr. Evans: The heads are readily available to request a sample and if you've been doing that, and we have not yet done that comparison.

Dr. Lockhart: You could probably develop a really simple relationship between the two. That is what they do with human blood and hair; they have a little equation which they can use to convert one into the other.

Chair
Lois Harwood

I have the pleasure this morning of introducing the third of our plenary speakers. This is Dr. Brian Shuter. I first met Brian in Whitehorse in 2002 and was very taken by both his and Dr. Lester's talks at that time. Dr. Shuter is a research scientist with the Ontario Ministry of Natural Resources and he is also an adjunct professor at the University of Toronto. I would like to welcome Dr. Shuter.

8.4 Theme 3: Co-Management Regimes & Harvesting

8.4.1 Lake Trout in the South and the North Part II: Growth and Sustainable Yields

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Note: this paper is a transcription of Dr. Shuter's talk presented at the meeting.

Thank you for your kind introduction. When we were talking – Lois, Nigel, and I – about what this talk should have in it, we were encouraged to take the approach we took in the Whitehorse meeting and extend it with a broader database. That is why the title of this talk is "South and North, Part II." "South and North, Part I" was in Whitehorse.

Three years ago in Whitehorse, Nigel and I put together a talk to look at the Ontario database based on 54 populations of lake trout where we had characterized some aspects of lake trout life history. We looked at how variable lake trout life history was in Ontario and tried to determine what environmental variables might be associated with that variation. At the end of that talk, we made an appeal for help to the audience, asking anyone who might have similar kinds of data to share these data sets with us so we could extend the range of this database. We would have a better understanding of how plastic the environmental variables were and what life history traits may be associated with that plasticity. We had a very good response from people and we now have a database that extends well beyond Ontario, and covers much of the distribution of the species across Canada. It consists of 120 populations and I am going to just give you a quick overview of what this database is telling us about lake trout life history, how variable this history is, and talk a little bit about the implications that this variation might have for sustainable harvests.

We have expanded the database from Ontario, and have added information from Quebec, British Columbia, the Yukon, the Northwest Territories, and Nunavut. Many people have helped: Susan Thompson (Yukon), George Low (NT), Nick Baccante (BC), Jim Reist (NT), and Daniel Nadeau (Quebec) are just a few of the people who have been really helpful in supporting this effort.

We have tried to summarize the life history of lake trout in two ways. First, we looked at the timing of the primary stages of life: age at sexual maturity and life span. Second, we looked at lifetime growth patterns and we summarized these in two quantities: growth rate prior to sexual maturity and maximum adult size. What I am going to talk about is the variation from the Canadian south to north in age at maturity, life span, growth rate prior to maturity, and maximum adult size. We found substantial variability in this geographic range.

We looked at the two timing metrics. These are age-at-maturity and total life span. All ages were based on otoliths. There was a five-fold variation in age-at-maturity starting at age three or four. We had one population that had an estimated age-at-maturity of two years. There were also three to four with age-at-maturity of 13 to 14 years. For total lifespan, we found a full four-fold variation from around age 10 to around 45, although the maximum age that we have documented in our database is 63 years. We included samples for populations where at least 100 fish were sampled for comparing maximum age in the populations.

Growth rate prior to maturity had a four-fold variation. If we looked at maximum adult size, there was three-fold variation from about 35 cm to a little over 1m. There was a hint of bimodality. When you examine all the data, they tend to confirm a bimodal pattern and I think Kim Howland, who is going to speak somewhere later today, will give you some examples of a lake where you see two growth forms living together in a single place.

A question that is interesting in principle, I think, and has been alluded to in a number of the talks that we have had at this meeting is how variable or how different are populations in the south and in the north? Are they different at all? Is there any association between local climate and some aspects of the life history of the animal? With our database we can address this question quantitatively and directly to get a sense of what the answer may be. What we see is that yes, there are some associations with local climate. There is a decline from North to South in age-at-maturity and observed total life span and increased mean annual air temperature where populations are located.

We found that the growth rate prior to maturity progressively increased as latitude decreased. This is saying that in the North, growth rates prior to maturity are lower than in the South. However, if we look at maximum adult size, there is no association with climate. This is basically saying that in the South and in the North we see small adults and we see large adults.

Of our four metrics, three are associated with climate and one is not associated with climate. What we can see in the data set at this point is that as you move from population to population within the scope of where lake trout live, you see very different life histories. You see fish that grow slowly, fish that grow quickly, fish that mature early, fish that mature late, fish that live for a very long time, and fish that live for a short time. At least some of this variation is associated with climate. Now, this is a fairly broad overview of the informational content of this database. Jenni McDermid, who is a doctoral student at the University of Toronto, has been analyzing these data using more sophisticated statistical approaches than what I have been showing.

We do not have a lot of harvest data in the database and we certainly do not have very much of what one could call sustainable harvest data. If you are thinking of sustainable harvest as sustainable yields, the simple conceptual model of how this works is that if you have a population that you exploit at a fixed rate for a long period of time, you get a constant yield from it. If you fish too hard you will extirpate it. If you fish with an intensity that lies somewhere within a 'safe range', you will have over the long term a constant sustainable harvest that can be maintained by the population. To try and get an estimate of what a sustainable harvest is, ideally one needs a long time series of harvest data and within that time series you need a period where the harvest levels seem to be relatively constant so that it is reasonable to apply the term sustainable. In Ontario, we have a few time series that meet these criteria, but not very many. I think we have about 10 or 12.

We do not have any data of this kind in our database from the north, so in the absence of data we can try to speculate or perhaps guess a little bit about what equivalent 'northern' data might look like. What would a reasonable sustainable yield distribution look like in the north based on what we know in the south? We know that growth rates decrease as you go south to north. So, if we accept this premise, the amount of biomass that you can remove from a population on an annual basis, if it is going to be sustainable, has to be somehow tuned to the amount of new biomass that is accumulating within the population. If we further assume the rate at which a population is able to accumulate new biomass is indicated by growth rate, then it is not unreasonable to us that sustainable yields will be related to population growth rates. We know from our life history database that growth rates of populations generally decrease as we go from south to north. If we look within our life history database and characterize populations as belonging to the south – Quebec and Ontario – or belonging to the north – Yukon, Northwest Territories, and Nunavut – we have this difference in mean annual climate. Basically, in the South we have a mean annual air temperature of 3.2° C which we can assume is associated with the yield distribution from the South, and in the North – Yukon, Nunavut and the Northwest Territories – we have a mean annual air temperature of -7 C. If that is the difference in climate between the south and the north, and we have some idea of sustainable yields in the south, we can ask how growth rates and timing of life processes change as we move from this warm climate to this cooler climate. Based on regression relationships, age-at-maturity increases by roughly 50 percent from the south to the north. Lifespan increases by roughly 50 percent and mean adult size does not change at all. A simple interpretation of this is that overall adult growth is lower in the north than in the south and if we look at immature growth rates they are definitely lower in the north than in the south by about a third. The pre-maturation growth rate drops by a third and the time to get to an adult size for maturity approximately doubles when based on these rough figures. It is perhaps not unreasonable to suggest that a conservative estimate of the yield distribution for northern populations could be obtained simply by halving the yield values exhibited by what we know about that distribution in the South. This is a preliminary guess at what a sustainable yield distribution for the North might look like based on our ideas of sustainable yield distributions in the south and the apparent association between life history characters and climate that we see in the life history database. A mean value of 0.74 kg ha^{-1} y^{-1} occurs in the south and a mean value of 0.37 kg ha^{-1} y^{-1} would occur in the north. One would want to be cautious about taking yield estimates and management rules that are founded on the biology of southern populations and transferring them directly to northern populations. It is likely that some other adjustments should be made for these climatic trends that we see across the distribution of this species.

If you accept some of the arguments that led us to the idea of reducing the average sustainable yields by about a half as you move from south to north, we are still left with a really interesting problem: within the south and within my revised northern distribution, the variation amongst populations in our estimates of sustainable yields is substantial, and in those previous climate graphs you saw that within a climatic region there is a lot of variation in the life history characters of populations.

The next question that arises from this, is what other aspects of the environment might be associated with this variation? In the south, the size of a lake is strongly associated with some life history characters. Here we are looking at maximum adult size - the life history character that was not associated with climate. Within the southern climatic region, this exhibits a strong positive association with lake area, and within the southern climatic region, harvest per ha (i.e. yield) exhibits a strong negative association with lake area. Basically, you have larger adult sizes in large lakes and lower sustainable yields (harvest/ha).

Why is lake size important in the south? There are many hypotheses to explain this, but few data to support these hypotheses. Is lake size important in the north? We do not know at this time. The data sets are not extensive enough in the north to address this question. To really understand more about this variability within a climatic region and to understand more about the variability that is driven by climatic differences, we need an expanded comparative database. We need to go from “Lake trout North and South, Part II” to “Lake trout North and South, Part III.”

I am going to end this talk in the same way that I did in 2002. Send us your data. Be part of the 2007 update. We need more data; there are some big holes that we would really like to fill. We would like to make this an international database, not just a national database. We have had tremendous cooperation from the people in California where there are five lake trout populations. They will be included on our database shortly. We would like to get some data from Alaska and from the centre of Canada. Some additional information from Alberta, Saskatchewan, and Manitoba would be great. We are hoping to get some yield data from Quebec and certainly if there are harvest time series that meet the criteria of long and relatively consistent harvest, we would like to expand the life history database to have a harvest database. I would like to end this talk with this appeal and we will probably be bugging everybody who has attended this conference about this after the conference ends. I hope that you might feel motivated to help us with this project, based on what seems to be quite interesting results from the new expanded database that we have developed between 2002 and 2005.

I would like thank all the people and organizations who contributed to this effort. Our intention ultimately is to try and have the database available on a website hosted at the University of Toronto and perhaps in a year or two we will have a preliminary version of it on-line. Thank you for your attention.

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Discussion

Unidentified Male Speaker: So where did Lake Superior fall out in your analysis?

Dr. Shuter: The Great Lakes were excluded from our analyses

Unidentified Male Speaker: So that exclusion of Lake Superor was because…?

Dr. Shuter: It is too big.

Unidentified Male Speaker: It's too big?

Dr. Shuter: Well, it has too many forms of lake trout. We do not have a protocol that will let us deal with a two-form question.

Unidentified Male Speaker: I am reluctant to ask this, to challenge some of your analyses. I do like your conclusions for the north and your advice, but you talk about individual roles played in the analysis of sustainable yield. If I were fishing a population really hard, so that the growth rates were being pushed to their maximum and then I analyze that population using the model you presented today, I might conclude that this is a sustainable yield when this is not true.

Dr. Shuter: Yes, that is true.

Unidentified Male Speaker: So I have the discomfort with that the analysis.

Dr. Shuter: I think ideally the data sets will become deep enough that you will be able to detect the overexploition.

Chair
Lois Harwood

Our next speaker is Dr. Michael Hansen. He is an expert in fish population dynamics and has a special interest in lake trout in the Laurentian Great Lakes. He is a professor of fisheries in the College of Natural Resources at the University of Wisconsin – Stevens Point.

8.5 Theme 4: Stock Assessment

8.5.1 Lake Trout Stock Assessment: From Survey Design to Population Models

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Introduction
Lake trout are slow-growing, late-maturing, and long-lived, so are vulnerable to recruitment over-fishing. The decline and near extirpation of lake trout stocks in the Laurentian Great Lakes, the largest lakes in which lake trout are native, serves as historical proof that the species is susceptible to recruitment over-fishing. Lake trout were sequentially over-fished in Lake Huron, Lake Michigan, and Lake Superior from the 1800s through the 1950s, prior to the appearance of the sea lamprey (Hansen 1999). During the period of stock collapse, fisheries were increasingly efficient in their pursuit and capture of lake trout, through innovations in fishing technology.

Stock assessment must be designed to detect recruitment over-fishing and to estimate the harvestable surplus. Stock assessments are most powerful when they integrate fishery independent and fishery dependent survey types. The survey design must account for the spatial scale of the aquatic ecosystem, such that large lakes should be monitored annually and small lakes should be monitored extensively across the spatial scale of the set of lakes. Within each lake, regardless of the spatial scale, the sampling design must employ index or random sampling to properly estimate variance of the estimated statistic. Herein, I discuss each of these elements of assessment programs for lake trout in North America.

Survey Types
Stock assessment is more powerful if both fishery-dependent and fishery-independent surveys are employed. Fishery dependent surveys provide a subjective index of fishery attributes, so fishery attributes (effort and catch) must accurately reflect fishing locations. However, the accuracy of reporting in fishery dependent surveys is muddled by external factors (IRS, mistrust of management agency, etc.). For example, in Lake Superior, changes in gear and fishing locations helped to mask underlying changes in lake trout stock density during the period of stock collapse (Wilberg et al. 2004). To reduce such bias, agencies must incorporate on-board monitoring to provide objective feedback on accuracy.

In contrast to fishery dependent surveys, fishery independent surveys provide an objective index of stock status. Fishery independent surveys must therefore not target sampling stations, whether sampling stations are fixed or random, and must not target areas of high catch/effort. If fishery independent surveys are prosecuted objectively, then catch/effort will reflect underlying trends in stock density and abundance. For example, fishery-independent surveys were corrected for changes in fishery attributes and then blended with fishery-dependent surveys to reconstruct the history of stock collapse and recovery during 1929–1999 (Wilberg et al. 2003).
Sampling Designs

Assessment programs are fundamentally different in large versus small lakes. The spatial scale of the assessment program must match the spatial dynamics of the stock or stocks. In large lakes, multiple stocks likely exist that each requires assessment. In small lakes, stock structure is more discrete, but number of stocks is large. The temporal scale of the stock assessment program must relate to value of the stock or stocks. For large lakes, uniqueness of each system requires that assessments be annual. In contrast, for small lakes, the number of stocks requires periodic, not annual stock assessment.

In large lakes, lake trout stocks are unique, so are generally not sampled randomly. In large lakes, assessments should be distributed to sample the full range of each stock. In addition, assessments should be conducted annually because costs are justified by the value of stocks. For example, in Lake Superior, index sampling is used within management areas, each of which is treated as a distinct stock, based on estimates of lake trout movement from tagging studies (Kapuscinski et al. 2005). Sampling sites within areas are at fixed index locations. Annual sampling is used at all index sites in each management area and sites are distributed throughout the depth range of lean lake trout (< 40 fathoms; Hansen 1997).

In small, spatially-disbursed lakes, lake trout stocks are less unique individually, so are randomly sampled. Assessments must be distributed randomly among the lakes occupied by the species. Assessments must be periodic, because costs preclude annual surveys of all lakes. For example, in Ontario inland lakes, a two-stage sampling design is used to sample watersheds as primary sampling units and lakes within watersheds as secondary sampling units (Lester and Dunlop 2004). About 10% of all lakes are sampled in any year and the design is used over a 5-year rotation. Within each 5-year rotation, some lakes are selected for annual surveys and some new lakes are selected randomly for sampling each year.

Sampling Methods

In large lakes, where unique and highly valued lake trout stocks exist, sampling methods are often focused on standardized index sampling. For example, in Lake Superior, adult lake trout abundance is indexed from catches during spring in 114-mm stretch-measure gillnets, corrected for soak time (Hansen et al. 1998). Lake trout recruitment is indexed from catches during summer in 51– and 64–mm stretch-measure gillnets. For both surveys, age composition is estimated from sub-samples of otoliths and annual mortality is then estimated from the age composition (Hansen et al. 1997). Commercial fishing effort and harvest is monitored through mandatory reporting and on-board monitoring. Recreational fishing effort and harvest is monitored through creel surveys of recreational fishing effort (counts) and catch rates (interviews).

In small lakes, where lake trout stocks are widely distributed across a landscape, sampling methods are often focused on randomly selected lakes within the population of lakes. For example, in Ontario inland lakes, MSY targets are set from data on total dissolved solids (TDS) and lake surface area (Shuter et al. 1998). On selected lakes, lake trout abundance and mortality is indexed using Spring Littoral Index Netting (SLIN) with small-mesh (38, 51, and 64 mm) gillnets composed of six panels (2.6 x 15.2 m), soaked for a short-duration (90-minute) during daylight, distributed in a spatially random manner in the littoral zone of each lake, and set perpendicular to shore (3–15 m depths). Angling effort, as a measure of fishing stress, is indexed using aerial surveys to take advantage of lakes that are clustered within watersheds. Flights are clustered during high-activity periods.

Modeling Approaches

In large lakes, where unique and highly valued lake trout stocks are monitored annually through fishery-dependent and fishery-independent surveys, stocks are modeled using age-structured approaches. For example, in Lake Superior, statistical catch-age models are used to estimate adult abundance, recruitment, and mortality from harvest at age in commercial and recreational fisheries and catch/effort at age in large-mesh and small-mesh gillnet assessment fisheries (Linton 2002). A projection model is then used to estimate future harvest quotas from trends in recruitment and abundance at age, with fixed natural mortality (including sea lamprey mortality). The rate of fishing mortality is set at a level that does not induce a population decline and harvest quotas are then estimated from abundance using Baranov's equation.

In small lakes, where spatially disbursed lake trout stocks are randomly selected for sampling, stocks are modeled using indirect methods. For example, in Ontario inland lakes, yield in lakes of differing sizes is modeled as a function of fishing mortality and fishing effort (Lester et al. 2003). Yield curves are asymmetrical because catchability is inversely related to lake trout density. Stock status in randomly selected lakes is judged from plots of standardized lake trout catch/effort against angling effort. Lake trout stocks are judged to be "healthy" if lake trout catch/effort is high and angling effort is low, whereas lake trout stocks are judged to be "overexploited" if lake trout catch/effort is low and angling effort is high. Lake trout stocks are judged to be in the early stages of overexploitation if lake trout catch/effort and angling effort are both high, whereas lake trout stocks are judged to be in the early stages of recovery if lake trout catch/effort and angling effort are both low.

Management Outcomes

Based on the results of stock assessment modeling, fishery managers must develop and implement appropriate responses to stock indices, such as input controls on fishing effort or output controls on harvest quotas. In Lake Superior, for example, stock assessment modeling suggested that even modest fishing mortality induced lake trout stock declines, so a conservative fishing mortality rate of $F = 0.14$ was adopted. State and tribal fishery managers then adopted harvest quotas that were commensurate with the accepted fishing mortality rate. In Ontario inland lakes, stock assessment modeling suggested that lake trout stocks in many lakes were overexploited, though the initial use of the modeling approach was based on lakes that were not selected randomly. If future evaluations of randomly selected lakes are similar, then Ontario fishery managers will need to consider reductions in fishing effort or creel limits to reduce exploitation stress.

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Chair
Ron Allen

To start this session, we are going to have Dr. Michael Papst speak. I have known Mike for a long time. He has lots of history here in the north. Twenty years ago we referred to him as one of the snowbirds. He would come up in the summer, do some work, and disappear. Then he got into the co-management aspect of things up here as well and he has certainly spent a lot of time and effort over the years in this part of the world and he does know his fish. I am pleased to have Dr. Papst come and give the first talk in this session.

8.6 Theme 5: Land Use Activities and Climate Change Effects on Lake Trout and their Habitats

8.6.1 Past, Present and Future Stressors on Lake Trout and their Habitats in the North

Dr. Michael Papst
Arctic Science, Dept. of Fisheries and Oceans, Winnipeg, Manitoba

My presentation will focus on small Arctic lakes, not on the Great Lakes of the Arctic. One of the interesting things about these small lakes is that they are in the front line of man's impact in the Arctic. These small lakes are the water source for mineral exploration camps, are impacted by road construction and maintenance, and are located above some of the most valuable mineral resources of the area. These lakes will be in the path of almost any industrial development that will occur in the Arctic, whether the developments are gas pipelines or diamond mines. As some of you already know, the richest areas for diamond mining are directly beneath some of these small Arctic lakes. It is not hard to forecast that some of these small systems are going to be the lakes most impacted by this industry and by climate change. Although these lakes have small surface areas and volumes, they often have substantial lake trout populations.

I am not the first person to examine this subject. I would like to draw attention to some of the earlier work of Lionel Johnson. His 1976 study of the ecology of unexploited lake trout populations in the Arctic is an excellent review (Johnson 1976). I mentioned this to Lionel earlier and he said, "oh, but the graphics are terrible". Never the less, this paper has really stood the test of time. It was very informative for me when I was asked to give this summary.

Some of the early research of M. C. Healey on the dynamics of exploited lake trout populations provides important insights into the ecology of Arctic lake trout populations. I have used Healey's (1978) paper on the dynamics of exploited lake trout populations. However, there are a number of related technical and data reports (see Healey and Kling 1975) and some unpublished works that are excellent sources of information. Most of this early work focused on fisheries development and on the apparent inability of lake trout populations to sustain high harvest rates. Today, concerns about fish populations in these small Arctic lakes has shifted from commercial fishing to issues like water drawdown, "fish-out", "salvage fishing", "complete draining of lakes", and "compensation for population loss". The impacts have shifted since 1976, but much of the underlying biology remains the same.

If we take a look at the Arctic region of Canada, we see that there is enormous variation in the size of lakes that contain lake trout populations. We find lake trout in bodies of water varying from the Arctic great lakes, like Great Bear Lake, to lakes that are often considered pond size. The Arctic climate is severe in its intensity and duration. A long harsh winter is followed by a short open-water season. Overall productivity in small Arctic lakes is generally considered to be low. Often, however, this low productivity supports a relatively high biomass of fish (Kalff and Welch 1974, Johnson 1976).

I began this review with a somewhat forgotten data set known as the ALUR Mapping Project. ALUR stood for “Arctic Land Use Resource Mapping Program”. This is an excellent data set. I suggest anybody who is interested in looking at the Arctic region, lake trout, and other fishes should take a close look at this data set. There is a series of reports and the quality of the field work was first rate for a general survey. The ALUR program covered very large areas in the Arctic, employed multi-mesh gill nets, and consistently used 12 six-hour sets for survey sampling. I will concentrate on the results listed in ALUR Report Number 11, where the results of the 1978 survey are described (MacDonald and Fudge 1979). This single survey covered an area of 312,000 km^2 where 11 fish species occurred, and summarized data for approximately 1,200 fish. Lake trout were approximately 27% of the total catch and lake whitefish were 20%. What is even more remarkable is lake trout were 60% of the total biomass of fishes that were caught. Given the large geographical area covered by this survey, the importance of lake trout to the Arctic aquatic ecosystem is clearly evident.

One important aspect of the ALUR data set was that almost all the fish were aged; such a complete analysis is rare amongst large-scale fisheries surveys in the Arctic. The presence of aging data allows the development of a summary growth curve or length-at-age distribution for lake trout across a large portion of the central Arctic. A significant number of lake trout were in the 10 to 20 year age range. However, a small number of fish as old as 40 years were also present. This age composition is similar to that reported by Healey (1978).

The next data set I examined was collected from the Chitty Lakes. This group of lakes has been designated a fisheries research preserve and was studied as part of a cropping study to examine sustainable harvesting of lake whitefish. Lake trout were present in all of the lakes studied during the lake whitefish harvesting, and also present in Baptiste Lake, the control lake for this 18 year study. Eric Gyselman of the Department of Fisheries and Oceans provided the results of this monitoring to me for this presentation.

Baptiste Lake has a surface area of 365 ha, and a mean depth of approximately 11 to 12 m. It is ice-covered from October to May during winter, and sometimes the ice-cover continues into June. It has an average annual temperature of 5.5°C and is stratified during the summer months. This stratification breaks down in September, and by October 1st the water temperature is 4°C or lower. These data provide an overview of the environment where lake trout live throughout much of the central Arctic.

The lengths-at-age data for lake trout from Baptiste Lake and from the ALUR survey were similar (Figure 1). Both growth curves exhibited high variation in length-at-age for fish 12 years or younger. This is pretty typical for many Arctic lakes. There were two distinct length groups in the population. The majority of the fish were in the range from about 500 to 600mm and a smaller group occurred at about 300 mm (Figure 2). This bimodal length distribution is typical of many populations in the Canadian north.

Recent diamond mine development in the Northwest Territories has provided an opportunity to compare results from these earlier fisheries studies to data from “fish-outs” where an effort was made to remove all the fish from a lake prior to draining. As a biologist, it is hard not to consider a “fish-out” as the ultimate impact man can have on a small Arctic lake. However, this type of impact does provide us with an opportunity to look at a range of degrees of sampling: the ALUR program could be considered a reconnaissance type sample, the Chitty lake program an intensive scientific sampling, and the diamond mine ”fish-out” a nearly complete sampling of the fish community.

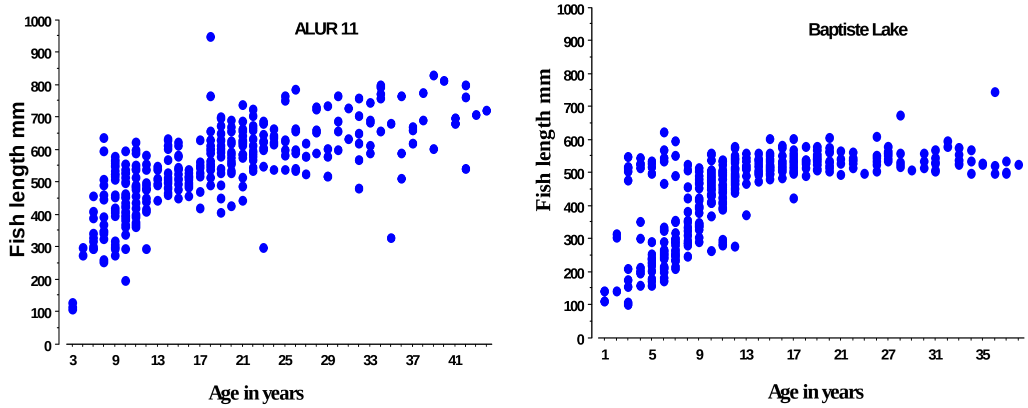

Figure 1. Length at age for lake trout from the ALUR study report 11 and the Baptiste Lake study fish community.

What I have done for this presentation is to take one dataset from a “fish-out”. It is not important which lake this was or what mine. The thing to remember here is that an effort was made to remove all the fish from the lake. The morphometry of this “fish-out” lake was similar to the lakes studied in the Chitty lake program:

- surface area “fish-out” lake 614ha versus Baptiste 365ha,
- maximum depth “fish-out” lake 32m versus Baptiste 32m,
- mean depth “fish-out” lake 7.4m versus Baptiste 11.7m, and
- most abundant species both lakes: lake trout.

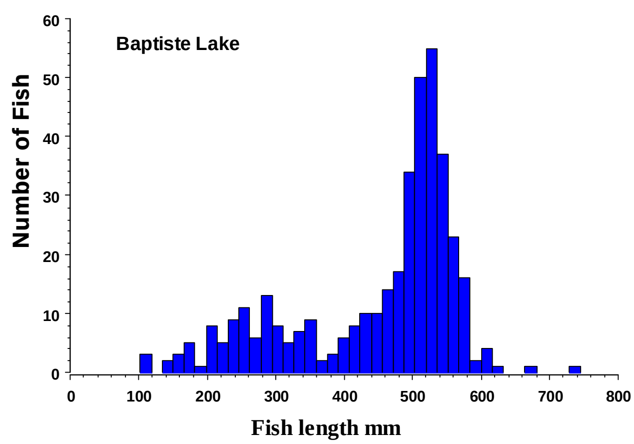

Figure 2. Fish length distribution for a sample of 389 lake trout from Baptiste Lake, the Chitty Lakes study area

Seven fish species were found in the “fish-out” lake: Arctic grayling (*Thymallus arcticus*), burbot (*Lota lota*), longnose sucker (*Catostomus catostomus*), lake trout, lake chub (*Couesius plumbeus*), round whitefish (*Prosopium cylindraceum*), and slimy sculpin (*Cottus cognatus*). This fish community structure is similar to that reported from other fish-out projects. Lake trout made up approximately 55% of the total number of fishes removed this lake. Based on weights of individual fish, 81% of the fish community biomass was lake trout. Round whitefish made up 14%, while Arctic grayling was 4%.

If we look at the length distributions (Figure 3), remembering that this represents an almost complete sampling of the fish community, again we see bimodality. A large number of smaller fishes and a 500 to 700mm modal group were collected, as has occurred in the other studies in this presentation. Aging structures were taken for this study, but they were never aged.

If we examine the distribution of individual lake trout weights from the “fish-out” lake, there clearly was bimodality in the length structure of the population (Figure 3). There were also six fish that were over 4.5 kg, off the scale in Figure 3. Some of the previous speakers have suggested that in some Arctic lake ecosystems, there are a few cannibalistic lake trout. It is certainly possible that these six trout may have had a similar role in the “fish-out” lake’s ecosystem.

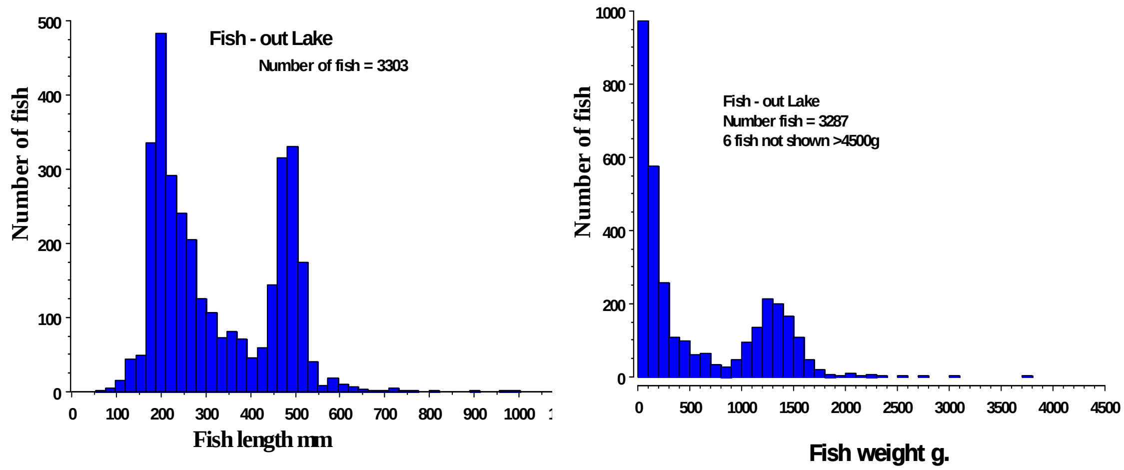

Figure 3. Length and weight distributions for lake trout from a “fish-out” lake.

If one assumes that the “fish-out” operation removed about 90% of the fish in the lake, the density of lake trout was approximately 6.0 ha^{-1}. Healey (1978) estimated that the density of trout for small arctic lakes would be in the range of 5 to 10 fish per hectare, based on data from the Chitty lake program. In retrospect, Healey’s (1978) rough estimates were similar to the estimate for the more complete fish-out lake.

Small Arctic lakes are going to be in the front line for industrial impact in the Arctic. Winter roads will cross them, industrial projects will use their water, and some projects will drain them. As I hope my talk has demonstrated, these same lakes are important lake trout habitats that support balanced ecosystems. The question becomes how best do we conserve and manage these remote, often small lake ecosystems?

The current management strategy of the Department of Fisheries is “no net loss” of productive capacity. If there is a modification to fish habitat, there can be “no net loss” of fish productive capacity. The lost capacity must be balanced by an increase in capacity at another location. It can become difficult at times to rationalize this strategy, and impacts like fish salvage, de-watering, and “fish-out” have brought this policy to a new set of extreme habitat modifications. No net loss focuses on fish habitat, not entire lake ecosystems. Small Arctic lake ecosystems and their lake trout populations will likely be impacted by large scale global changes like climate warming; the “no net loss” strategy will not be adequate to address these impacts.

The answer to how do we conserve and protect these ecosystems is by taking an ecosystem approach. Although the term ecosystem approach has been over-used in recent years, the concept is sound. Does such an approach mean we need to launch a new large-scale research program? I hope my presentation has demonstrated that this is not necessary. We can begin by examining data sets like the ALUR survey and the Chitty lakes program. In addition, the establishment of a small Arctic lakes preserve would ensure that we have a reference set of lakes to ensure that this type of Arctic ecosystem is conserved and to provide a location for ecosystem scale research in the future.

We must move away from considering these small Arctic ecosystems as a sum of marginal lake trout habitats and begin considering them as unique and interesting ecosystems. If this is linked to the establishment of ecosystem objectives and reference points, we will have a means to determine an overall strategy to better conserve and protect these ecosystems.

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Discussion

Unidentified Male Speaker: I agree with you, we are going to have to be much more innovative, but one of the things DFO is going to have to do is make datasets such as the Chitty Lakes dataset generally available. The problem is that they are not generally available and a lot of the old DFO data sets are lost. It is really unfortunate.

Dr Papst: Well, that is a very good point. In fact, one of the reasons why I was restricted to looking at only one of the ALUR data sets was that our library, which I think is first rate, in Winnipeg only had half the set. And very fortunately one of my colleagues had one of the other key documents and I was able to get it. We are going to have it copied and put back into the library. For some reason over the years it has disappeared. So it is very true. Some of those datasets are made difficult to access, even for us.

Chair
Ron Allen

Our next speaker is Dr. John Casselman. John is no stranger to most of us. He is well known for his work on fish aging as well as many Great Lakes issues. He has been with the Ontario Ministry of Natural Resources for many years and we welcome him to this meeting to speak to us about lake trout and climate change.

8.6.2 Effects of Climate and Climate Change on Lake Trout Populations and Fisheries

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Introduction

The lake trout is a coldwater fish that supports important commercial, sports, and subsistence fisheries. It occupies a broad range of habitats across its extensive natural North American range, encompassing some 30° of latitude (43° to 73° N) (Figure 1). It prefers cool, well-oxygenated waters, and summer temperature conditions are critical in influencing its available habitat and vertical distribution.

Water temperature conditions are changing (Casselman 2002) across the range of the species and will greatly influence growth, recruitment, population dynamics, and structure of lake trout fish communities. The challenge is to manage and sustain lake trout resources under changing environmental conditions. This will require more detailed information on local habitats and will require incorporating new insights about many factors.

The object of this review is to examine the effects of temperature conditions and global warming on lake trout over a broad range of latitudes across its extensive North American range, from the temperate to the arctic region (Figure 1). Air temperatures from Whitehorse in the Subarctic and water temperatures from the Bay of Quinte in the Great Lakes Basin will be used to examine the type and extent of these changes at the extremities of the lake trout range.

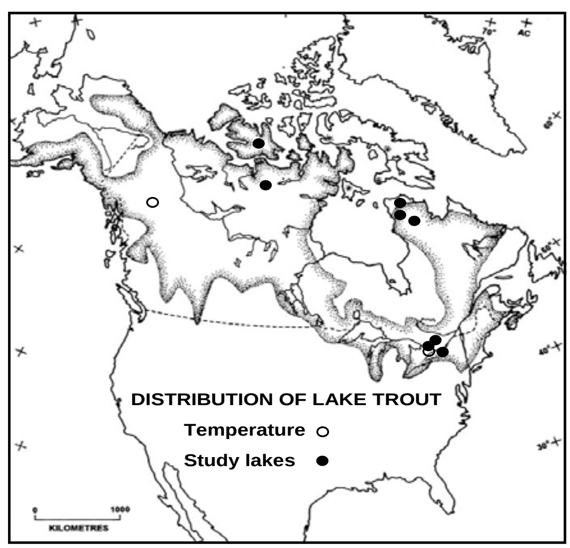

Figure 1. Distribution of native lake trout in North America, indicating the location of populations used in this study and the sources of temperature data in the south and north.

Summer depth distribution of lake trout is extremely variable over a broad range of thermal habitats and is distinctly different from the subarctic to the Arctic regions. Specific examples from intensive netting studies will be examined and compared. Juvenile growth will be considered, particularly at the northern edge of the range, to determine how it is affected by temperature. Incubation of eggs and fry is greatly influenced by fall and winter temperature conditions (Casselman 2002). The effects of climate change and global warming will be examined as they influence environmental conditions and spawning success, with particular reference to recruitment dynamics.

Global warming will also affect lake trout fish-community structure. Aspects of this will be examined by using specific examples associated with centrarchid invasions in the southern part of the range.

Thermal requirements and optimum temperatures

Lake trout, a coldwater species, spawn in the fall at approximately 10°C (Table 1). On the other hand, coolwater fish are usually spring spawners, and warmwater fish spawn at late-spring and early-summer temperatures (Table 1). The thermal requirements of coldwater fish, as determined from optimum temperature for growth, and the preferred, or selected, temperature are generally in the 10°C to 15°C range. The average of the optimum and preferred temperatures indicates that lake trout have a thermal requirement of approximately 11.5°C (Table 1). These summary temperatures make it possible to consider how fish will respond to changing temperature, either within a specific habitat or across a latitudinal cline.

Table 1. Temperature requirements of typical temperate-region Great Lakes fish of the three major thermal groupings. Coldwater species are fall spawners, coolwater are spring, and warmwater species are early summer spawners. (Modified from Casselman 2002).

Thermal grouping	Species	Spawning	Optimum	Thermal requirement: Preferred	Thermal requirement: Mean
coldwater	brook trout	8.7	15.0	13.0	14.0
	lake whitefish	5.7	15.2	11.1	13.2
	lake trout	10.6	11.7	11.2	11.5
	Mean	8.3	14.0	11.8	12.9
coolwater	yellow perch 9.3	22.5	23.3	22.9	
	walleye	8.0	22.6	21.7	22.2
	northern pike6.9	20.0	23.5	21.8	
	Mean	8.1	21.7	22.8	22.3
warmwater	bluegill	23.7	30.2	31.3	30.8
	white perch	20.1	28.8	29.8	29.0
	smallmouth bass	18.0	27.0	27.4	27.2
	Mean	20.6	28.7	29.5	29.0

Thermal conditions, climate change, and global warming

The best indicators of aquatic thermal conditions, of course, come directly from water temperature. However, long-term water-temperature data are limited, and air temperature is more frequently available and reliable. Air temperature is much more variable, and its effects on fish are often less easily understood and applied. Some of the most extensive nearshore water-temperature data for the Great Lakes Basin come from a long-term series associated with the Bay of Quinte in eastern Lake Ontario (Casselman 2002). Midsummer surface temperatures at the southern part of the range, well documented for the nearshore waters of Lake Ontario

(Figure 2), are in the range of 20°C to 25°C and greatly exceed the thermal requirements of lake trout. At these surface temperatures, lake trout must seek cooler temperatures and deeper habitats during the midsummer period. In the Great Lakes Basin, nearshore temperature conditions in the open-water period of April to September have increased significantly over the past six decades, by almost 1.5°C. This change, however, was more extreme from the mid-1970s to the present, as indicated by midsummer temperature conditions (Figure 2). Also, winter ice cover has decreased significantly over the same six-decade period, most markedly after the mid-1970s.

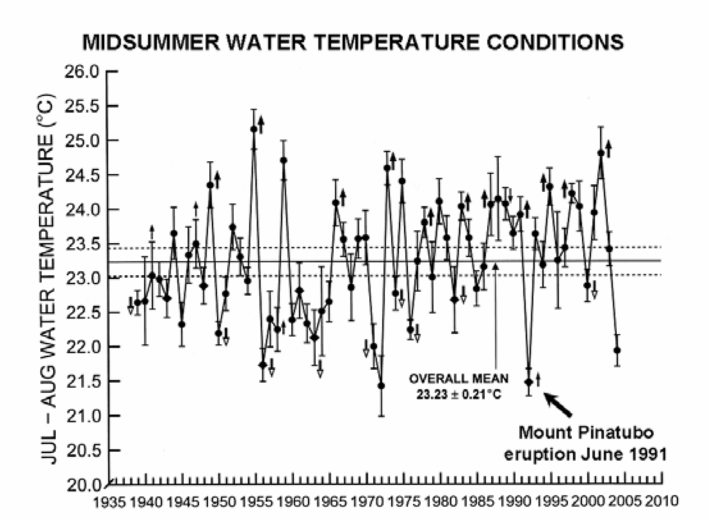

Figure 2. Midsummer July-August water temperature conditions in the shallow, sheltered inshore waters (3.2 m) of the Great Lakes Basin, specifically from the Bay of Quinte – eastern Lake Ontario. Large closed arrow up indicates an El Niño event in the tropical Pacific expressed as an extremely high (>95% CL) temperature. Small closed arrow up indicates an El Niño event not expressed by extremes in the Bay of Quinte. Large open arrow down indicates a La Niña event in the tropical Pacific expressed as an extremely low (<95% CL) temperature. Small arrow down indicates a La Niña event not expressed in the Bay of Quinte. The 1992 temperature response to the Mount Pinatubo event is indicated. A temperature depression occurred even though El Niño conditions existed in the tropical Pacific.

Such long-term water temperature data do not appear to exist for the subarctic and Arctic regions, but air temperature is available. Air temperatures for Whitehorse in the Yukon (60° 42'N, 135° 03'W, Department of the Environment, Meteorological Branch) for the past six decades indicate midsummer temperature conditions of 12°C to 14°C, close to but slightly above the optimum for lake trout. In contrast to the Great Lakes Basin, April to September temperatures showed no trend over time, but the CUSUM (cumulative sum of residuals about the mean) indicates a substantial increase since 1988. This recent temperature increase is seen across much of the Canadian subarctic region. Considering monthly temperatures, April has shown a dramatic change over time, increasing significantly from approximately -1°C in the 1940s to +1°C in the 2000s (Figure 3). April temperatures over this six-decade period have increased from freezing to thawing conditions. This would significantly increase the length of the open-water period in the spring, increasing the length of the growing season for lake trout at the northern extremity of the range.

Midsummer Depth Distribution

Midsummer vertical distribution of lake trout in temperate and subarctic lakes near the southern and northern limits of the range of the species was examined by using multi-mesh gill nets fished at various depths in typical lake trout lakes and populations. Fish size influences depth distribution of lake trout (Figures 4 and 5). In midsummer, juvenile lake trout in the temperate region are typically found in a deepwater refugium below the adults (Figure 4). Subadults and adults are found shallower; the midsummer depth distribution of these larger fish is directly related to size. Temperature data collected during experimental netting in the southern part of the range indicate that in midsummer, juvenile lake trout are found at temperatures well below the optimum (Figure 4). Also, if deepwater oxygen is reduced or depleted, the juveniles would be forced to move up among the adults, making them vulnerable to cannibalism. Large lake trout are extremely piscivorous. Small juvenile lake trout are found in this critical deepwater habitat for up to 4 to 5 years, until they reach approximately 20 to 30 cm in length and are more

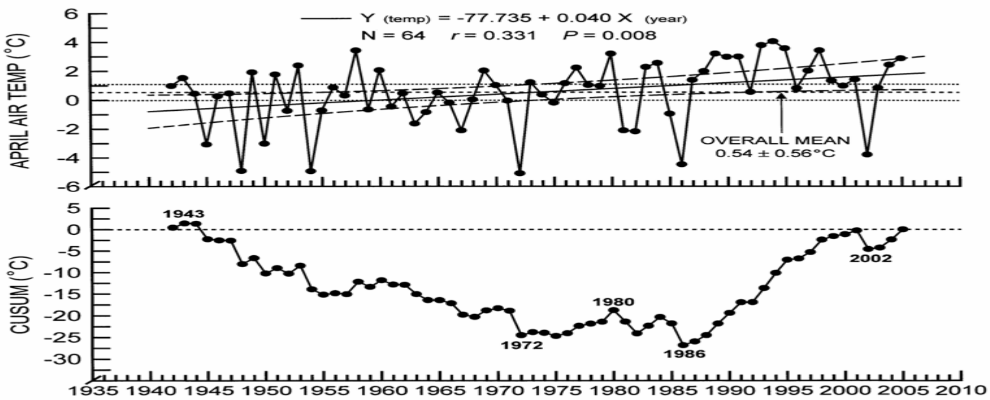

Figure 3. Mean annual April air temperature at Whitehorse, YT, indicating a significant increase in temperature over the 60-year period. The bottom plate is the accumulated sum of the residuals about the mean. The years on the CUSUM indicate a change in dynamics.

able to escape adult predation. They are slow-growing, usually planktivorous, inactive, and especially difficult to catch and sample. When they move out of this deepwater refugium into shallower water, growth rate increases significantly, documenting this change in habitat. This deepwater juvenile refugium is a very restricted part of the lake and in 213 inland lakes in Ontario amounts to only 5.2% of the lake volume. The quantity and quality of this critical habitat greatly restrict lake trout recruitment, growth, and productivity. The larger juveniles in this deepwater refugium can be cannibalistic; this would have a density-dependent and compensatory effect on recruitment.

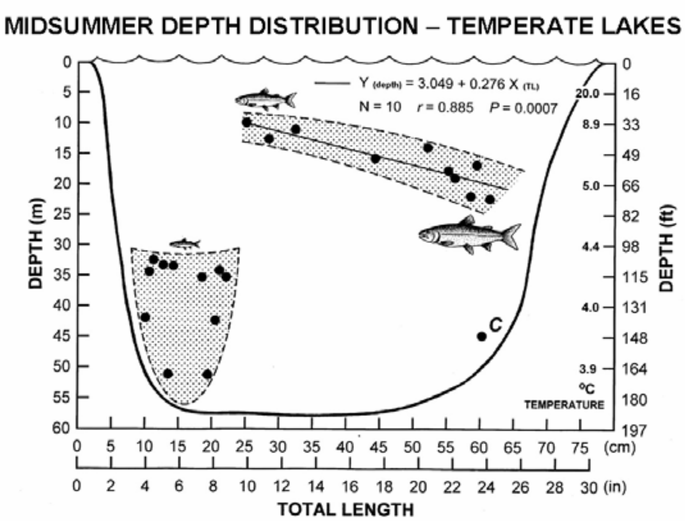

Figure 4. Midsummer depth distribution of lake trout in temperate-region lakes near the southern limits of the range of the species. Distribution is plotted in relation to fish size. The regression between size and depth is provided. Temperatures are indicated, showing that the larger lake trout are found just below the thermocline and juveniles are in the cold, deep portion of the lake. Data were collected by multi-mesh gill nets and depth-stratified netting in South Wildcat Lake.

Stocked juveniles also descend into this deepwater habitat, and can be competitors and predators of native lake trout, negatively affecting natural recruitment. This vertical size distribution seems to be important in allowing the juveniles to seek a deepwater refugium, spatially separating them from the cannibalistic adult fish. Nevertheless, some of the very largest lake trout are often caught in very deep water among the juveniles, and stomach analysis confirms that they are cannibalistic, preying upon the smaller juveniles.

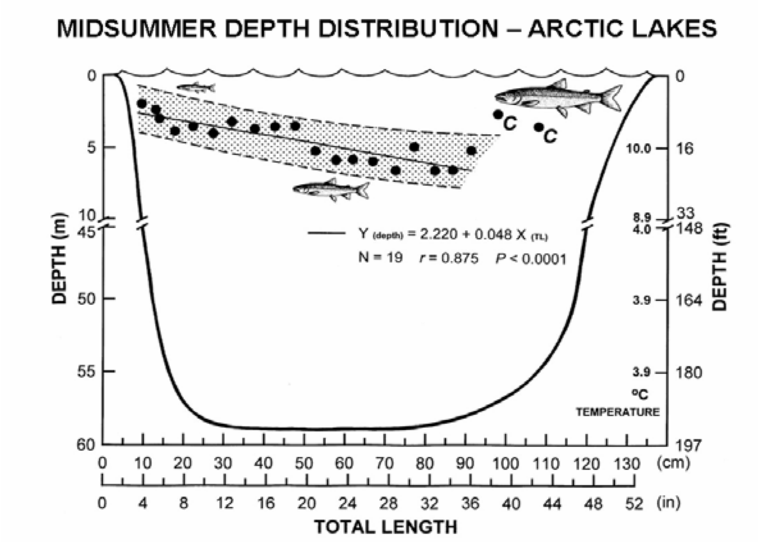

Figure 5. Midsummer depth distribution of lake trout in the northern part of the range, near the northern limits of the species. Young juveniles are found in shallow water around the shore and above the adults, and for subadults and adults, vertical distribution is directly related to the size of the fish. The regression between size and depth is provided. Data were extracted from multi-mesh gill nets set at various depths through the water column in Couture, Tasiat, Strange, and McAlpine lakes in the sub-Arctic.

Midsummer depth distribution in subarctic and Arctic lakes is quite different from that in temperate lakes. At these latitudes and temperatures, juvenile distribution is not restricted by temperature. Most notably, in contrast to southern populations, smaller juveniles are found in shallow water around the shore and above the adults (Figure 5). For all sizes, vertical distribution is directly related to body size. Lake trout distribution in northern lakes is generally very shallow. In midsummer, they are found in the warmer surface water, often close to shore (Figure 5). In contrast to the temperate region, some of the largest lake trout are often found inshore, preying directly on small juveniles. In the northern part of the species' range, juveniles are distributed in a less restricted way in a more productive and abundant inshore habitat around the shoreline, where cover is readily available. Under these conditions, they would grow more rapidly than would temperate-region lake trout because they are able to take advantage of more optimal temperature conditions even though the growing season is shorter.

In northern habitats, increased summer temperatures may enhance growth, but depending upon latitude and locale, temperature may reach a level that forces the juveniles deeper and makes them more vulnerable to cannibalism by larger individuals. Recognizing this and assessing the effects of temperature and changes in vertical distribution to a more southern type would be very difficult and challenging.

Lake Trout Growth and Temperature

The effect of temperature on lake trout growth in the temperate region is very difficult to analyze because of midsummer temperature stratification and the ability of lake trout to range and select a broad range of temperature conditions over depth. In the Subarctic and Arctic, juvenile lake trout live inshore. This makes a study of annual growth and temperature much easier and reliable. Preliminary studies using otolith incremental analysis indicated a direct relationship between April to September air temperatures and otolith growth in young lake trout (<6 years). Under these conditions, it is apparent that cold summers, particularly the one associated with the Mount Pinatubo eruption, negatively affected inshore temperatures and juvenile growth. Decreased growth of juveniles in 1992 was quite apparent in the markedly narrow annual growth increment in the otolith. More data are needed to confirm a positive effect related to warm summer conditions, but this would be most pronounced and apparent at the northern extremity of the range, since somewhere across the latitudinal cline, temperature conditions would increase to the point where juveniles might simply move deeper. If this occurred, the thermal responses would be less easily detected and, at the same time, would make the juveniles more vulnerable to adult predation, reducing recruitment. In the otoliths of older subarctic lake trout, it is apparent that temperature conditions in the cool 1960s negatively affected growth and possibly recruitment in some populations.

Long-Term Recruitment Dynamics

By contrast, warm summer temperature conditions appear to affect lake trout recruitment negatively in the southern part of the range. Long-term year-class strength trends in 99 Quebec lakes (50 years) and 58 Ontario lakes (30 years) indicate a substantial decrease in recruitment beginning in the late 1970s and early 1980s (Figure 6). Year-class strength data for these two general areas were highly significantly correlated ($r^2 = 0.27$), indicating a broad universal factor, most likely temperature. The longer Quebec data set was negatively correlated with midsummer water temperatures in the Great Lakes Basin ($r^2 = 0.19$).

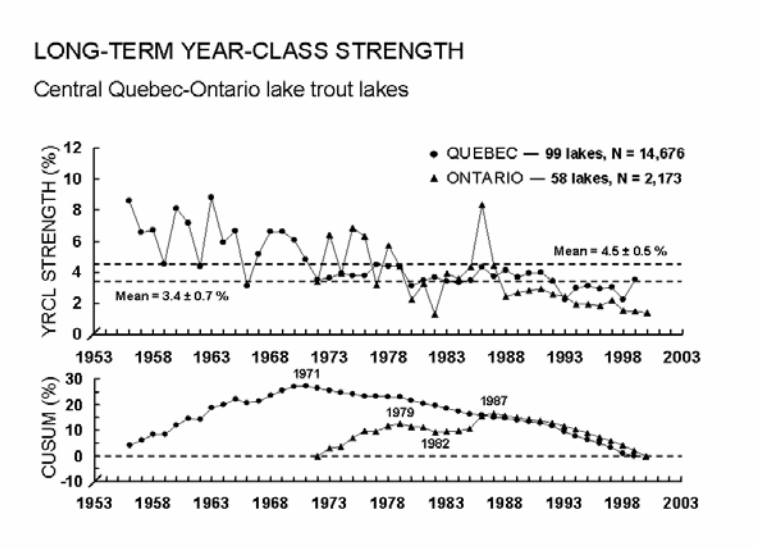

Figure 6. Relative year-class strength collected during intensive sampling of Quebec lakes from 1956 to 1996 and Ontario lakes from 1972 to 2000. CUSUM indicates that recruitment has declined rather substantially in both sets, most notably since the mid-1980s.

Direct evidence that decreasing recruitment is related to increasing temperature conditions is seen in a case-history comparison of a set of deeper, shallower lake trout lakes in eastern Ontario. In lakes that are not affected by other factors (overexploitation, etc.), deep lake trout lakes have significantly more heat units per surface area than do shallower lake trout lakes. In a well-documented comparison of two adjacent and remote lakes, Barnard (deep) and Crystal (shallow), in the Addington Highlands of Ontario, the implication of heat has been implicated in failing recruitment. Extensive temperature studies over a 6-year period confirm that Barnard Lake, with a smaller surface-area-to-volume ratio, cools more slowly in the fall and is warmer during winter. In Barnard Lake, there has been virtually no recruitment since the late 1970s and early 1980s, and now the lake has a greatly reduced population of old individuals 15 to 20 years of age, while lake trout recruit regularly in adjacent Crystal Lake and the population is abundant, with an average age of 4 to 5 years.

Extensive laboratory and field studies (Casselman 1995), as will be detailed subsequently, confirm the importance of low temperature in fall and winter for enhanced lake trout egg and fry survival, development, and recruitment.

Spawning, Recruitment, Environmental Conditions, and Global Climate Change

Detailed in situ incubation studies conducted on Yorkshire Bar in eastern Lake Ontario and under controlled laboratory conditions, using lake water and a natural fall thermal regime, provided insights into the effects of temperature and environmental conditions on recruitment success of lake trout (Casselman 1995). The incubation studies confirmed the importance of accumulated thermal units on successful hatch and emergence in the spring. Temperature at spawning time had a strong negative effect on fry emergence in spring (Figure 7). Spawning time of lake trout is strongly influenced by photoperiod and has been documented to occur on almost exactly the same date every year regardless of temperature. Thermal units directly affect time of hatch and successful recruitment. In Lake Ontario, a 2°C temperature increase at time of spawning halves spring emergence (Casselman 1995).

Water temperatures in the post-spawning period (December) in the nearshore waters of Lake Ontario have increased markedly in recent years (Figure 8). Over the past six decades, an average December temperature of 1.2°C +/- 1.8°C separates years that were ice-covered from those that were open-water. A marked increase in fall water temperatures has occurred since 1995 (Figure 8), and warmer conditions add substantially to the accumulation of the 420 thermal units needed for a 50% hatch of lake trout eggs. Increasing thermal conditions in fall can cause premature hatch (Casselman 1995).

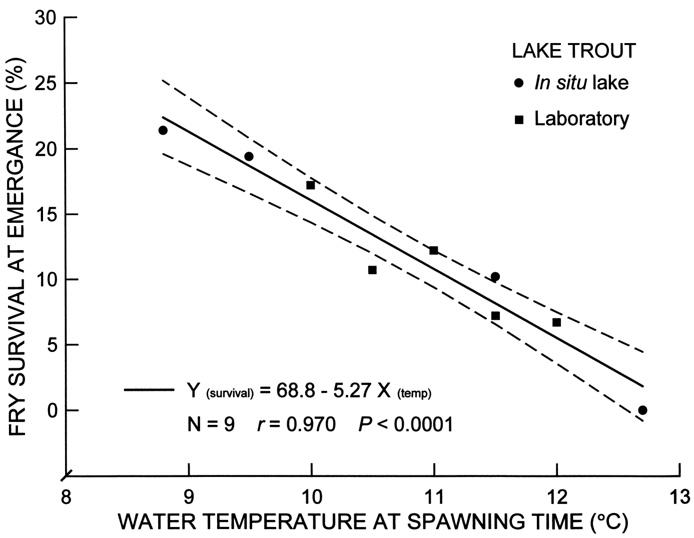

Figure 7. Relationship between fry survival at emergence in the spring and water temperature at time of lake trout spawning in the fall. Data were collected *in situ* on spawning shoals in eastern Lake Ontario (Casselman 2005). Water temperature at spawning time explains 94% of the variance in fry survival at time of emergence.

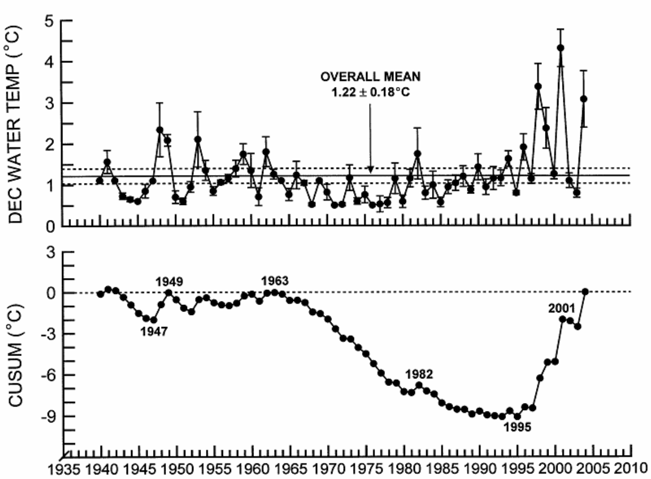

Figure 8. December water temperature conditions in the shallow inshore waters of Lake Ontario. CUSUM indicates a substantial increase in water temperatures beginning in 1995.

The negative relationship between spawning temperature and emergence in the spring (Figure 7) provides a way to assess survival and emergence in an increasing fall temperature regime. If we assume that average water temperature at time of spawning, during the last two weeks of October and the first week in November, is 9.8°C, then a temperature increase of 1°, 2°, and 3°C, would result in decreased emergence the following spring by 1.5-fold, 2.4-fold, and 20.1-fold, respectively. Fall temperatures are increasing in the southern part of the range; this will negatively affect lake trout emergence and recruitment.

Using this spawning temperature-recruitment relationship and applying it to fall temperatures in the Great Lakes Basin for the spawning period over the past four decades, we can predict fry emergence in the spring as an indicator of relative year-class strength (Figure 9). The CUSUM of predicted year-class strength indicates a substantial decrease in recruitment commencing in the early 1980s. This is associated with increasing fall temperatures during the same period and provides a theoretical explanation for the trends seen in year-class strength of lake trout from a large number of Quebec and Ontario lakes (Figure 6). This is supporting evidence that year-class strength of lake trout in the southern part of the range can be negatively affected not only by warmer falls and winters but also, as indicated by Barnard and Crystal lakes, by accumulated heat and a thermal inertia effecting a lag in fall cooling of deep lakes.

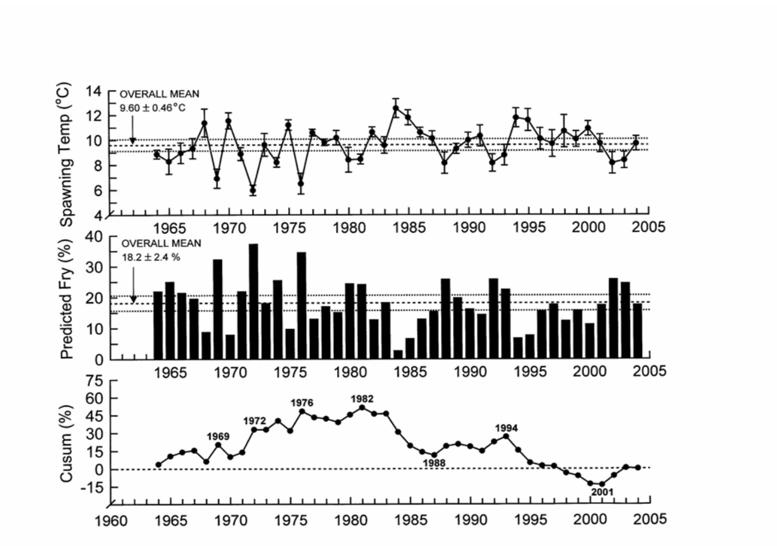

Figure 9. Temperature of inshore waters of Lake Ontario from the last two weeks in October to the first week in November and predicted fry emergence; spawning temperature, and CUSUM of this predicted emergence.

Low oxygen can also accentuate this effect. For example, increased sedimentation associated with increased productivity and plankton production can directly affect oxygen conditions in the interstices of the spawning substrate. In Lake Ontario, this increased sedimentation created a biological oxygen demand in the fall accentuated by high temperature conditions that depress oxygen to a level that affected survival of lake trout eggs in the interstitial spaces (Table 2). This has been confirmed on Yorkshire Bar during incubation studies conducted in 1986 and 1992 (Table 2). At low or decreasing temperatures, oxygen saturation increases. Also, on the side of the spawning shoal that receives prevailing winds, downwelling and associated warmer surface temperatures and sedimentation accentuate this effect, whereas on the opposite side, where there is upwelling, lower temperatures and less sedimentation lessen the effect (Table 2). These interstitial conditions provide considerable insights and confirm that warm and early fall temperatures and biological oxygen demand can interact to negatively affect early survival, development, and recruitment with increasing temperatures.

Table 2. Interstitial oxygen concentration in lake trout spawning substrate on Yorkshire Bar, 1986 and 1992, using small dialysis chambers placed in the cobble gravel substrate at sites of egg deposition. Installed at beginning of spawning period at various locations on the bar, comparing west (downwelling) and east (upwelling) sides, examining how interstitial conditions reflect habitat degradation. Duration of study in days.

					Interstitial oxygen			
					West side		East side	
Date installed	Days	Depth (m)	Temp. (°C)	Oxygen saturation (ppm)	Concentration (ppm)	Saturation (%)	Concentration (ppm)	Saturation (%)
Oct 28 1986	9	4-6	11.5	10.9	5.3	45.6	7.0	64.2
Nov 5 1986	13	4-6	9.0	11.6	6.3	54.3	11.0	95.0
Oct 28 1992	11	4	10.9	11.1	1.4	13.0	3.6	32.4
Mean	11	4-6	10.5	11.2	4.3	37.6	7.2	63.9

From time to time, large, older lake trout are angled from southern Ontario lakes, and otoliths are removed to assess age and recruitment. Careful and accurate age assessment of these fish, indicates that many come from the 1970s; they confirm the importance of thermal conditions in producing strong year classes. Although cold falls and winters are important in the southern part of the range, warm summers the following year are equally important. Cold falls and winters enhance survival, hatch, and emergence of lake trout eggs, whereas warm springs and early summers increase plankton production and accelerate growth. If year-class strength is assumed to be associated only with emergence and subsequent conditions, the impression would be that warm years produce strong year classes. However, this is only part of the sequence of factors that include synchrony with preceding cold falls and winters. The 1970s had several of these unique temperature combinations of very cold falls and winters followed by warm springs and summers (e.g., 1972-73, 1974-75, and 1977-78). The synchrony of these extreme combinations has been rare in recent years.

Invasive Species and Global Climate Change

Species invasions associated with warming climatic conditions can dramatically alter fish community structure. In lake trout lakes in the Haliburton Highlands of Ontario, centrarchid invasions, particularly rock bass but also smallmouth bass, have affected lake trout communities. Midsummer (July-August) temperature conditions directly affect year-class strength of warmwater species. This log recruitment relationship applies not only to smallmouth bass (Casselman 2002) but also to rock bass (Figure 10). Long-term rock bass recruitment data from eastern Lake Ontario indicate that El Niño years substantially increase recruitment of this invasive littoral-zone predator. When midsummer temperature conditions are examined to predict effects of global climate change, with temperature increases of 1°, 2°, or 3°C, the increase in rock bass recruitment will be 2.0-fold, 3.9-fold, and 7.7-fold, respectively. Rock bass prey heavily on littoral-zone species that are important prey fish for large-bodied piscivores, in particular lake trout. Rock bass are primary competitors for lake trout prey, directly affecting lake trout size, growth, and productivity (Vander Zanden et al. 2004). Rock bass are also known predators of larval lake trout. In a three-decade study of three watersheds in the Haliburton Highlands of Ontario, 91% of the year-classes of rock bass and smallmouth bass that invaded the lake trout lakes of the watershed were related to El Niño years (primarily 1973, 1975, 1983, and 1991).

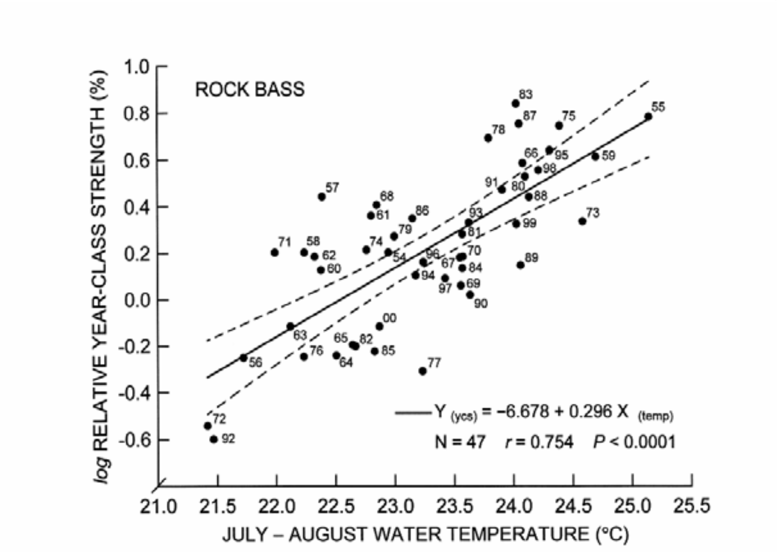

Figure 10. Relationship between year-class strength and July-August water temperatures for rock bass, an important inshore centrarchid invader of lake trout lakes. Relative year-class strength data come from long-term sampling of rock bass and scale ages for the Bay of Quinte – eastern Lake Ontario.

With global warming, initially northern pike would be the primary invader in cold northern lakes; they would be both competitors for available prey and direct predators of the juvenile lake trout living in the littoral zone.

Summary

Temperatures increased markedly in the south in summer and fall and in the north in spring. But northern latitudes provide truly optimal lake trout habitat. Midsummer depth distribution of juvenile lake trout varies markedly across the range: deep in the south, inshore and shallow in the north. Northern conditions would be more productive and an appropriate recruitment situation in the extremity enhanced by global warming. These distributions make lake trout particularly vulnerable to invading species associated with global warming (e.g., northern pike predation in the north, centrarchid competition and predation in the south). Recruitment is negatively affected by fall and winter temperatures in the south caused by accelerated development and premature hatch. Deep lakes in the south can have a thermal inertia compared with shallow ones, resulting in elevated fall and winter temperatures negatively advancing hatch and emergence.

Two extreme conditions have been presented here for comparative purposes. The primary assessment and management challenge would be to determine how environmental conditions are changing in a specific locale and to understand how these changes would affect distribution, recruitment, and productivity of this widely distributed coldwater fish.

Acknowledgements

I thank Lucian Marcogliese and Ken Scott for assisting with illustrations and preliminary analyses. The subarctic work was done in collaboration with Steve Campana and Cynthia Jones, the long-term recruitment in Quebec and Ontario with Henri Fournier and Wayne Selinger, the Barnard and Crystal study with Steve Lawrence, and the invasive species impacts with David Brown. The assistance of these many collaborators is much appreciated.

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* * * * *

Discussion

Unidentified Male Speaker: Is there any other way that lake trout could try and compensate for the change in climate, such as spawning at a later time?

Dr. Casselman: No, we are not seeing that. In fact, over this short period of time we're not seeing a switch to spawning later. It seems like the spawning time is photoperiod activated and this relates to egg development starting in mid-summer. As soon as daylight starts to shorten, egg development starts. They are locked into this and we do not see a major shift. The best example of this is John Gunn who did some work on some lakes and over a three-year period, which included an El Nino event in 1991, which is a warm year, and they spawned on the 8th and 9th of October in all three years.

9 Contributed Papers

9.1 Concurrent Session #1 – Harvesting & Co-management

Session Chair – Dr. Burton Ayles, FJMC

9.1.1 Co-occurring Management Strategies and Ecosystem Change Have Impeded Assessment of Lake Trout Restoration in Lake Ontario

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We discuss how overlapping management actions and coinciding ecosystem changes precluded assignment of mechanisms to two developments in the status of the Lake Ontario lake trout population.

Lake trout restoration in Lake Ontario began in the early 1970's with sea lamprey control and annual releases of hatchery-reared lake trout. Increases in stocking and expansion of sea lamprey control led to a build-up of adult lake trout that peaked in 1986. About the same time managers were implementing sport fishing regulations designed to reduce an excessive sport harvest and push the mean age of mature females past 7.5 years. Although adult abundance peaked in 1986, mean age of mature females did not surpass 7.5 years until 1996. Recently harvest regulations have come under intense scrutiny, but deciphering the mechanisms that led to high survival of adults is complicated by the coinciding effects of regulations, stocking changes and lamprey control.

Survival of stocked yearlings was stable during 1984-1990 but declined by 91% during 1991-1993 and remained low. While survival was declining managers reduced stocking by 40% in response to preyfish declines. Concurrently the strain composition of annual stockings was shifted to favor sea lamprey resistant fish which, coincidently, are less vulnerable to sampling at young ages. The recruitment declines led to an abrupt 30% decline in adult abundance in 1998 which refocused attention on yearling survivorship. Although stocking reductions were not expected to decrease yearling survival, recent information suggests a survivorship threshold at about 35% above current stocking levels. Of several factors examined, the abundance of lake trout >732 mm long related most strongly to the survivorship declines. Confounding the determination of the causes of poor survivorship are past and continuing ecosystem changes including invasion and expansion of dreissenid mussels, abundance and distribution shifts of prey fishes, and the loss of Diporeia.

9.1.2 Efforts to Suppress Lake Trout Outside Their Native Range

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Introduction

Flathead Lake, in western Montana, was once noted for its abundant bull trout, *Salvelinus confluentus*, population. Today the Flathead Lake and river ecosystem exemplifies the growing problem in which native biodiversity is threatened by introduced fishes and invertebrates. Predation by lake trout, *S. namaycush*, introduced to Flathead Lake in 1905, has restructured the fish assemblage of Flathead Lake. Because there are few examples of bull and lake trout existing in sympatry, managers fear complete replacement of native trout by lake trout (Donald and Alger 1993, Koel et al. 2005). Lake trout in Flathead Lake demonstrate high productivity and resilience to exploitation. Managers are in the early stages of a program to reduce lake trout numbers for the purpose of increasing native trout.

For many decades following their introduction in Flathead Lake, lake trout numbers remained low, stable, and dominated by older age classes. However, lake trout population dynamics in Flathead Lake changed with the introduction of *Mysis relicta*. *Mysis relicta,* first detected in Flathead Lake in the early 1980's, provided an abundant prey base for lake trout, which increased the abundance and shifted the age structure of the lake trout population toward younger age classes. Recent sampling indicates that *Mysis* make up over 90% of the diets of lake trout age 4 and less (Figure 1). This trophic shift provides an explanation that the expanded lake trout population is the product of increased juvenile survival. The fish consumed by lake trout are primarily lake whitefish, *Coregonus clupeaformis*, which become increasingly more important in the diet of larger fish.

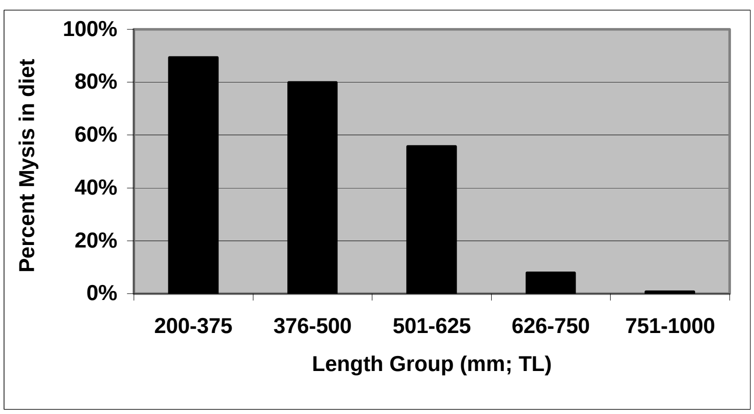

Figure 1. Percent of *Mysis relicta* in the diets of different length groups of lake trout in 1998.

Bioenergetic modeling (Kershner and Beauchamp 2001) indicates substantial, but much less predation on native trout (Figure 2).

Discussion

Managers of Flathead Lake have chosen public angling as the first strategy to accomplish lake trout reduction as part of a larger effort to increase native trout numbers. Today there is a high yield lake trout fishery (0.8 kg ha^{-1} $yr^{-1)}$ supported by low pressure (2.5 h ha^{-1} yr^{-1}) that results in annual mortality rates averaging about 0.35. The lake fishery consists entirely of nonnative species. In most years

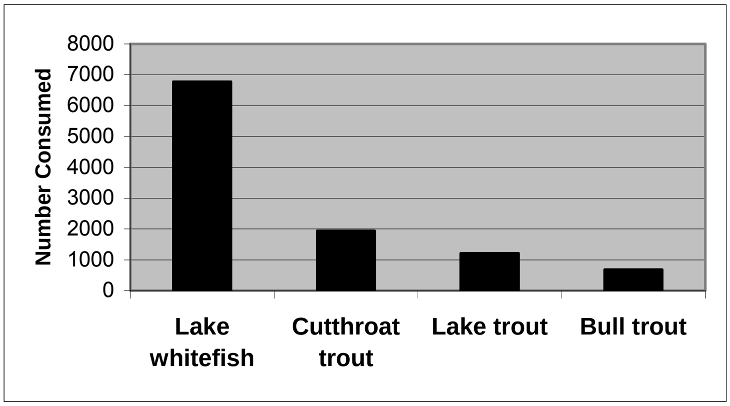

Figure 2. Estimates from bioenergetics modeling of the number of prey fish consumed per 1000 lake trout, 2001.

lake trout represent over 90% of the weight of fish harvested and hours of pressure applied, with lake whitefish and yellow perch, *Perca flavescens,* making up the remainder. These factors combined with the robustness of the population raise doubt about the ability of anglers to mount sufficient pressure to reduce the population enough to facilitate native trout recovery. Because most anglers target lake trout, managers were concerned that anglers who were so invested in the lake trout fishery would refuse to participate in the program to reduce that fishery. In addition, there are many intrinsic factors that limit angler success. Among these are: a small angler base, the large size of the lake (50,000 ha), the need for specialized gear, and an unwillingness on the part of anglers to harvest a high percentage of their catch. Managers have responded by liberalizing regulations, i.e., allowing two lines and a bag limit of 20 (Figure 3), and sponsoring fishing contests.

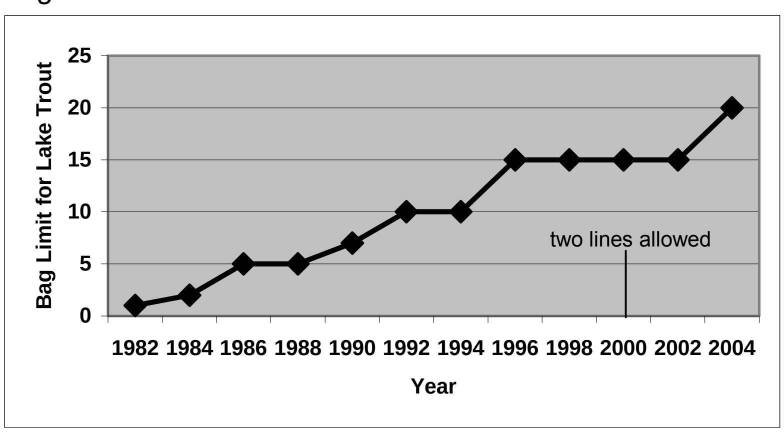

Figure 3. Bag limits for lake trout in Flathead Lake, 1982-2004.

While the public has given only modest support for the concept of lake trout suppression, there has been growing support for fishing contests. The contests are structured on a lottery system in which all fish less than 710 mm (TL) are submitted for a lottery ticket that can win up to a US$2,000 prize. These contests are intended to stimulate angling interest and more importantly, to increase harvest. Over the last seven years anglers have consistently limited their harvest to less than 70% of their catch. The contests motivate anglers to catch their limits and to harvest 100% of their catch.

We surmise the following reasons that anglers who do not whole-heartedly support lake trout suppression have responded positively to the contests. First, the participating anglers are highly competitive. The multiple week format of the contests and daily website and media postings of results motivates anglers. Second, many of these anglers are gamblers by nature and are motivated by the cash lottery prizes. Third, participants are altruistic or generous. After receiving their lottery tickets, most anglers donate their catch to the contest organizers who then distribute the fish to food banks. Anglers noticeably respond to this feature of the contests. And finally, some anglers acquiesce to the inevitability of change, and that they can either participate or be left out. We are not aware of any participants who are motivated solely by the desire to benefit native species. Harvest generated by the contests has doubled each of the last three years. By 2005, harvest in the contests has risen to represent about 25% of the average annual harvest.

Despite the growth of the fishing contests, many questions remain about their utility as a viable management tool. For example, there are currently no strong indicators that the present level of harvest has resulted in a measurable change in the lake trout population structure. Further, we do not know the full potential of the contests or the level of harvest necessary to reduce the lake trout population. An even greater unknown is the level of harvest that is sufficient to allow native trout to rebound. Managers hope to answer these questions by encouraging further growth in these contests, and by monitoring the direct effect on lake trout, and the secondary effects on native trout.

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Acknowledgements

Montana Fish Wildlife and Parks co-manages the Flathead Lake fishery with the Confederated Salish and Kootenai Tribes and is a partner in efforts to reduce lake trout.

9.1.3 Contrasting Views of Fair Share in Lake Trout Fisheries

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Introduction

Do fishing regulations deliver a correct message to anglers about their fair share in harvesting lake trout? To address this question, we estimated an angler's fair share from two perspectives: an angler and a fisheries biologist. We assumed the angler's perspective is based on fishing regulations that dictate a maximum allowable daily harvest (i.e. catch limit). We assumed the biologist's perspective is based on models that predict maximum sustainable annual harvest and surveys that estimate annual fishing effort. Our calculations for Ontario lakes revealed a large mismatch between these two views of fair share.

The Angler's View

The Ontario recreational fishing regulations summary specifies catch limits, open season and size restrictions for lake trout. These regulations vary across management zones and they have become more restrictive in recent years. The daily catch limit is currently 2 or 3 fish in most management zones and the average season length (i.e. number of days per year when fishing is allowed) is 247. To estimate fair share from an angler perspective, we used a catch limit of 2 fish and a season length of 250 days. These regulations imply an angler can legally harvest 500 fish per year (i.e. 2 fish/day x 250 days). Of course, this number greatly overestimates the expected annual harvest of a typical angler because few anglers fish every day of the open season. According to the 2000 Survey of Recreational Fishing in Canada (DFO 2003), Ontario anglers fish an average of approximately 10 days per year. Thus, an angler who fishes for lake trout and takes a limit each day would harvest 20 fish per year (i.e. 2 fish/day x 10 days). We expect most anglers would not consider this harvest as excessive and propose it as an estimate of fair share from an angler's perspective.

The Biologist's View

A biologist seeking an estimate of an angler's fair share in harvesting lake trout needs to know how many lake trout can be safely harvested from a lake and how many anglers fish that lake. We used a lake trout exploitation model (Shuter et al 1998) to estimate safe harvest levels (Fig. 1). That paper reported maximum sustainable harvest levels for lakes of different sizes. Because maximum sustainable harvest should be viewed as a threshold (not a target), we divided it by two to calculate a safe harvest level. We used creel survey data collected by the Ontario Ministry of Natural Resources to obtain estimates of fishing effort on a sample of lake trout lakes (n=102, Fig. 2). To calculate how many anglers fished each lake, we divided effort (# angler-days) by 10 days, the average number of days fished per year by Ontario anglers (see above). The biologist's view of fair share was then calculated for each lake as the safe harvest divided by the number of anglers. Because angling intensity was highly variable, fair share estimates ranged widely from 0.6 to 103 fish per angler-year. The frequency distribution of these estimates (Fig. 3) indicates a mean of 8.5 and a median of 4.5 fish per angler-year. In 90% of cases, the biologist's view of fair share was less than the angler's view (i.e. 20 fish per angler-year).

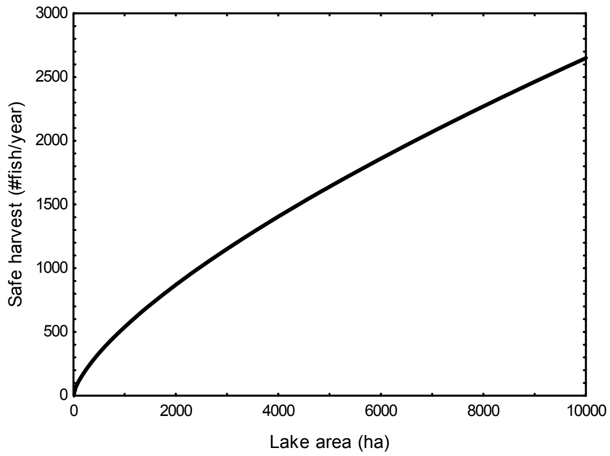

Figure 1. Estimated safe harvest of lake trout (based on Shuter et al 1998).

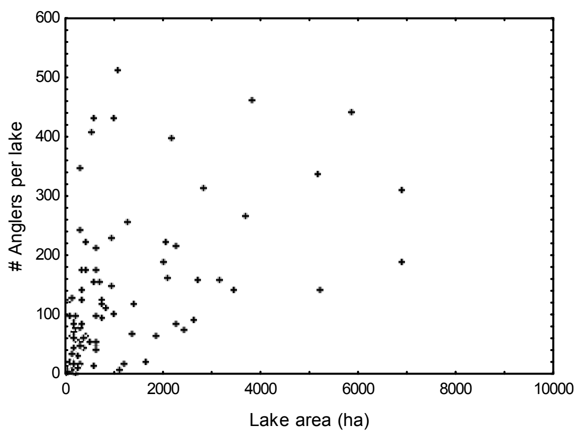

Figure 2. Estimated number of anglers fishing for lake trout on various lakes in Ontario.

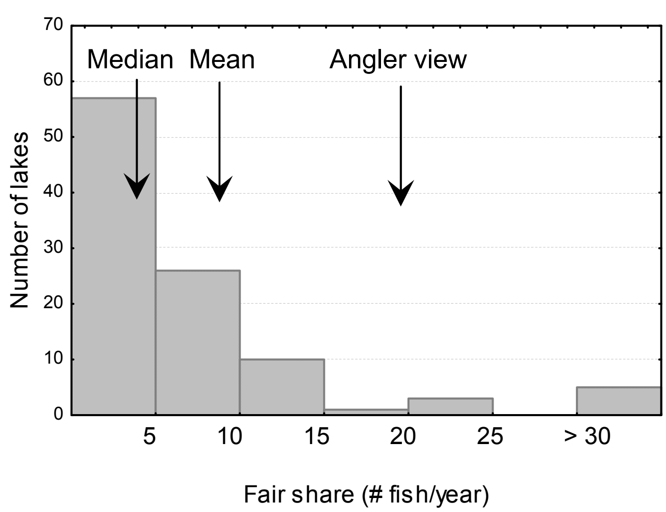

Figure 3. Frequency distribution of the biologist's estimate of fair share for the sample of lakes shown in Figure 2.

Discussion

Our results indicate that fishing effort on lake trout lakes can be very high and, consequently, a biologist's estimate of fair share is often much less that an angler's view of fair share. In short, an expectation of harvesting 20 lake trout per year is too high for many lakes. Reducing the catch limit from 2 to 1 would produce an angler's view (10 fish per year) that roughly matches the mean of the biologist's view, but the angler's view of fair share would still exceed the biologist's view for most lakes (see Fig. 3). The angler's expectation must be reduced 4-fold to bring his/her view in line with the median of the biologist's view and create a better balance between viewpoints. A creel limit of 0.5 fish/day would be needed to create this match!

An alternative, more direct, means of delivering messages about fair share in lake trout fisheries is to issue a license with a stated 'fair share' quota. For example, information supplied when issuing a license could state that anglers should not harvest more than x lake trout per year, where x would vary depending on level of fishing effort. For data shown here, $x = 5$ is appropriate. But our data are mainly from lake trout lakes in the heavily populated southern portion of Ontario. In less-populated areas, fishing effort is lower and a higher annual quota (per angler) could be offered. This quota could be modified through time as changes in the level and spatial distribution of fishing effort occurred. Its value would provide a direct signal to anglers about changing demands on the resource.

The open access, common property nature of lake trout management in Ontario is an inherent constraint to effective harvest control (Olver et al 2004). We believe that historical (and current) fishing regulations have promoted unrealistic expectations of lake trout abundance and harvest potential. Consequently, public acceptance of more restrictive regulations on lake trout lakes has been hampered. An educational campaign, stressing the limited productive capacity of lake trout and the popularity of lake trout fishing, is needed to establish a more realistic angler view of fair share and facilitate changes in fishing regulations. A potentially useful vehicle is the issuing of a 'fair share' quota that is tailored to changes in the demand and supply of lake trout in different management zones. Ideally, the quota should be enforced, but if the required enforcement mechanisms and resources are not available, this explicit tactic (i.e., advertising fair share) still serves better than the current management approach which offers few clues and can result in unrealistic angler expectations of fair share.

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9.1.4 Sampling of Lake Trout Subsistence Harvests in The Husky and Sitidgi Lake Areas of Canada's Western Arctic: Program Delivery by Local Inuvialuit Fishermen in the "Cottage Country" of the North

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Abstract: Subsistence harvesters of the Inuvialuit communities of Tuktoyaktuk and Inuvik NT have long conducted a traditional annual spring harvest of lake trout in Husky and Sitidgi Lakes, in association with the annual geese and caribou hunting. The five year sampling program was coordinated by the Dept. of Fisheries and Oceans, with all field sampling being conducted by the same three trained monitors. The consistency among monitors and years, the long-time established rapport of the samplers with fishers in the community, all contributed to the success of the study. Data collected as part of this study are for the first time available to characterize the time, location and parameters of lake trout taken in the fishery. Data from the fishery are relevant for fisheries (co-) management purposes, and important to communities, government and industry for planning, assessment and mitigation of exploration and development activities related to possible future hydrocarbon activities in this region.

9.1.5 Process and Product: Co-operatively Managing Great Bear Lake and its Watershed

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Introduction
The Water Heart: the Management Plan for Great Bear Lake and Its Watershed ('the Plan') has been produced for a portion of the Great Bear Lake watershed. This paper discusses background on the Plan development, its major components, and its status to date.

Background
The Plan was produced by the Great Bear Lake Working Group (GBLWG). This ad hoc group was formed in 2002 at the request of the people of Déline to assist them to protect the natural and cultural heritage of Great Bear Lake (GBL). The GBLWG included the people of Déline (represented by elders and various Déline organizations established under the Sahtu Dene and Métis Comprehensive Land Claim Agreement ("the Claim")), the Federal Government (DFO, Indian and Northern Affairs and Dept of Environment), the Territorial Government (the Department of Environment and Natural Resources), Regional Co-management Boards also established under the Claim (Sahtu Land Use Planning Board, Sahtu Renewable Resources Board, Mackenzie Valley Environmental Impact Review Board) and Non-Government Organizations (Canadian Parks and Wilderness Society - NWT Chapter).

The Plan deals only with the portion of the GBL watershed within the Sahtu Claim area (which includes the entire lake). This represents about 62% of the watershed, and is mostly in the Déline District.

The Plan was produced through a series of GBLWG and technical working group workshops between October 2002 and May 2005, which were co-ordinated by a facilitator/drafter and a community co-ordinator. Traditional knowledge and scientific knowledge were both integral to the process. Elders' stories are woven throughout the Plan, and form the basis of the chapters. The name of the Plan (the Water Heart) is from a Sahtugot'ine (people of Great Bear Lake) story passed along through many generations in Déline. A summary of the story is: the man Kayé Daoyé travelled to the centre of Great Bear Lake and found its heart. Contemplating this heart, he became aware that it is connected to all beings — the land, the sky, plants, other creatures, people — and that it helps sustain the entire watershed of Great Bear Lake.

Based on Dene law, ecological knowledge, and legal systems, the Plan ties together healthy land and healthy people. It works with/within a variety of legislation that govern activities on the land: the Claim, the Mackenzie Valley Resource Management Act, Fisheries Act, NWT Water Act, etc. The Plan has been submitted to the Sahtu Land Use Planning Board, and the Plan (or its amended version) will be enforceable once the Sahtu Land Use Plan is approved by the Federal and Territorial Governments, and the Sahtu Secretariat Incorporated (in essence the Sahtu Aboriginal Government).

Summary of the Plan
The Plan is based on the vision 'Keep Great Bear Lake clean and bountiful for all time'. This vision was set by the GBLWG at its first meeting. In the Plan, about 23% of the Sahtu portion of the watershed is to be designated Conservation Zones or Protected Areas. No industrial development would be allowed in those areas.

The rest of the watershed, including GBL itself, is considered a Special Management Zone. In this zone, development is allowed under certain conditions, though certain activities will be prohibited altogether. The **prohibitions and conditions** of the SMZ will be enforced under the Land Use Plan. It is important to stress that the Claim gives beneficiaries certain rights, such as certain hunting, trapping and fishing rights. No policies, prohibitions, conditions or other clauses in the Plan takes away any rights ensured under the Claim.

The following are **prohibited** throughout the watershed:

- Bulk water removal/sales;
- Deposit harmful waste in water, on the land or in the air;
- Introduction of alien/exotic plant or animal species;
- Activities that result in or contribute to the loss of any wildlife or plant species in the watershed;
- Aquaculture and fish stocking;
- Digging up or otherwise harming the bottom of GBL (community docks, environmental monitoring equipment and similar are still allowed)
- Activities that contribute to the loss of genetic diversity in the GBLW (e.g., unique trout, whitefish and cisco stock in GBL; Bluenose East and Bluenose West barrenground caribou herds)

Before development proceeds, it must meet certain **conditions**. The following must be proved or agreed to by the proponent before any development can proceed:

- Set up appropriate research and monitoring to show that the land is staying healthy;
- Clean up when they finish the work (appropriate restoration);
- Give a sufficient security deposit to the regulatory authority before they start work so that there is sufficient money set aside to properly clean up the site;
- Keep the habitat of fish and wildlife safe;
- Keep all the water that flows from its site into GBL at least as clean as it is now (background levels or better for surface and groundwater);
- Minimize damage to permafrost; and
- Keep fish abundance at current levels or better.

As an example of how these conditions are detailed in the Plan, the wording for the latter condition is: "As a general rule, fish stocks in the GBLW must be managed conservatively in order to minimize the risk of degrading the quality of GBLW fisheries. Lake trout populations on GBL must not be allowed to fall below levels which ensure that the catch of large trophy lake trout (fish in excess of 9kg) by any lodge remains stable at baseline levels. Baseline levels will be established for various stocks as determined by harvest studies in areas used by fishing lodges."

Discussion
Three things are needed for the Plan to be useful: formal approval (previously mentioned), management of the full watershed, and implementation.

The GBLWG acknowledges that the Plan is just a start to managing our activities in the GBLW. For example, the Plan does not cover the Great Bear River (the outflow of the Lake). Also, the Plan is seen as a good start for sharing knowledge and perspectives with the people of the Dehcho, Tlicho, Nunavut and others who are in the non-Sahtu part of the GBLW. Some issues (e.g., climate change, long range transport of airborne pollutants) take place at a larger scale than the watershed, and need to be taken into consideration at a broader territorial or national level.

Implementing the Plan includes ensuring patrols and enforcement, education, cleaning up existing waste and toxic sites, and research and monitoring. A companion document to the Plan itself, *Ecological and Cultural Research Monitoring Plan for Great Bear Lake and its Watershed* (R&M Plan) (Andrews, Bayha *et al*) was also published in May 2005. Seventeen authors from 10 agencies and companies contributed to the R&M Plan: clearly co-ordination was, and will continue to be required for this work.

The R&M Plan was produced as a framework to set general direction, yet is written in a fairly detailed manner so as to be comprehensive. There are 9 research areas, with a total of 47 projects, described: Terrestrial (5 projects); Water Quantity (6 projects); Water Quality (6); Permafrost (2); Fisheries (10); Aquatic Ecology (6); Neh Karila K'ets'Edi (Conservation and Protected Areas, 5 projects); Cultural (7); Economics (no projects described). As a framework, it is meant to be "adaptive" and change as knowledge is gained and opportunities pursued.

Throughout, Déline's input is critical: to the writing of the Plan, doing research proposals, undertaking research, and making management decisions based on that research. Broader research in areas such as caribou management, sustainable economic development, and groundwater, are needed.

Another aspect of implementation is broadening the level of support and understanding of GBLW and the Plan. The process, though inclusive, needs to be further extended in groups such as the youth in Déline, scientists in Canada, and circumpolar politicians.

Conclusion

The process of developing the Great Bear Lake Management Plan has helped in moving towards the vision to 'Keep Great Bear Lake clean and bountiful for all time'. However, to truly change the way we manage activities on the land, this Plan needs to be legally enforced through the Sahtu Land Use Plan, and ongoing commitment to the Plan's implementation by the many partners who helped develop it.

10 Contributed Papers

10.1 Concurrent Session #2 – Stock Assessment (Part One)

Session Chair – Graham Van Tighem, Yukon Fish and Wildlife Management Board

10.1.1 Composition and Yield Potential of Lake Trout in Paxson Lake, 2002

BRENDAN SCANLON

Introduction

Lake trout (*Salvelinus namaycush*) support important recreational fisheries in Alaska roadside and remote lake systems. The life history of lake trout however allows this species to be over-exploited when not managed properly. Lake trout are characterized as having slow growth rates, low fecundity, alternate-year spawning regimes, strict habitat requirements (cold, deep, oligotrophic lakes with a sufficient prey base and few competitors), and extreme susceptibility to changes in habitat (Martin and Olver 1980). Careful monitoring of this species is important to help manage the many popular lake trout fisheries.

Because lake trout inhabit deep water and typically occur in low densities, stock assessment research is difficult and costly, and may result in biased and relatively imprecise estimates, particularly in large or remote lakes. In lieu of stock assessments, researchers and managers in Alaska are increasingly using models to estimate yield potential (YP) of lake trout based upon environmental variables such as lake surface area (LA), thermal habitat volume (THV), and concentration of total dissolved solids. Both THV and LA models have been applied to lakes in Alaska.

Lake area models use surface area as a measure of available preferred habitat. As lakes increase in size, so generally does their depth and THV (Marshall 1996). In contrast to THV, LA is relatively static resulting in more stable YP estimates. In the absence of stock assessments, the LA model developed by Evans et al. (1991) has been applied to Alaskan lakes to determine if annual harvests (biomass per year) for lake trout exceed the estimated YP (J. Burr and T. Taube, Alaska Department of Fish and Game, Fairbanks, personal communication).

When applying the LA model to Alaskan lakes, it is recognized that the predicted yields attained from the model are more conservative than from other yield models based on environmental variables (Evans et al. 1991). Therefore in Alaskan lakes, harvests that exceed the estimated YP's are used only as an indication that there may be a potential concern with the stock. Because the model is being used solely as an early indicator of potential concern, uncertainties inherent in it were not quantified as part of this project.

Study Area

Paxson Lake (62˚50' N, 145˚35' W) is located along the Gulkana River, and is part of the Copper River drainage. Paxson Lake is 1,575 ha with a maximum depth of 29 m and an elevation of 625 m. In addition to lake trout, other species found in Paxson Lake include sockeye salmon (*Oncorhynchus nerka*), Arctic grayling (*Thymallus arcticus*), lake whitefish (*Coregonus clupeaformis*), round whitefish (*Prosopium cylindraceum*), Alaska whitefish (*Coregonus nelsonii)*, and burbot (*Lota lota*). Since 1991, 5% of the lake trout harvested in Alaska came from Paxson Lake, and annual harvest has ranged between 2% and 9% of the total Alaska harvest.

OBJECTIVES

Model description

Evans et al. (1991) developed an empirical relationship between estimated harvests (kg/ha^{-1}/yr^{-1}) and lake surface area (ha) from 43 lakes in Ontario, Canada:

$$\log_{10} YP = 0.60 + 0.72 \log_{10}(Area)$$

Applying this relationship to Paxson lake (1,575 ha) results in a YP of 798 kg/yr.

Research objectives

The research objectives for this experiment were to:

1. estimate the proportion of lake trout ≥ 600 mm TL on the known spawning grounds of Paxson Lake such that the estimate is within five percentage points of the true proportion 95% of the time; and,
2. estimate the mean weight of lake trout ≥ 600 mm TL (i.e., vulnerable to harvest) in Paxson Lake with precision sufficient to be 95% confident that the estimated threshold number of lake trout that can be harvested each year (i.e., YP_{number}) does not exceed the true value by more than 20%.

Results

From 11 September through 18 September, 711 unique lake trout were captured (603 males, 108 females) using beach seines on the spawning grounds and sampled for length, sex, maturity, and marked with a uniquely-numbered Floy tag. Of these, 211 were weighed (41 males and 22 females were identified during sampling). There was no observed tag loss or mortality during the experiment, and 70 lake trout with Floy tags from prior experiments were identified.

Length Composition

The mean length of all lake trout was 525 mm FL (SE = 85 mm). The mean length for males was 518 mm FL (SE = 60), and the mean length for females was 570 mm FL (SE = 75 mm. The proportion of lake trout sampled from the spawning grounds that was ≥ 600 mm FL was 9% (SE = 0.5%). This proportion is similar to results from previous experiments conducted on Paxson Lake in 1995 and 1997. The proportion of fish ≥ 600 mm FL was 7% (41 of 603 fish) for males and 18% (22 of 108 fish) for females. The length frequency distribution of lake trout sampled on the spawning grounds in 2000 was significantly different from the length distributions of lake trout sampled using the same procedures in 1995 and 1997.

Yield Potential

The mean weight of lake trout ≥ 600 mm FL captured on the spawning grounds was 2.7 kg (SE = 1.2 kg). The mean weight for males ≥ 600 mm FL was 2.6 kg (SE = 1.6 kg), and the mean weight for females ≥ 600 mm FL was 3.0 kg (SE = 1.9 kg). By dividing the YP of 798 kg/yr by the mean weight of lake trout ≥ 600 mm FL (those fish vulnerable to harvest), the yield potential of lake trout at the current length and weight composition of the population is 278 fish/year.

Growth

Information on growth was supplied by 67 of the 70 lake trout recaptured from previous experiments conducted from 1987 through 1995, and again in 1997. The greatest amount of growth experienced was 185 mm (from 510 mm FL to 695 mm FL) from a female originally sampled on 21 September 1992, and the least amount of growth experienced was 3 mm (from 552 mm FL to 555 mm FL) from a fish of unknown sex originally sampled on 16 September 1994. One measurement of negative growth was likely due to measurement error and excluded. The largest average annual growth rate was 19.43 mm/yr for a fish first sampled in 1995 (555 mm FL to 691 mm FL), and the lowest average annual growth rate was 0.38 mm/yr for a fish first sampled in 1994 (552 mm FL to 555 mm FL). It must be noted that these estimates of annual growth do not account for changes in yearly growth rates between sampling events. For a detailed examination of growth rates of lake trout in Paxson Lake and other lakes in Alaska, see Burr (1997).

Discussion

The yield potential of 278 lake trout/year is higher than was the harvest of lake trout from Paxson Lake in 2000 (228), and higher than the average harvest over the last three years (258 fish). The estimated YP is also close to the average yearly harvest since the regulation was changed to two fish ≥ 24 in (600 mm TL) in 1994 (328 fish /yr). It appears that the change in the harvest regulation has been effective in reducing harvest to near YP levels, and currently there is appears to be no reason to make the current regulations more restrictive or initiate further study.

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10.1.2 Identification and Assessment of Lake Trout Spawning Habitat through Underwater Surveys Using Volunteer Scuba Divers

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Introduction

Identifying and assessing spawning habitat is one of the most difficult and important aspects of fisheries habitat management. Traditionally, fisheries managers have relied upon techniques such as surface observations to detect and describe habitat or passive netting (gill nets/trap nets) to capture spawning adults and indirectly confirm the presence of spawning habitat. These techniques although useful, provide limited information and can be restricted by environmental conditions (visibility) and limited to when the adults are present on the spawning shoals.

For the past several years, Kenora District, Ontario Ministry of Natural Resources has trained and worked in partnership with volunteers to undertake and evaluate a new technique; underwater surveys using volunteer scuba divers. The technique has proven to be an effective and cost efficient tool, expanding the knowledge of lake trout spawning habitats and documenting the impacts of human activities on lake trout spawning habitat.

All projects have been funded through the Community Fisheries and Wildlife Program (CFWIP) and the technique has been applied to a variety of other species.

The presentation is divided into two parts with the first part focusing on the benefits of diving, site selection and the survey technique. Part two summarizes the results of eight lake surveys and over 60 spawning shoal assessments. A case history illustrating the impacts of human activities on lake trout spawning habitat is provided to demonstrate how practical fisheries management data can be obtained using this technique.

Community Fisheries and Wildlife Involvement Program (CFWIP)

CFWIP is an MNR sponsored partnership program that provides volunteers the opportunity to participate in hands on fish and wildlife management projects. MNR provides financial help, expertise, and equipment, while volunteers supply their time, ideas, enthusiasm and expertise. In this case, the MNR has tapped into the expertise of a very specialized group of volunteers, scuba divers.

Each workshop participant was given a copy of CFWIP “Beneath the Surface”. The workshop presentation was based largely on the underwater footage depicted in this video. The video focuses on the value of involving volunteers; how to undertake underwater surveys; and presents three case histories illustrating management problems and solutions derived from the underwater surveys.

Why Dive?

Diving allows us to identify and assess lake trout spawning habitat without restrictions typically associated with traditional assessment techniques. Since the divers are in close proximity to the substrate, visibility is not a factor. Divers use the presence or absence of eggs to confirm spawning habitat. As a result, the time period when the survey can be undertaken is much longer than depending on the presence of adults. Divers can undertake qualitative and quantitative assessments of the spawning shoals, including measuring physical characteristics. Egg distribution, depth and density can also be quantified by divers. Divers can also detect problems and make evaluations that are not apparent from the surface. Underwater cameras allow divers to provide a visual record for others to evaluate and study.

Finally, diving provides the third dimension. In many ways, our traditional sampling techniques are analogous to sending probes into a foreign world; hoping that the samples taken are representative of that world. Diving allows the investigator to enter the fishes' world and see habitat through their eyes.

Why use volunteers?

Volunteer scuba divers provide expertise, training and equipment not readily available to any government agency. Divers and volunteers allow you to expand the scope of your survey and accomplish more in a shorter time period. Each dive team is capable of swimming and evaluating .75 to 1 km of shoreline and can undertake more than one survey in a day. Volunteer divers are plentiful and eager to be involved. We have organized dive surveys ranging from a handful of divers to over 60 divers in the water at one time! Using volunteer divers is extremely cost efficient with cost savings in the range of 10:1.

The educational component of involving volunteers is equally as important. They obtain a better understanding of resource management; the complexity of issues; and difficulties of collecting data. Once they see and understand the problem, they become the greatest advocates and supporters.

How to select sites

Three parameters, basin depth, fetch and substrate, are used to identify potential spawning locations. The first two can be determined with a contour map and for the initial screening process we recommend concentrating on the deepest portion of the lake, and shorelines exposed to fetches greater than 0.5 km. If time is limited, select shorelines oriented to the prevailing wind.

Shorelines identified during the mapping exercise are then assessed in the field for suitable substrate. The interstitial spaces (incubation chambers) within the substrate must satisfy two criteria. They must be clean, free of silt, to ensure the eggs do not suffocate and provide protection from predators. Generally these areas possess multiple layers of material as opposed to a single layer of material and are usually found at depths less than 2m.

Viewing aids as simple as polarized sunglasses to viewing tubes and underwater cameras have allowed us to detect spawning locations not readily apparent from the surface and expanded our knowledge of the types of shoreline lake trout will use. The most surprising locations found were those associated with 90° walls or cliff faces. Lake trout will spawn on underwater ledges or fallen rock debris (talus) associated with these shorelines. Talus sites indicate spawning sites are continuing being created or added to.

Survey Technique

The survey technique is effective and simple and can be taught to divers within an hour. Dive teams generally consist of 4 divers but can be smaller or larger depending on the width of the shoal. The team will swim at a 45° angle from the shore with the dive team leader in front and closest to shore (Figure 1), while the anchor diver ensures the rope is kept tight, preventing the divers from "bunching" up. Divers are attached to the rope two meters apart and look actively for eggs by lifting and moving rocks. When eggs are found, the dive leader is signalled by a tug of the rope and a marker float is released. Volunteers in the accompanying boat record these locations on a map to delineate the size of the shoal and the amount of spawning activity.

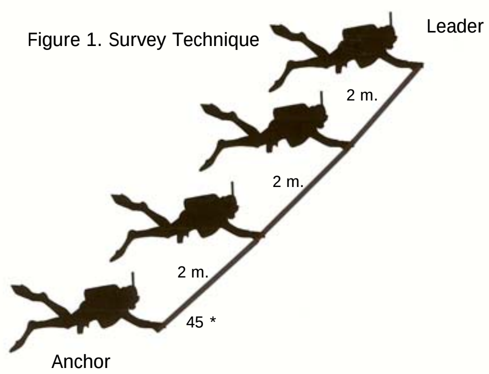

Figure 1. Survey Technique

Shoal profiles are undertaken on representative sites. Again, the survey profile technique (Figure 2.) is simple and provides both qualitative and quantitative information. Two divers extend a 25 m. weighted rope perpendicular to the shoal or to where the shoal drops off steeply. The divers ascend up the marked rope, recording depth, type and condition of substrate and number of eggs they observe in a 1m square on either side of the rope. The divers are instructed to count only the eggs visible on the surface or with the minimal movement of surface rocks. Although this does not provide an accurate density of eggs it does gives an estimate of relative abundance in relation to depth and other shoals. Other techniques including air lift pumps can be used to determine more accurate estimates of egg density.

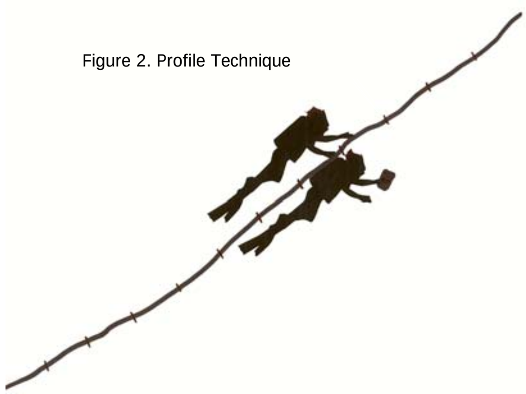

Figure 2. Profile Technique

Knowing the length, width, condition of substrate and relative egg abundance permits a ranking of the shoals. Understanding the physical parameters that constitute high quality spawning habitat can be used in the rehabilitation or construction of spawning shoals.

Summary Results

Over sixty spawning shoals have been assessed and they ranged in length from 10 to 1000 m. with one exceeding 2000m of continuous spawning habitat, but half of it had been lost to shoreline development (see Clearwater Bay Case History). Over ninety percent of the eggs were recorded in depths ranging from 0.5 to 2 m. but occasionally were found in depths exceeding 15 m. These situations occurred with steep profile shoals and we suspect the eggs were deposited in shallow water but "rolled" down to deeper depths.

Two types of shoal profiles have been described from the surveys with Type One being the most prevalent. Type Two profiles are generally associated with steep cliffs or underwater ledges. In both cases, the shoals are adjacent to steep drop offs into deep water.

The surveys showed lake trout will spawn successfully on a variety of substrates as long as the substrate provides a clean protective incubation chamber. Substrates ranged from cobble and boulders in glacial till areas to shale, angular rock, rock/rubble and vertical shale embedded in the substrate in shield areas.

Divers noted that when eggs were broadcasted over large boulders, they were quickly eaten unless they fell into the protective crevices of the substrate. Divers also observed that the surface condition of the substrate can be deceiving. On numerous occasions, surface rock covered with silt or periphyton looked initially unsuitable, but when the diver lifted the surface rock, the area where the eggs would incubate was perfectly clean.

Case History Clearwater Bay: Impacts of Shoreline Development on Lake Trout Habitat.

Divers assessed a spawning shoal adjacent to and within two cottage subdivisions. The survey verified with underwater footage, that shoreline alteration (docks and boathouses etc.) on or adjacent to lake trout spawning habitat results in negative impacts ranging from the degradation of spawning habitat to the total loss of spawning activity and spawning habitat

The negative effects occurred in a variety of ways. In the extreme, spawning habitat was lost by physically covering it with structures such as docks and boathouses. Or the protective rock that provides crevices and spaces for the eggs to incubate had been removed and used in crib dock construction. The impacts also occurred in a subtler manner. Lake trout seek out areas kept clean by wave action and to protect their boats, cottagers build docks to block wave action resulting in sediment and debris being deposited and covering the substrate used by trout for egg incubation.

Divers could detect the difference in substrate quality as they approached a subdivision Within 20 to 40 m. of a subdivision, clean substrate began to be covered with silt and as the divers proceeded through the subdivision the dock effect compounded resulting in the substrate being entirely covered with silt which in turn encouraged macrophyte growth. These observations were not obvious from the surface.

Divers also documented a band of benthic algae occurring at the 6 to 7m depth that occasionally extended into the shallows fronting some cottages.
Samples taken by divers at the impact sites were dominated (98%) by non-nitrogen fixing blue green algae (e.g. Oscillatoriales) which are dependent on an external source of nitrogen. In comparison samples taken at control sites were dominated by diatoms (82%) and nitrogen fixing blue green algae (e.g. Tolypothrix, Nostic, and Anabaena). The source of nitrogen has not been verified yet, but septic leakage may be responsible.

Copies of CFWIP “Beneath the Surface” and the Workshop Presentation can be obtained from the corresponding author.

10.1.3 Using Population-Level Risk and Uncertainty as a Basis for Lake Trout Management in Banff National Park

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Introduction

Since the 1880s, Lake Minnewanka has provided a popular lake trout (*Salvelinus namaycush*) fishery within Banff National Park. As the National Parks Act establishes maintenance of natural systems to be the Park's first priority, managers must assess whether current harvest levels meet this requirement. As neither data nor decisions are perfect, maintenance of native fish population requires weighing uncertainty in information against risk of actions (or inaction). We present a risk assessment approach that allows managers to incorporate this uncertainty and assess potential consequences of different decisions.

We break our approach into six ordered steps. First, the problem must be identified relative to some ecological system (e.g., individuals, populations or communities). Second, the manager must choose an appropriate variable, or variables, that describe the state of the system. Third, a limit reference point (LRP), in units that match the state variable, must be defined. For example, the LRP may delineate a boundary for system viability. Fourth, appropriate actions must be developed relative to where the system lies in relation to the LRP. Fifth, data collection or monitoring is required to determine the current state of the system. And finally, the current system state is compared to the LRP and appropriate management policies are implemented to produce actions identified in step four. Uncertainty is introduced into the assessment at two steps; both the LRP and current system state are not known perfectly.

Methods

1. *Define the problem* – Does current angling harvest from Lake Minnewanka threaten the viability of lake trout populations? While the National Parks Act extends beyond the population level, availability of data prevented us from defining the system at different scales. That is, we could not address community- or ecosystem-level effects.

2. *Identify state variables* – Existing data from Lake Minnewanka consisted largely of creel information collected at periodic intervals starting from the mid 1980s (1984, 1985, 1986, 1991, 1995 and 2000). Given the data, we chose angler harvest ($kg \cdot ha^{-1} \cdot y^{-1}$) as the variable to describe population state.

3. *Define the LRP* – As angler harvest was used as the state variable, we used maximum sustainable yield (MSY) as the LRP. The use of MSY for a reference point has been described previously (Caddy and McGarvey 1996) and differs from its earlier use as a target (Larkin 1977). In our case, MSY is a threshold to be strongly avoided for numerous reasons (Larkin 1977).

The MSY for lake trout in Lake Minnewanka and its uncertainty was based on three sources. First, empirical data from 11 lakes in North America relating long-term sustained yield to maximum asymptotic length of lake trout was used to estimate MSY (Figure 1). Uncertainty was addressed by using parametric (regression equation) and non-parametric (asymptotic lake trout length for Lake Minnewanka) bootstrapping to develop an empirical function for the posterior distribution in MSY with a non-informative prior (Hastie et al. 2001). Second, we used the life-history model of Shuter et al. (1998) and applied it to Lake Minnewanka. Life history parameters for age-at-maturity, natural mortality and age-at-recruitment into the fishery were based on observed asymptotic lengths and growth rates for Lake Minnewanka. Remaining parameters for the model and their uncertainty were taken from Shuter et al. (1998). The model was numerically optimised for fishing mortality to determine MSY. Parametric and non-parametric bootstrapping was again used to develop a posterior distribution for MSY. Third, a statistical catch-at-age model (Haddon 2001) was developed for Lake Minnewanka from the six creel surveys. Although creel surveys were not completed in consecutive years, the longevity of lake trout allowed cohorts to be tracked across multiple surveys. Furthermore, a strong contrast in angling effort and harvest exists between the 1980s (up to 22.5 angler hours·ha^{-1}·y^{-1}) and 2000 (7 angler hours·ha^{-1}·y^{-1}). MSY was obtained from the catch-at-age model through numerical optimisation. Parametric bootstrapping of residuals from the catch-at-age model (Haddon 2001) was again used to develop a posterior distribution. The three distribution functions were combined using Bayesian methods to develop a single empirical distribution for MSY in Lake Minnewanka.

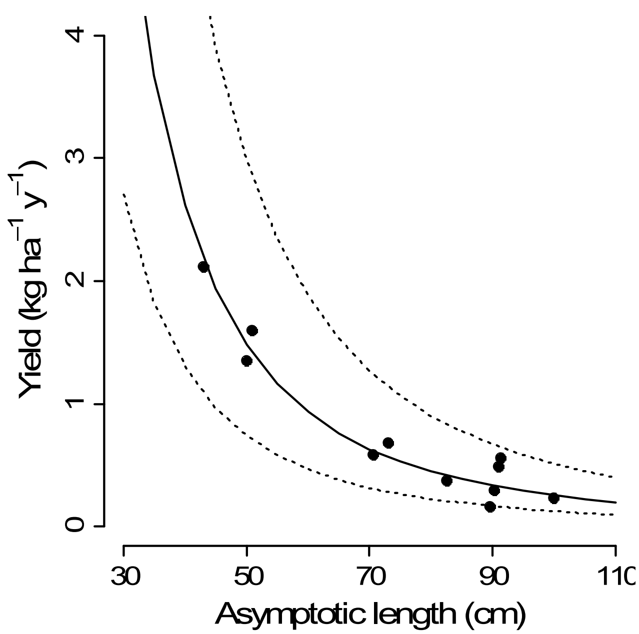

Figure 1. Long-term sustained yield of lake trout from 11 lakes across North America. The solid line is the least-squares regression fit with 95% prediction interval (dashed lines).

4. *Actions required if LRP is exceeded* – If the probability of exceeding the LRP is high, then angler harvest should be reduced. The definition of high will depend on risk levels accepted by managers.

5. *Monitoring to identify current system state* – We used creel data collected in 2000 to estimate current angler harvest and compare this to the LRP. Non-parametric bootstrapping of the creel data was used to develop an empirical distribution for estimated yield (kg·ha^{-1}·y^{-1}) in 2000.

6. *Potential management policies if LRP exceeded* – Current regulations for Lake Minnewanka are a two fish bag limit. If probability of exceeding the LRP was high, we assessed the ability of both a one-fish bag limit and catch-and-release regulations to reduce this probability.

Results

The empirical distribution for the Bayesian estimate of MSY in Lake Minnewanka indicates a 50% chance it is ≤0.72 kg·ha^{-1}·y^{-1} (Figure 2). The distribution incorporates the combined uncertainty within our three methods of estimating MSY: empirical data on long-term sustained yield (Figure 1); Shuter et al.'s (1998) life-history model; and, a statistical catch-at-age model developed from creel surveys. There is a high probability (≈88%) that MSY lies in the interval 0.5-1.0 kg·ha^{-1}·y^{-1} for Lake Minnewanka. Given the creel data for 2000, the most likely harvest estimate for that year is 1.1 kg·ha^{-1}·y^{-1} with a 95% confidence interval ranging from 1.0-1.3 kg·ha^{-1}·y^{-1}. Combining uncertainties in MSY and harvest for 2000 produces an estimated probability of exceeding MSY of 98%.

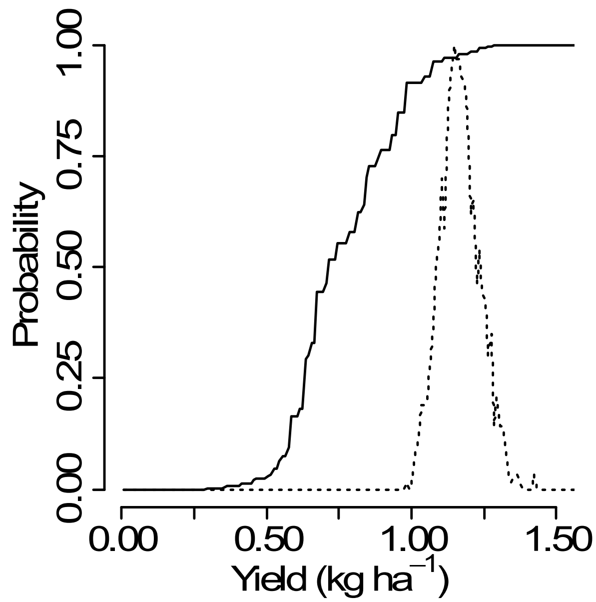

Figure 2 – Empirical cumulative distribution for the Bayesian estimate of MSY in Lake Minnewanka (solid line) and empirical probability density for actual yield in 2000 (dotted line). The probability density for yield is estimated from the creel data and scaled between 0 and 1 for comparison to MSY.

Given a high probability of exceeding the LRP (98%), two management policies for reducing harvest (one- and zero-fish bag limits) were evaluated. Creel data for 2000 show that only 25% of the anglers catch ≥2 lake trout; therefore, a reduction in the bag limit from two to one fish in 2000 would not cut harvest in half. Under a one-fish bag limit, the probability of exceeding MSY in 2000 would have remained at ≈66%. In contrast, dropping the harvest to zero (and assuming a 15% hooking mortality rate) results in a probability of <1% for exceeding MSY in 2000. However, should angling effort increase to mid-1980 levels, the probability of exceeding MSY increases to 31% even with catch-and-release regulations.

Discussion

Given data available and our assessment of MSY, there is a high probability the LRP has been exceeded in Lake Minnewanka and appropriate management policies reducing harvest should be implemented. Switching from a two- to one-fish bag limit does not reduce harvest sufficiently to produce a low-risk scenario; in contrast, catch-and-release regulations do meet this objective provided angling effort remains similar to or less than observed in 2000. Finally, our assessment of MSY is based on limited data for Lake Minnewanka that has been obtained exclusively by anglers. Because these data may be biased, we recommend fisheries independent data be obtained to both: a) improve estimated life-history parameters and population structure used for the derivation of MSY; and, b) provide additional state variables that describe the lake trout population.

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10.1.4 The Winter Habitat of Lake Trout in a Small Boreal Lake

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The winter ecology of lake trout, *Salvelinus namaycush*, has not been well-studied in small boreal lakes. Small lakes stratify strongly in the summer, and can limit feeding opportunities for lake trout in lakes that lack mid-water prey species. The destratification of small boreal lakes in the fall can increase the suitable habitat area and subsequently may represent a time of increased feeding opportunity for lake trout. We used radio-acoustic positioning telemetry and fixed data receivers to examine the spatial and pelagic distribution of lake trout fitted with depth-sensing transmitters. Fish distribution data were collected over three consecutive winters (2002, 2003, and 2004) from Lake 373, a single-basin, 27 ha (Z_{max} = 21 m) boreal shield lake at the Experimental Lakes Area in northwestern Ontario. We examined the habitat used by lake trout during the periods when Lake 373 was destratified, excluding the spawning season. In winter, the depth distribution of lake trout was strongly skewed with half of all recorded lake trout depths in the upper 3 m of the water column (median depth = 2.8 – 3.2 m). This distribution is in contrast to observations from the stratified season, when lake trout were normally distributed at depths which varied between 8.2 – 11.7 m among years. The range in depths that lake trout were observed encompassed the entire water column in both the stratified and destratified periods. The narrow depth distribution of lake trout in the winter suggests a more restricted habitat selection during this time period and may be related to prey availability, although other variables are being examined. A further comparison of spatial distribution and movement patterns will be discussed.

10.1.5 Seasonal Depths and Temperatures Occupied by Lake Trout in Lake Huron as Measured with Implanted Archival Tags

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Surgically implanted archival tags were used to record temperatures occupied by lake trout in Lake Huron during 1999 and 2000 and depths and temperatures during 2002-present. A $100 (US) reward resulted in good cooperation from sport and commercial fishers with returns of around 20% of tags deployed. Datasets spanned from a month at large to over two years. During winter and spring, when the zone of surface water mixing extended below the depth range occupied by lake trout, variability among individual fish and among strains was low and followed surface temperature. From June to mid August, lake trout of Upper Great Lakes origin used significantly warmer waters than lake trout of Finger Lakes, New York origin. Most fish selected summer temperatures lower than preferred temperatures reported in laboratory studies. In October, both strains occupied water temperatures warm or warmer than occupied in summer. In Lake Huron, lake trout of either origin did not move deep enough in winter to experience temperatures two to four degrees above freezing provided by the inverse winter stratification as Chinook salmon did in a companion archival tag study. Most lake trout periodically exhibited a strong diel vertical movement pattern. Some were deeper during the day and moved shallower and warmer at night, but the more common pattern was to be near bottom at night and to become pelagic during the day. We also compared the seasonal depth distributions of lake trout to the distribution of lake whitefish in a companion archival tag study. The lake whitefish is the primary commercial species in Lake Huron and the goal is to mange the whitefish fishery for an acceptable bycatch of lake trout. Distributions are nearly identical in May and June. Lake trout gradually move deeper and the greatest separation occurs in September-November.

11 Contributed Papers

11.1 Concurrent Session #3 – LT Biology (Part One)

Session Chair – Dr. Charles Krueger

11.1.1 Phenotypic Diversity of Lake Trout in Great Slave Lake (NWT)

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Introduction
Lean lake trout have been the focus of major restoration efforts in the Laurentian Great Lakes since the 1950s. Lake trout, however, are not monotypic. Multiple shallow- and deep-water forms were historically known from at least three Great Lakes communities (Goodier 1981, Brown *et al.* 1981). These observations have led to the position that lake trout restoration policies for the Great Lakes should be refined to include deep-water forms (Krueger and Ihssen 1995; Eshenroder and Krueger 2002). Very little, however, is known about the ecology of deep-water forms, and, until recently, phenotypic diversity of lake trout was thought to be restricted to the Laurentian Great Lakes.

Diel vertical migration presents a physiological challenge to deep-water fish, such as lake trout, by requiring them to regulate buoyancy with only partial assistance from the swim bladder (Alexander 1993). As water depth increases, so does the hydrostatic pressure on gas-filled swim bladders. More external pressure increases the amount of gas needed to fill the bladder to maintain neutral buoyancy. As a result, many deep-water fishes, especially those that undergo daily vertical migrations, display alternative buoyancy mechanisms – such as increased fat content or longer paired fins. These mechanisms provide lift that reduces the energy the fish expends overcoming the tendency to sink while swimming with a compressed swim bladder. Consistent with the challenge of buoyancy regulation in deep-water habitats, the deep-water siscowets in Lake Superior have a higher lipid composition than the sympatric shallow-water lean form. Humper trout, the third form known from this lake, are intermediate in lipid composition and habitat depth (Eschmeyer and Phillips 1965).

A better understanding of the phenotypic diversity associated with habitat depth should provide new insight into the ecology and evolution of lake trout diversity and make possible improved restoration policies for the Great Lakes. A growing body of literature has demonstrated that phenotypic diversity of lake trout may be more widespread than previously thought (Blackie et al. 2003, Alfonso 2004, Krueger *et al*., this symposium). We have been exploring the deep-water lake trout communities in several large

Canadian lakes and comparing them to the Lake Superior community. In this presentation, I discuss our findings from Great Slave Lake.

The objectives of our research were to: 1) Determine whether lake trout phenotype is associated with depth-of-capture in Great Slave Lake. Specifically, we were interested in the traits expected to be adaptive in deep- versus shallow-water habitats. 2) Establish whether phenotypes are discrete or continuous. The traditional approach for studying lake trout morphotypes has been to visually assign individuals to a morphotype and then to describe the differences. In comparison, we asked whether "types" exist at all. 3) Compare phenotypes in Great Slave Lake to phenotypes in Lake Superior. The focus of this comparison will be relationships among shape, fin length, coloration, buoyancy, and habitat depth.

Methods

Seventy-two lake trout were collected from 13 gill-net sets across two depth strata (0-50 m and 50-100 m) in the East Arm of Great Slave Lake in Augusts of 2001 and 2002. The East Arm is distinguished from the rest of the lake by its deep-water habitat and rocky substrate. Four measures were obtained from each fish: 1) percent buoyancy with swim bladder deflated (weight in water/weight in air), 2) brightness (coloration), 3) fin lengths (dorsal, caudal, anal, pectoral, and pelvic), and 4) body shape. Morphological measures were digitized from photographs. Body shape was quantified using a geometric morphometric approach. All data reported in this presentation are from lake trout longer than 46-cm standard length.

To test whether each measure differed between depth strata, ANCOVA models were used. Depth strata and sex were the independent factors and standard length was the covariate in these analyses. A UPGMA cluster analysis and a discriminant function analysis were used to determine whether lake trout clustered based on phenotype. Traits included in the cluster analysis were buoyancy, pectoral- and caudal-fin lengths, head depth, body depth, and caudal depth. A two-block partial-least-squares analysis was used to test for covariation patterns between shape, buoyancy, depth, and fin length.

Results and Discussion

1. **Phenotype differed between depth strata.** Lake trout collected from the 50-100-m depth stratum had lower percent buoyancy than those collected from the 0-50-m depth stratum (mean difference 2.4 %; $F_{1,44} = 40.7$, $P < 0.001$). Lake trout in the 50-100-m depth strata were also darker in color ($F_{1,17} = 27.2$, $P < 0.001$), had longer pectoral fins (mean difference 1.3 cm; $F_{1,39} = 21.4$, $P < 0.001$), and deeper body profiles ($F_{28,17} = 6.8$, $p < 0.001$) than those caught in the 0-50-m depth strata.

The low percent buoyancy (higher fat content) and longer pectoral fins of lake trout caught in the 50-100-m depth strata should be adaptive in this habitat if these trout are swimming with compressed swim bladders. Higher percent buoyancies of lake trout in the 0-50-m depth strata may be adaptive if a higher muscle-to-fat ratio improves competitive performance in shallow-water habitats.

2. **At least two groups of lake trout phenotypes exist with intermediates between each mode.** Lake trout grouped based on buoyancy, fin length, and body-depth measures (Fig. 1). Group 1 had low percent buoyancies, long pectoral fins, and deep-body profiles as compared to Group 2. Jack-knifed cross-validation rates of a discriminant function separating these groups were high (Group 1: 91.3% and Group 2: 84.2%). Consistent with this finding, the two-block partial-least-squares analysis

demonstrated that body shape covaried with depth, buoyancy, and fin-length measures (R = 0.87; permutation test $P < 0.001$; Fig. 2). Extreme deep-bodied profiles were associated with deeper water, lower percent buoyancy, and longer pectoral fins. Extreme streamlined shapes were associated with shallow water, higher percent buoyancy, and shorter pectoral fins. Inconsistent with the groupings identified in the cluster analysis, however, was the observation that discrete groups did not occur in the covariance plot. Lake trout intermediate in shape were also intermediate in depth, buoyancy, and fin values (Fig. 2).

Intermediate phenotypes may reflect incomplete reproductive isolating mechanisms, incomplete differentiation among forms, or undescribed forms. Alternatively, they may result from environmental contributions to phenotypic expression (i.e., phenotypic plasticity). Their presence suggests that phenotypic diversification is an ongoing process, not just a historical event.

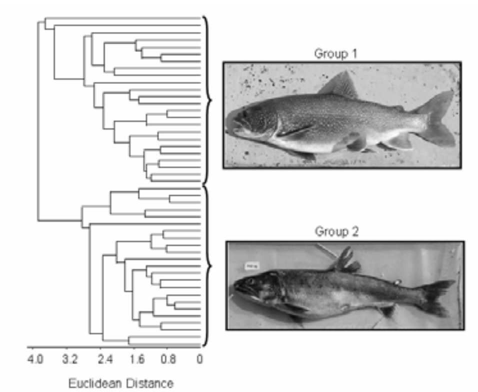

Figure 1: *Two groupings of lake trout phenotypes identified by UPGMA cluster analysis.*

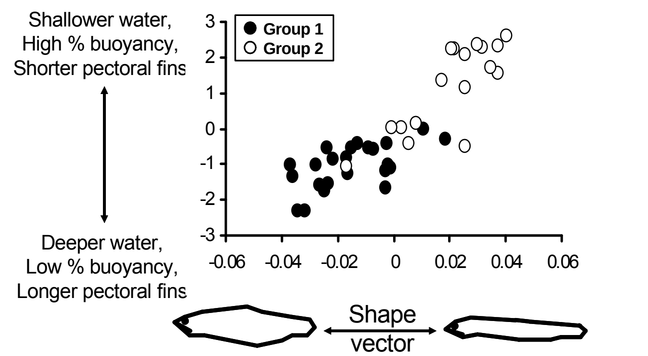

Figure 2: *Covariance between body shape and fin-depth-buoyancy scores derived from a 2B-PLS analysis. Outlines on the x-axis represent extreme body shapes.*

3. **The phenotypic pattern of a shallow-water lean and a deep-water fat lake trout in Great Slave Lake was remarkably similar to the lean and siscowet assemblage in Lake Superior.** Previous genetic studies (Eschemeyer and Phillips 1965; Ihssen and Tait 1974) support inferring a genetic basis for the phenotype-habitat associations observed in both lakes. This association was presumed to be adaptive based on the reasoning presented above.

The parallel patterns observed have two implications relevant to understanding lake trout ecology and their restoration. First, parallel selection pressures, related to buoyancy regulation and habitat depths in these massive lakes, may have contributed to the phenotypic diversification of lake trout. Second, the similar patterns in both Lake Superior and Great Slave Lake, a less perturbed community, may provide a basis for refining restoration objectives to include deep-water lake trout in the Laurentian Great Lakes.

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11.1.2 Deep and Shallow Water Forms of Lake Trout in Lake Mistassini (QB)

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Introduction

Lake trout phenotypic diversity correlates, in part, with the use of deep-water habitats and was believed, until recently, to be restricted to the Laurentian Great Lakes. Two of the three forms known from Lake Superior, the humper and siscowet, inhabit deep water and coexist with a shallow-water lean form (Khan and Qadri 1970, Moore and Bronte 2001). The recent discovery that phenotypic diversity occurs across a broader geographic scale (i.e., Great Slave Lake and Great Bear Lake) gives new insight to the present understanding of lake trout ecology and evolution. Deep-water habitats in Great Slave Lake, for example, are occupied by a deep-bodied, high-fat-content, blunted snout, similar to the siscowet in Lake Superior (M. Zimmerman *et al*., this symposium). A siscowet-like form has not been described from Great Bear Lake; however, research on this lake has focused primarily on shallow-water habitats (Blackie *et al.* 2003, Alfonso 2004, K. Howland *et al.*, this symposium).

The ubiquity of a siscowet-like trout in deep-water communities would provide a context for understanding the origins and maintenance of lake trout phenotypic diversity. Humper trout in Lake Superior are also similar to siscowets in that they have higher lipid content than leans (humpers are intermediate to leans and siscowets) (Eschmeyer and Phillips 1965) but differ from siscowets in their morphology, habitat distribution, and life history (Rahrer 1965, Burnham-Curtis and Bronte 1996, Moore and Bronte 2001). Humper trout have been hypothesized to be a "form" of lean (Eschmeyer and Phillips 1965) or to be hybrids between leans and siscowets (Burnham-Curtis 1993, Burnham-Curtis and Smith 1994). If deep-water communities outside the Great Lakes are dominanted by humper-like trout, hypotheses on lake trout phenotypic differentiation should be re-examined.

The present study documented phenotypic diversity of lake trout in a large, deep lake (Lake Mistassini) on the eastern extent of the species range. While of substantial size (2150 km^2), Lake Mistassini covers less than 1/10th the area of Lake Superior or Great Slave Lake. We test the hypotheses that 1) lake trout occupying deep-water habitats in this lake will have lower percent buoyancy (i.e., higher lipid content) than those occupying shallow-water habitats and that 2) a deep-water form, if present, will resemble siscowet trout from Lake Superior and Great Slave Lake. Our research focused on three objectives. First, we determined whether lake trout phenotype was associated with capture depth. Second, we tested whether discrete forms of lake trout could be identified without prior categorization of individuals. Third, any existing deep-water phenotypes from Lake Mistassini were compared to those known from Lake Superior and Great Slave Lake.

Methods

One hundred twenty-three trout were collected in 12 gill-net sets across three depth strata (0-50 m, 50-100 m, and 100-150 m) in the east and west arms of Lake Mistassini (50º40'N 73º20'W). Four measures were obtained from each fish: 1) percent buoyancy with swim bladder deflated (weight in water/weight in air), 2) brightness (coloration), 3) fin lengths (dorsal, caudal, anal, pectoral, and pelvic), and 4) body shape. Morphological measures were digitized from photographs. Body shape was quantified using a geometric morphometric approach.

To determine whether each measure differed among depth strata, ANCOVA models were used. Depth strata and sex were the independent factors and standard length was the covariate in these analyses. Two UPGMA cluster analyses based on shape measures and on buoyancy-brightness-depth measures were used to determine whether lake trout clustered based on phenotype. The validity of identified clusters was evaluated based on jack-knifed classification rates of a discriminant function analysis and on the consistency of individual membership to groups identified in these two analyses. A two-block partial-least-squares analysis was used to test for covariation patterns between shape, buoyancy, brightness, and depth.

Results and Discussion:

1. **Phenotype of lake trout caught in less than 50 m of water differed from those caught deeper than 50 m.** Lake trout in the 50-100-m and 100-150-m strata had lower percent buoyancies (Fig. 1A), were lighter in color (Fig. 1B), and had different body shapes (Fig. 1C) than those collected from the 0-50-m stratum. The deep-water lake trout had blunter snouts, deeper head and midbody profiles, narrower caudal peduncles, and eyes at higher head elevations than the shallow-water lake trout. Fin lengths (size-adjusted) also differed between depth strata (MANOVA: $F_{5,89} = 3.5$, $P = 0.006$); however, these differences were not likely to have a functional significance. Pair-wise comparisons of individual fin lengths between the 0-50-m and 50-150-m strata did not differ (ANOVA: $P > 0.1$), and the function that best discriminated fins between depth strata (Wilks $\lambda = 0.83$, df = 5, $P = 0.003$) had a very low jack-knifed classification rate (69% for the 0-50-m stratum and 63% for the 50-150-m stratum).

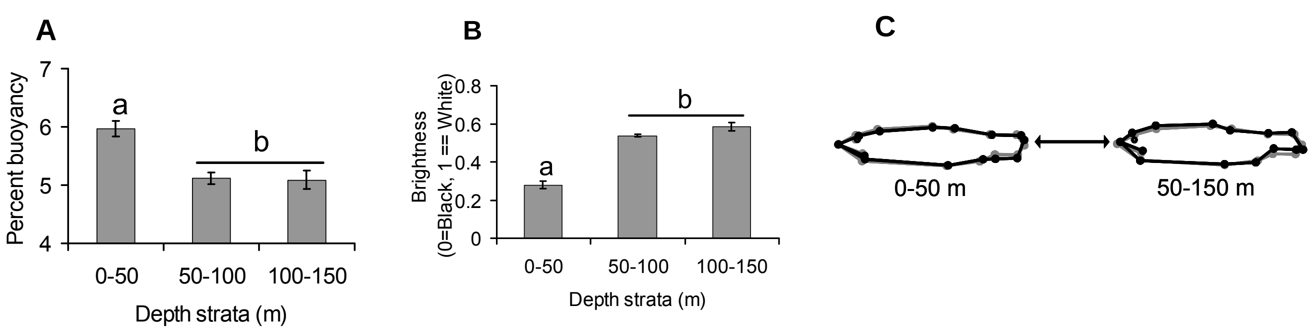

Figure 1. Lake trout buoyancy **(A)** ($F_{2,84} = 15$, p << 0.001), brightness **(B)** ($F_{2,70} = 92$, p << 0.001), and shape **(C)** ($F_{28,55} = 5.1$, p << 0.001) differences among depth strata in Lake Mistassini. For each measure, the 0-50-m stratum differed from the 50-100-m and the 100-150-m strata, but the two deepest strata did not differ from each other (Scheffe tests: P < 0.01). Graphs show means and standard errors of size-adjusted measures. Dark outlines in **(C)** represent the shape characteristic of each depth strata. Gray outline in **(C)** is the average shape of lake trout in Lake Mistassini.

2. Two forms of lake trout exist in Lake Mistassini, but phenotypes do not occur as discrete groups. Two groups were identified by cluster analysis based on shape, buoyancy, brightness, and depth measures (Fig. 2). In general, Group 1 were dark-colored, high-percent buoyancy lake trout with a streamlined shape that were collected from shallow habitats. Group 2 were light-colored, low-percent buoyancy lake trout with a deep head and mid-body profile and narrow caudal peduncle that were collected from deep-water habitats.

Jack-knifed classification rates of the function discriminating between Groups 1 and 2 were high in both analyses (shape classification - 90%; buoyancy-brightness-depth classification - 100%). Twenty-four percent of the individuals, however, were assigned to different groups in the two analyses (76 % consistency between analyses). This result was likely due to the presence of intermediate phenotypes whose body shapes sort differently than buoyancy-brightness-depth values with respect to the general shallow- versus deep-water phenotype. The presence of intermediate phenotypes was supported by results of the two-block partial-least-squares analysis. A plot of covariance among traits demonstrated a continuum of body shapes and a broad spectrum of buoyancy, brightness, and depth values associated with intermediate shapes ($R = 0.66$; permutation test $P < 0.001$; Fig. 3).

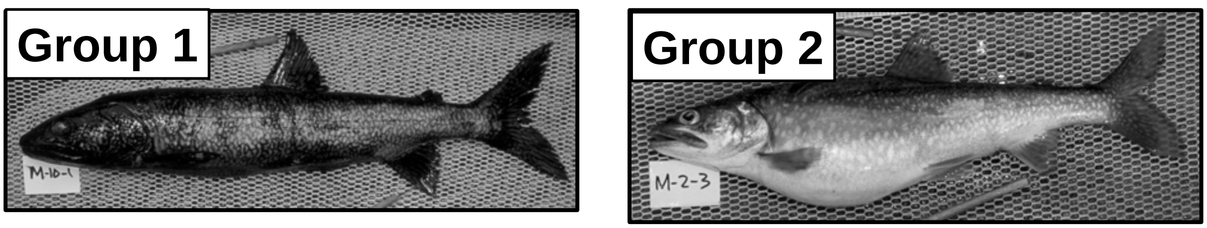

Figure 2. Lake trout forms in Lake Mistassini identified from cluster analyses based on body shape measures and buoyancy-brightness-depth values.

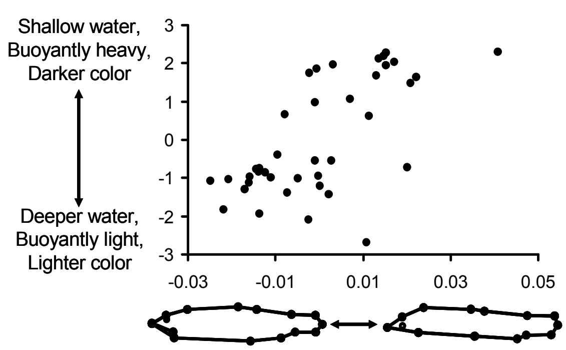

Figure 3. Covariation between shape and buoyancy-brightness-depth measures of lake trout in Lake Mistassini as identified by a two-block partial-least-squares analysis. This plot explains 86 % of the covariation between shape and buoyancy-brightness-depth blocks. Outlines on x-axis represent extreme body shapes along this axis.

3. **Deep-water lake trout in Lake Mistassini, Lake Superior, and Great Slave Lake have lower percent buoyancies than the sympatric shallow-water lean forms.** This finding suggests that a common selective pressure associated with buoyancy regulation in deep-water (i.e., high pressure) habitats has contributed to phenotypic differentiation in lake trout.

Deep-water lake trout in Lake Mistassini resemble the humper trout from Lake Superior. As compared to the sympatric lean form, the deep-water trout in Lake Mistassini, like the humper trout of Lake Superior, had lower percent buoyancies, deeper head and midbody profiles, narrower caudal peduncles, and smaller size at maturity. Distribution and abundance of humper-like trout, however, differed between lakes.

Humper trout in Lake Superior occur as isolated populations on offshore humps that resemble sea mounts. Humper-like trout in Lake Mistassini were abundant in deep-water habitat of little relief as well as on offshore humps and steep banks along the shoreline.

These results challenge the hypothesis that humper trout have resulted from hybridization of lean and siscowet forms and give new perspectives for hypotheses regarding lake trout speciation in North America. Siscowet-like trout were not found in Lake Mistassini. Their absence from our sampling, however, does not prove their absence nor does it reveal whether siscowet-like trout were historically present in this lake. If a siscowet-like form has never inhabited Lake Mistassini, the existing humper-like form must either be the descendent of a colonizing form (presumably the lean form) or have resulted from dispersal of an ancestral humper population following deglaciation. At present, we favor the first explanation; however, resolution awaits genetic analysis of our samples. If a siscowet-like form has historically (or does presently) inhabit Lake Mistassini, the comparatively high abundance of the humper-like form suggests that the humper phenotype is competitively dominant in this lake.

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11.1.3 Differentiation of Lake Trout Forms: A Working Hypothesis

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Introduction

Among North America's Great Lakes, Lake Superior is foremost in having had its lake trout described as distinct phenotypes (forms) of which there are three—a shallow-water piscivore (so-called lean), a high-fat-content deep-water piscivore, and a small-bodied, deep-water, invertebrate feeder (the humper). Forms superficially similar to these have been reported (this conference) as occurring in either Great Slave Lake or Lake Mistassini (QB), and we have observed humper-like and fat-like forms in Great Bear Lake. The existence of three of these general forms in at least one or more of four lakes suggests that common selection pressures, peculiar to very large lakes, maintain the diversity of these lake trout complexes. Here, for purposes of discussion, we assume that the shallow-water piscivore, the widely distributed lean, was ancestral in each of these lakes and the fat-like and humper-like forms, where they occur, were derived in sympatry. Based on these assumptions, we advance a hypothesis on the sequence of speciation events for lake trout in large lakes and identify possible mechanisms for separation.

Results and Discussion

A form of lake trout resembling the humper of Lake Superior occurs in all four of the large lakes known to contain multiple forms of lake trout whereas the fat-like morphotype has been observed from just three (does not occur in Lake Mistassini). The wider distribution of the humper-like form suggests that it can differentiate more readily than the fat-like form, making it a stronger candidate for the first speciation event in large lakes. In Lake Superior the humper is found only on isolated, deep offshore reefs (humps). A deep-water lake trout resembling the humper also coexists with a lean form in Rush Lake, a small (~300 ha) water body located very near Lake Superior in the state of Michigan. This disjunct distribution, however, may be an artifact of post-speciation events.

We suggest that humper-like lake trout were much more widely distributed in Lake Superior during deglaciation than in modern times, a finding consistent with our idea of their early speciation. Rush Lake ~10,000 YBP was a small depression in the bottom of Lake Duluth, which was the first of the proglacial lakes of zoogeographical significance to inundate part of what today is Lake Superior. At present Rush Lake is 82 m deep and its elevation is 12 m higher than the surface of Lake Superior, but during Lake Duluth times the depression that was to become Rush Lake had a depth of 227 m. We infer that, as the proglacial lakes receded, humper-like and lean-like lake trout were stranded in Rush Lake (leans could have invaded later via rivers) and have coexisted since that time. If true, humper-like trout at one time inhabited inshore waters, indicating their range has since contracted.

Assuming humper-like trout arose in the first speciation event and became widespread in deep water, what caused the ensuing speciation of the fat-like lake trout? Here we suggest that speciation of ciscoes provided a novel deep-water pelagic food that fundamentally changed the food web of the large lakes discussed here. Deep-water ciscoes, comprising six named species, were especially prominent in the Great Lakes where they supported an important commercial fishery. Less is known about the abundance of deep-water ciscoes in the Canadian Great Lakes under discussion. The shortjaw cisco (*Coregonus zenithicus*), one of the deep-water ciscoes of the Great Lakes, occupies deep waters in all of the large lakes (our tentative finding) known to contain multiple forms of lake trout. Insomuch as the shortjaw cisco is much less widespread than its presumed ancestor, the cisco (*C. artedi*), and only occurs in sympatry with it, we assume that the shortjaw cisco is a recent species. The addition of a whole trophic level (planktivores) in the deep-water pelagia of these large lakes would have created opportunities for lake trout to expand its niche. We hypothesize that adaptations associated with feeding more efficiently on this new trophic level resulted in differentiation of the piscivorous, fat-like form of deep-water lake trout. This scenario infers that humper-like trout were already speciated before deep-water forms of ciscoes proliferated. We further hypothesize that once what would become the derived forms of lake trout separated from their ancestor, they were selected to varying degrees for traits, such as lower specific gravity, longer fins, more closely spaced eyes, and/or a larger eye, that are associated with piscivory while making rapid ascents from waters deeper than 100 m.

We believe that separation precedes differentiation in fish like lake trout that spawn in aggregations. Just how separation of lake trout populations occurred in large lakes is obscure. Severe drops in lake levels that turn deep-water spawning sites into shallow-water spawning sites is widely recognized as one way for lacustrine fish to separate. This mechanism has been proposed for the Great Lakes where water levels have cycled through drops of as much as 60 m. Storm events, especially in large lakes, disperse lake trout eggs spawned in shallow water to deep water where they can entrain in substrates suitable for incubation, and, conceivably, any survivors may, as adults, home back to such sites for spawning, creating disjunct populations. A third possibility involves over crowding and selection for deep-dwelling phenotypes. If spawning habitat is not limiting, those fry emerging from incubation sites that warm slightly earlier may, because of their larger size, out compete fry emerging from later-warming (deeper water) sites resulting in a severe culling of progeny originating from deeper sites. Severe culling could favor selection for phenotypes that occupy deep waters to lessen competition with individuals originating from shallower spawning sites. This process seems possible only in very large lakes where a culled spawning aggregation is isolated enough from other spawning aggregations to allow selection to overcome the inhibitory effects of immigration.

11.1.4 Phenotypic Diversity of Lake Trout in Great Bear Lake, NWT

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Introduction

Great Bear Lake is the last of the great lakes to contain lake trout populations that have not been severely altered by exploitation and therefore provides an example of how under natural conditions lake trout function in a large lake ecosystem. There has never been a large scale commercial fishery on Great Bear Lake. There is, however, a world class trophy sport fishery and a subsistence fishery, with the majority of fishing taking place in waters of less than 30 m deep. Stock assessment studies of lake trout over the past 5 years have revealed a great deal of morphological variation in the lake trout of Great Bear Lake coupled with divergent growth and dietary patterns within the lake trout stocks inhabiting these shallow areas (Howland et al. 2004).

Our initial assessments of lake trout size-at-age among individuals showed a pattern of divergence at approximately 10 years of age indicating two growth patterns within the population, while field observations suggested a substantial level of variation in both diet and morphology of lake trout in Great Bear Lake. Initial comparisons of stomach contents during field sampling showed a possible relationship between patterns of growth and diet where invertebrate feeders exhibited slower growth (Howland et al. 2004). We predicted there might also be a link between variation in morphology and diet/growth patterns given that this has been well documented for a number of fish species, particularly Salmonids. To obtain a more complete understanding of the relationship between diet, growth, and morphology, we have taken an approach of combining stable isotope analyses with detailed identification of stomach contents and digital imaging of lake trout morphology.

Methods

All samples were collected as part of stock assessment studies conducted in the Keith Arm area of Great Bear Lake between 2000 and 2005. Stomachs were frozen in the field and later preserved in 70% ethanol. Dietary items were sorted by eye or using a low-power dissecting microscope. Items were categorized as fishes or invertebrates and, where possible, identified to species (fishes) and order (invertebrates). Invertebrates were further categorized as surface, benthic, or pelagic, and fishes were measured (where possible) and categorized as large (>100 mm) or small-bodied (<100 mm). Fish muscle tissue and whole invertebrates were frozen in the field for subsequent stable isotope analyses. These samples were later dried to a constant mass at 65ºC, ground to a fine powder and analyzed for carbon and nitrogen at the National Water Research Institute Stable Isotope Hydrology and Ecology Laboratory. Results were recorded as δ values in per mil (‰) deviations from international standards where enrichment per trophic level is expected to be 3-5‰ and 0-1‰ for $\delta^{15}N$ and $\delta^{13}C$, respectively (Peterson and Fry 1987). Digital images were recorded for all trout sampled over the past 3 years with the intention of quantifying morphological variation and relating these to patterns of diet and growth. For the preliminary analyses presented in this paper, lake trout morphotypes were categorized by eye based on key traits. Ideally, types should be quantified through body measurements which is being conducted at the present time.

Results and Discussion

Diet - Detailed examination of stomachs from lake trout collected in Great Bear Lake during 2002 showed that they fed on a variety of food items and that the majority of invertebrates in the diet were surface or pelagic rather than benthic in origin (Table 1). In contrast to more southern lakes, trout may be able to spend more time feeding at the surface in Great Bear Lake because of the cooler water temperatures during summer months. Most stomachs had either exclusively invertebrates, a combination of invertebrates and small-bodied fish, or exclusively large-bodied fish (Table 2).

Table 1. Lake Trout Stomach Contents 2001/02 (n=112)

Invertebrates	
Surface:	
	Dragon flies (Odonata)
	True flies (Diptera)
	Flying ants, Wasps (Hymenoptera)
	Moths (Lepidoptera)
	Grasshoppers (Orthoptera)
	Beetles (Coleoptera)
Benthic:	
	Amphipoda
	Diving beetles (Coleoptera)
	Caddis fly larvae (Trichoptera)
Pelagic:	
	Mysis relicta (Mysidacea)
Fish	
Small-bodied: (20%)	
	Slimy sculpin (*Cottus cognatus*)
	Ninespine stickleback (*Pungitius pungitius*)
	YOY lake cisco (*Coregonus artedii*)
Large-bodied: (20%)	
	Lake cisco (*Coregonus artedii*)
	Burbot (*Lota lota*)
	Grayling (*Thymallus arcticus*)
	Round whitefish (*Prosopium cylindraceum*)
Other	
Duck leg	

The basic food web for Great Bear lake based on stable isotopes is shown in Figure 1. This is a preliminary summary. The $\delta^{15}N$, a good indicator of trophic status, showed that most lake trout fed at the highest trophic position, approximately 3% higher than forage fishes such as lake cisco, slimy sculpin, and nine spine stickleback suggesting that most have fishes in their diet even though stomach content data do not necessarily confirm this. The $\delta^{13}C$ which provides an indication of food base (terrestrial, aquatic, pelagic, or benthic) was quite variable for lake trout suggesting a mixed diet. However, most samples were around -27‰ which is consistent with a terrestrial food source or a lake cisco diet. When we examined the stable isotope signatures in relation to stomach contents, we did not see any pattern of separation between lake trout with invertebrate versus fish diets. The lack of concordance between stomach contents and stable isotope signatures may be because lake trout which appear to be feeding exclusively on invertebrates (based on stomach contents) actually have some fish in their diets. Perhaps there is seasonal variability in food sources that was not accurately reflected in our samples which were collected during the open water season. Individuals that utilize abundant surface insects during the warmer open water period may need to switch to other dietary items in periods when this food source is unavailable. Additionally, some of the predaceous terrestrial invertebrates within the diet of insectivorous lake trout may have enriched $\delta^{15}N$ (e.g., dragon flies) leading to a higher signal in these trout. Further stable isotope analysis of

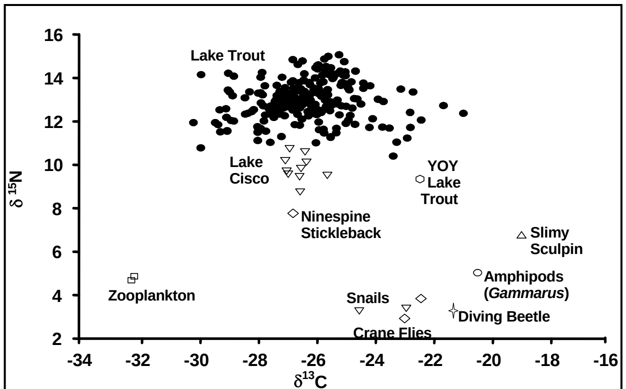


Figure 1. Food web of Great Bear Lake based on results from stable isotope analyses. Data for adult lake trout and lake cisco were collected as part of this study. All other data were provided by Marlene Evans (Environment Canada, Saskatoon)

other components of the food web, particularly invertebrates commonly found in stomachs of lake trout will help address this question.

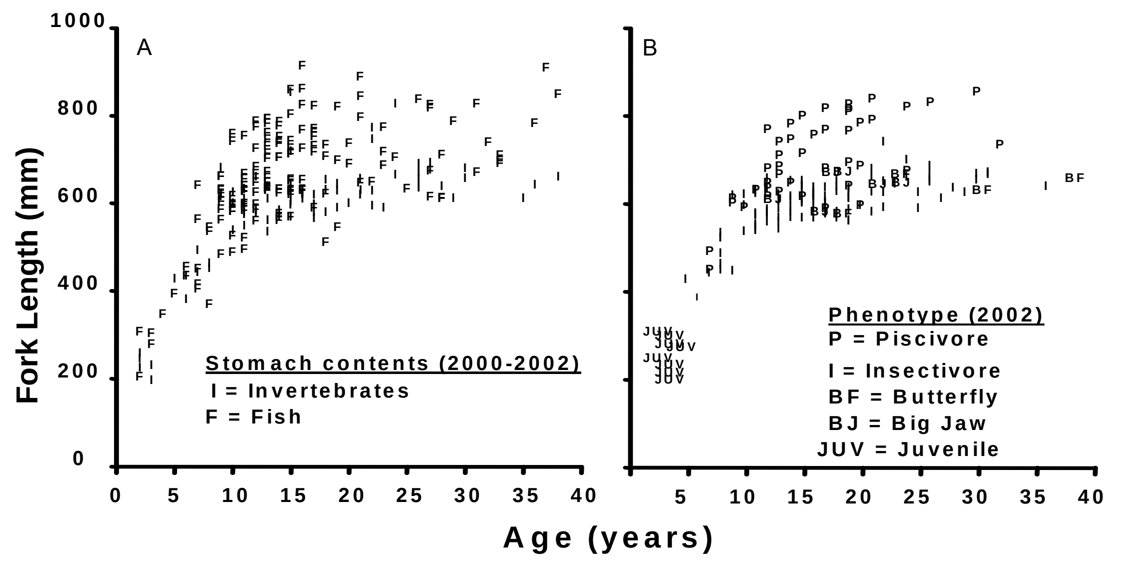
Table 2. Proportions of lake trout morphotypes (piscivore vs. insectivore) containing broadly grouped dietary items. Stomach contents were grouped according to body size of forage fishes and presence/absence of invertebrates, and based on samples collected during 2002 for which there were full stomachs (n=73).

Stomach Contents	**Piscivore (%)**	**Insectivore (%)**	**All (%)**
Large Fishes (>100 mm)	57	4	30.5
Large Fishes (>100 mm) & invertebrates	13	4	8.5
Fishes (size unknown) & invertebrates	-	13	6.5
Small fishes (<100 mm)	4	2	3
Small fishes (<100 mm) & invertebrates	9	27	18
Invertebrates	17	50	33.5

Morphology – Using easily visualized key traits, we identified at least 4 types of lake trout that occur in regularly fished areas (<30m deep) and a 5th type that is predominantly found in deeper areas. Interestingly, our findings concur with traditional knowledge of local residents, which independently suggests there are 5 types of trout in the Keith Arm area of Great Bear Lake (personal communication; Charlie Neyelle, elder, Deline, NWT). We named and characterized the 4 shallow water types as follows: a) "Piscivore (Grey)": flat head, long jaw, short fins, elongate body, and long narrow caudal peduncle; b) "Insectivore (Red Fin)": curved head, short jaw, moderate fins, deep body, and moderate caudal peduncle; c) "Butterfly" (2.5%): long fins, sub-terminal mouth, deep body with hump, and short wide caudal peduncle; "Big Jaw (Bulldog)" (2.5%): large curved sub-terminal lower jaw. The piscivorous and insectivorous forms were most common, making up 95% of the fish that we collected.

Relationships between morphology, diet and size at age – We found a good relationship between morphology (two common trout morphs) and diet. A high proportion of the piscivorous form had large fishes in their diet, while the opposite pattern was seen in the insectivorous form where most individuals had either invertebrates or a mixture of invertebrates and small fish in their diets (Table 2). However, when we examined stable isotope signatures of these morphs, we did not see any pattern of separation. The overlapping isotope signatures suggest diet is quite varied and that the insectivorous morph likely feeds on both fish and invertebrates. This is supported by the stomach content analysis which showed this morph to frequently have smaller bodied fishes in the diet.

When we examined diet and morphology in relation to size at age, we found both were good predictors of this biological parameter. Furthermore, clear separations occurred between lake trout with different diets and the different morphs. Lake trout with an invertebrate diet (Fig. 2A) or the insectivorous morph (Fig. 2B) tended to be a smaller size at age.



Figures 2. Size at age for lake trout with A) invertebrate vs. fish diets and B) of various morphotypes

Conclusions

The results of our work show that there is clearly variation among lake trout even within shallow water habitats of Great Bear Lake. There may be further diversity in shallow inshore or pelagic areas. However, Johnson (1975) suggested that most trout in Great Bear lake are located at depths of less than 30 meters, the depth at which we captured most of our samples. If deep water variants exist, they are probably less abundant than shallow-water forms and less likely to be targeted during sport fishing. Further work in other basins of Great Bear Lake (currently in progress) will give us a better idea if this level of variation is common throughout the lake and if similar morphs exist elsewhere.

We saw consistent relationships between growth, morphology, and stomach contents. However, stable isotopes signatures did not appear to be related with type of diet or morphology. Because the type of diet (large versus small food items) and morphology (piscivore versus invertebrate feeding body form) were good predictors of size-at-age, gape limitation rather than other specialization may largely determine the diet of individual trout within the lake. Lake trout are opportunistic feeders as indicated by stomach contents and stable isotope signatures. They appear to utilize a wide range of food items which are probably varied throughout year. We suggest that lake trout morphs with a smaller gape feed mainly on invertebrates and small fish whereas those with larger gape feed on larger bodied fish. Variation in size at age among morphs is likely related to differences in the quality of these two diets.

Further research will involve stable isotope analyses of lake trout stomach contents to get a better idea of the relative contribution of food web components to accretion of lake trout flesh. We are also currently developing better quantitative methods for identifying lake trout morphs (morphometric analyses of both shape and linear measures) with the hope that this will allow us to more accurately and easily categorize samples. Once we have categorized types, we plan to examine genetic patterns to see if there is any evidence of reproductive or ecological segregation.

We feel it is important to account for this variation to effectively manage the lake trout populations of Great Bear Lake, particularly if there is substantial growth difference between the two most common morphs. We need to be aware of such differences and how these may influence various biological indicators we use in stock assessments. These findings have implications for catch and release in the sport fishery on Great Bear Lake because smaller lake trout are typically kept for shore lunches under the assumption they are younger. Based on our results, typical sizes of trout that are kept for shore lunches may be some of the oldest and slowest growing fish in the population. Thus, some lake trout morphs may be harvested at a higher rate than other morphs.

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11.1.5 Niche Selection and Phenotypic Variation in Lake Trout

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Lake trout, *Salvelinus namaycush*, are known to have a high degree of phenotypic variation. Micro-evolution of lake trout morphs in North America has been proposed to be correlated to the development of niche differentiation. In large lakes there have been many morphologically distinct types described with two forms, the "siscowet", *S. namaycush siscowet*, and the "lean", *S. namaycush namaycush* being recognized as sub-species.

Historically, there have been a variety of forms described based on habitat, external coloration, flesh coloration, size at maturation, diet, and external morphology or shape. The earliest description was by Thompson (1883) who described several forms in the Laurentian Great Lakes such as "Salmon trout" which were large (up to 70 lbs); "siscowitt" (up to 12 lbs); half-breed "siscowitt" (up to 5 lbs), "potgut" (up to 12 lbs); "rock or black trout" (up to 40 lbs); "gray or shovel-nosed trout" (up to 70 lbs); "California trout" with yellow spots and flesh (up to 10 lbs) and "red trout" (up to 42 lbs). Goode (1884) noted varieties in Lake Michigan such as "black trout" with salmon colored flesh; "lake trout" with white flesh; "reef trout or racers" which were long and slim with coarse meat in shallow water; and "potbellies", a short, "chubby" variety taken in deep-water. Goodier (1981) noted several forms in Lake Superior such as "leans" with having streamlined bodies, coarse (dry) flesh and inhabiting shallow waters; "humpers or paper-bellies" on reefs; "siscowets and half-breeds" which were fatty, chunky deep-water forms. Brown et al (1981) recorded four variants in Lake Michigan: "black siscowets"; "white siscowets"; "half-breeds" which they concluded might be immature siscowets; and "humpers" which had a very white ventral region with thin skin on the belly. Hubbs and Lagler (1949) noted a unique form in Rush Lake. Also, variants have recently been observed in Canada's Northern Great Lakes. For example "leans" and "siscowets" have been observed in Great Bear Lake (J. Johnson DFO pers. comm.). In Great Bear Lake we have recorded five morphs to date: a large "lean" or "gray" form similar to those noted by the authors above; "humpers"; and three rather unique forms "redfins", trout with very bright red fins; "butterfly trout" with long flowing fins both of which inhabit surface waters and feed on insects and "bulldog trout" which have heavy jaws and feed on fish (Table1).

There are several hypotheses proposed for how lake trout have radiated. Based on the observation that leans and siscowets occupy different depths and that the morphology, fat content and swim bladder differs it has been proposed that the driving selective force on lake trout evolution is depth. Alternatively, diet variation with corresponding growth patterns and morphological changes has been proposed as driving the development of different forms. Other suggested factors are water conductivity, lake size, latitude, climate change and intra and inter-specific competition.

Table 1. Lake trout forms observed in Canadian Lakes.

FORM	HABITAT	E. COLOR	SIZE	FLESH	DIET	SHAPE
Lean/Lake	Shallow		32 kg	White	Fish	streamlined
Siscowett	Deep		5 kg	White/oily	Fish	chunky
Humper/ Potbelly	Shallow	White belly	5 kg	White		Deep belly
Half - breed	Deep		2 kg	White/oily		chunky
Black/Rock	Shallow	Dark?	18 kg	Red		
Reef/Racer	Shallow		?	White		
Salmon	Shallow		32 kg	Red?		
Gray	Shallow	Light?	32 kg	White/Red	Likely differs	Shovel-nosed
California	Shallow	Yellow spots	4 kg	yellow		
Red	Shallow		19 kg	Red?		
Bulldog	Shallow		5 kg	Pink	Fish	Heavy jaw
Redfins	Surface		5 kg	White	Insects Fish	
Butterfly	Surface	green	5 kg	Red/White	Insects Fish	Long fins

Perhaps, many of these factors combined to cause rapid radiation of the lake trout type. We propose that lake trout evolution has been influenced by the gradual climate amelioration from the last ice age and the resulting effects on the environments available to lake trout in large lakes. In stage 1 after glaciation there were large pro-glacial lakes such as Lake McConnell (Figure 1). These lakes were cold and swept by high winds coming off the glaciers which created a constantly churning, turbid environment that has no analog today. There was likely colonization by lake trout and possibly rapid development of diverse types in this system. Stage 2 involved "post-glacial" lakes where the climate has warmed, the glacier has moved back and the high winds and glacial fed melt water subside enough for the lake to become clear. The lake has a relatively constant temperature within the range preferred by lake trout and does not stratify. The lake trout have unlimited access to all parts of the lake. There is rapid development of diverse types with insectivores, benthic feeders and fish eaters developing. Allochthonous foods such as flying terrestrial insects play a major role and surface feeding rainbow trout-like forms evolve as well as some of the standard forms. A good example of this stage might be Great Bear Lake. Stage 3 occurs when the climate warms enough that lakes stratify in summer. These changes drive lake trout into specialization for shallow or deep habitats characterized by the lean and siscowet forms. Some types such as the insectivores die out whereas others come into existence (e.g. siscowets). Lake Superior and Great Slave Lake are good examples of stage 3. Stage 4 involves further radiation into shallow and deep forms. As the climate warms more the shallow forms become isolated from each other in different sections of the lake and develop specific adaptations to localities. The lower Great Lakes such as Lake Ontario or Lake Michigan are stage 4 examples. A summary of the radiation of forms from glaciation to stage 4 is shown in figure 2.

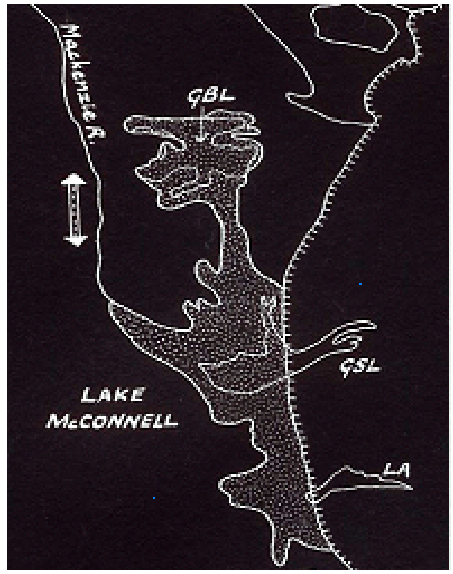

Figure 1. Glacial Lake McConnell at 10k B.P.. The outlined modern lakes are LA - Lake Athabasca; GSL - Great Slave Lake; GBL - Great Bear Lake. Lake McConnell is stippled and the glacial front projecting from the left side.

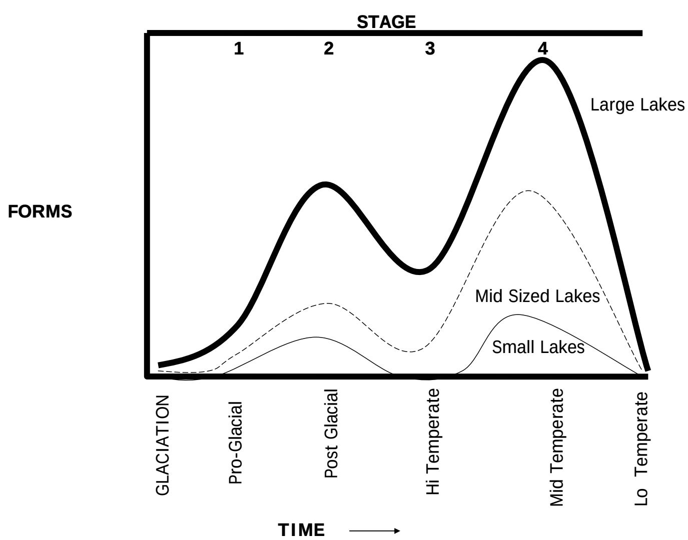

Figure 2. A schematic representation of the multiple radiations of lake trout forms from glaciation to the point where thermal extinction occurs. Although there is little organized data for mid-sized and small lakes it is proposed that they would go through a similar evolutionary pathway but with less total number of forms.

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12 Contributed Papers

12.1 Concurrent Session #4 – Stock Assessment (Part Two) & Mercury

Session Chair – Dr. Terry Dick

12.1.1 Lake Trout Movements and Habitat Use in a Small Northern Lake

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***Abstract*:** A major problem in the environmental assessment of small northern lakes is to establish appropriate mitigation strategies following perturbations. While there has been a tendency in the past to concentrate on spawning sites, other aspects of habitat use have been less well developed. Our objective was to establish patterns of movements of lake trout relative to depth, substrate, temperature and location in Chitty Lake. Chitty Lake was mapped using acoustic technology and benthic samples have been collected. Based on unique acoustic signals from different substrate types and verification with benthic samples a composite map of substrates has been completed for Chitty Lake. In September 2004 lake trout were fitted with acoustic tags, some of which record temperature and depth, and all recorded location. Data from the acoustic tags are collected by receivers placed strategically around the lake. Since the tags will continue to send a signal for three years they will record seasonal and annual fish movements over the various substrate types and depths. Of particular interest is fish movement under the ice during short photoperiods. Since lake trout were tagged after spawning it was possible to determine the sex of individual fish, and consequently long term movements of males and females are documented. The acoustically tagged fish will also allow us to establish if there are movements of fish between Chitty and Alexie lakes. Since large volumes of data are being collected, programs for data management and simulating fish movements have been developed. As more is learned about fish movements over known substrate types and depths efforts will be concentrated on describing, at the fine scale, the heavily used regions of the lake by tagged fish.

12.1.2 Hydroacoustic Assessment of Lake Trout Populations in Small Inland Lakes

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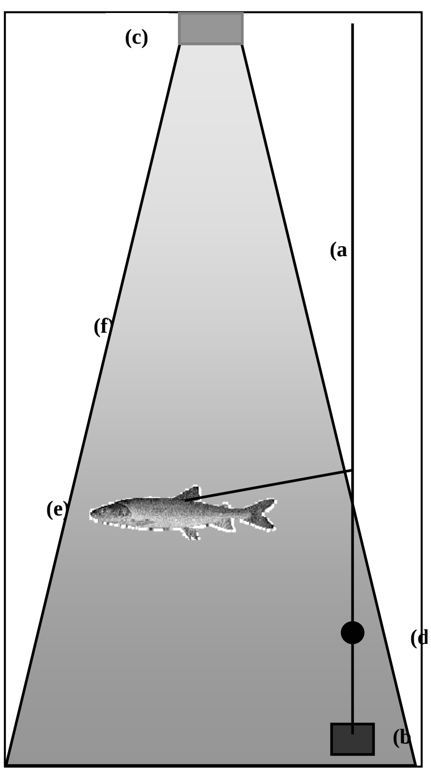
Introduction

A great deal of fisheries science conducted today is focussed upon understanding either the natural processes and/or anthropogenic stresses which affect the distribution and abundance of fish. In inland lakes, natural processes such as the recession of glaciers and the subsequent evolution of the resultant isolated fish communities have created tremendous variation in the abundance and distribution of fishes across the landscape. Anthropogenic stresses such as harvesting, habitat modification, species introductions and climate change are altering these fish communities at a very fast rate in comparison to natural processes. Addressing the research and management questions necessary to develop our understanding of the dynamics of fish communities and provide us with a basis for modeling the impacts of future stresses has both facilitated and required the development of improved sampling techniques.

Innovations and improvements in sampling techniques over the last few decades have allowed fisheries studies to be conducted more rapidly, at broader scales, and at finer spatial and temporal resolutions. This project examined the feasibility of using hydroacoustic assessment methods to assess lake trout abundance in small inland lakes in Ontario.



A crucial component in estimating fish abundance through hydroacoustic methods is the relationship between fish size and acoustic target strength. To facilitate the use of hydroacoustic assessment methods in the study of lake trout populations, the relationship between target-strength (dB) and length of adult lake trout was analyzed. Several *ex situ* methods of measuring the target-strength at 120 kHz of live, adult lake trout of a known size were investigated. These methods included the use of large pens, suspended cages and tethering. Tethering (Figure 1) proved to be the most efficient means of obtaining numerous target-strength measurements from individual fish.

Figure 1: Schematic showing method of tethering lake trout for target-strength analysis. A weighted line (a and b) was suspended below the transducer (c), a calibration sphere (d) was positioned above the weight. The lake trout (e) was tethered at the end of a 1m line 7-8 m below the transducer face and within the cone angle (f) or the transducer.

Using this method, a target strength – length relationship of TS=20•Log_{10}(TLEN) – 65.25, where TS is target strength in dB and TLEN is total length in mm. was found for lake trout (Figure 2). Target strength was found to be quite variable between fish and there seemed to be differences in target strength between spring and fall.

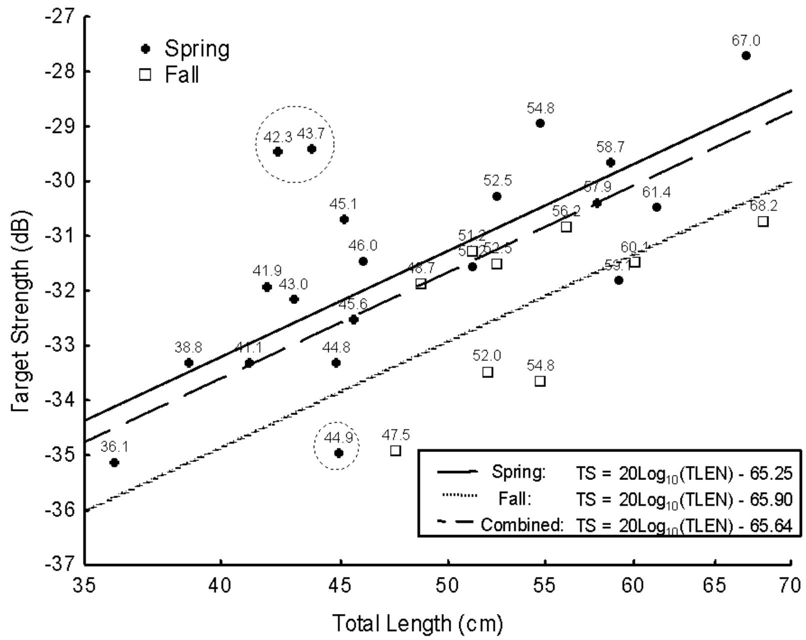


Figure 2: Relationship between target strength and total length for spring, fall and combined data. Fitted relationships for spring and combined data have had identified outliers removed.

The target strength relationship obtained from these experiments was then used to assist in the analysis of repeated acoustic surveys of a lake trout population for which mark-recapture estimates were available. Monthly hydroacoustic surveys using a 120 kHz split-beam echosounder deployed from a small boat were conducted from early June to September on a small (489 ha) lake trout lake which is home to a simple fish community.

The data were analyzed using echo-counting methods to generate abundance estimates for adult lake trout which were directly comparable to long-term mark-recapture population estimates. Target-strength distributions of lake trout were similar in July, August and September (only one adult sized lake trout was observed in June). Acoustic abundance estimates suggested a seasonal trend with estimated numbers of adult lake trout increasing from June to September (Figure 3). This could be due partially to behavioural changes from spring to fall. It appears lake trout become more detectable by acoustic methods as surface waters warm and lake trout move into deeper water.

Acoustic estimates of adult lake trout abundance in July (3451), August (4661) and September (5495) were in general agreement with the mark-recapture estimate of abundance (4257) although the confidence limits for acoustic estimates of abundance are quite large.

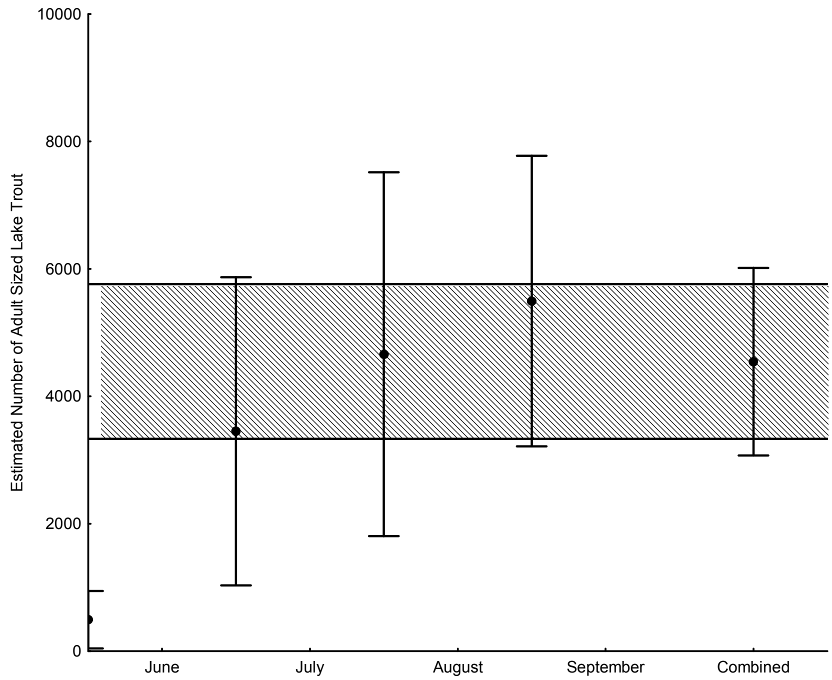


Figure 3: Estimates of adult-sized lake trout abundance and associated 95% confidence limits of the estimate. Shaded area spans the upper and lower confidence limits of the population estimates calculated from mark-recapture data. The combined estimate uses data from July, August and September to produce one estimate.

Discussion

While results from this study are encouraging, more detailed work is required before it will be practical to routinely use acoustic methods to assess lake trout abundance in inland lakes. Results from the July, August and September surveys suggest an average detectability coefficient (q) of lake trout by acoustic methods as being close to 1, but there is also an indication that detectability changes seasonally, most likely as a result of behavioural changes. It is reasonable to expect that detectability will also vary between lakes, likely resulting from behavioural changes related to the different foraging opportunities available to lake trout. To use hydroacoustic methods to assess lake trout populations in a practical manner it will be necessary to repeat this study on other lakes which differ in the forage base available to lake trout and in lake morphometry. These studies are in progress.

12.1.3 Effects of Lake Fertilization on a Lake Trout Population at Saqvaqjuac, Nunavut

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Introduction

Although whole lake fertilization is a proven technique to increase the production of many fishes in temperate climates (Vinberg & Lyakhnovich 1969), there are few examples of this being successful in the Arctic. For example, Schindler et al. (1974) showed that increasing phosphorus loading to Merreta lake on Cornwallis Island increased algal production, but believed recruitment of Arctic char (*Salvelinus alpinus*) was impacted by low winter oxygen conditions. In a more recent study, Lienesch et al. (2005) fertilized a small Alaska lake and they believed this increased growth but decreased recruitment of lake trout (*S. namaycush*). Like the Meretta lake example, they believed winter hypoxia was responsible for decreased recruitment. Although lake trout growth increased starting the second year of fertilization, this might be due to poor recruitment leading to a reduced number of predators rather than solely increased prey production. The purpose of this study is to report results for lake trout of a five year fertilization study in an Arctic lake located in Nunavut.

Methods

There are many small lake trout lakes located on the Precambrian shield on the west side of Hudson's Bay. One of these, P&N lake, a small (7 ha, 10 m Z_{max}) lake located about 36 km north of Chesterfield Inlet, Nunavut, was studied for two years prior to fertilization (1977 and 1978), for 5 years of P (0.1 g m^2 yr^{-1}) and N (1.0 g m^2 yr^{-1}) fertilization (1979 to 1983), and one year (1988) post-fertilization. Fertilizer was added to the lake twice weekly for 10 weeks during the ice-free season each year by mixing the fertilizer with lake water in the bottom of a boat, and then adding it through the boat drain plug while slowly cruising across the lake (Welch and Legault 1986). Fertilization immediately increased phytoplankton production (Welch et al. 1989), followed first by increased chironomid emergence (Welch et al. 1988), and then by increased amphipod and trichopteran production (Jorgenson et al. 1992). The fish communities of P&N and nearby, natural Spring Lake (7 ha, 7 m Z_{max}) were lake trout, landlocked Arctic char, and ninespine stickleback (*Pungitius pungitius*).

Lake trout were captured by angling (jigging through spring ice), small mesh trap nets, electrofishing, and short-sets of small mesh gill nets (38.1 mm stretched (19 mm bar) mesh) in P&N Lake from 1977 to 1983 and in Spring lake from 1978 to 1983. Gill net sets were generally set for 10 to 15 minutes and fish were quickly removed from the nets to minimize mortality. Very few individuals were killed by capture techniques. In 1988, P&N Lake was fished with 50.8mm stretched (25 mm bar) mesh gillnets that were set overnight and most fish were killed. Lake trout that were captured from 1977 to 1983 were anaesthetized (MS 222®), measured (fork length), and marked using fin scarring (Welch and Mills 1981). A sub-sample of the total catch was weighed each year, and was stomach probed with forceps to remove food organisms.

The Jolly-Seber (Jolly 1965, Seber 1982) model was used to calculate abundance estimates, their standard errors, annual survival, and recruitment for the lake trout in each lake. The Jolly-Dixon "full model with constant survival" (Jolly 1982) was used to calculate the 1988 estimates. We calculated condition (k) for the samples collected each year as well as growth curves based on fin-ray ages (Mills et al. 2006).

Results

There was no detectable impact of lake fertilization on lake trout abundance, recruitment, or survival. Lake trout abundance changed little during the entire study period in P&N Lake and in Spring Lake (Figure 1). Although estimates for the P&N population increased in 1982 and 1983, the confidence intervals for these estimates were larger than other years, so they were not significantly different from the earlier estimates. In addition, Jolly-Seber recruitment estimates showed no increase in recruitment; there was also no evidence for increased recruitment based on age distributions of the catches. Similarly, annual survival did not increase and was similar to that in Spring Lake (Figure 1).

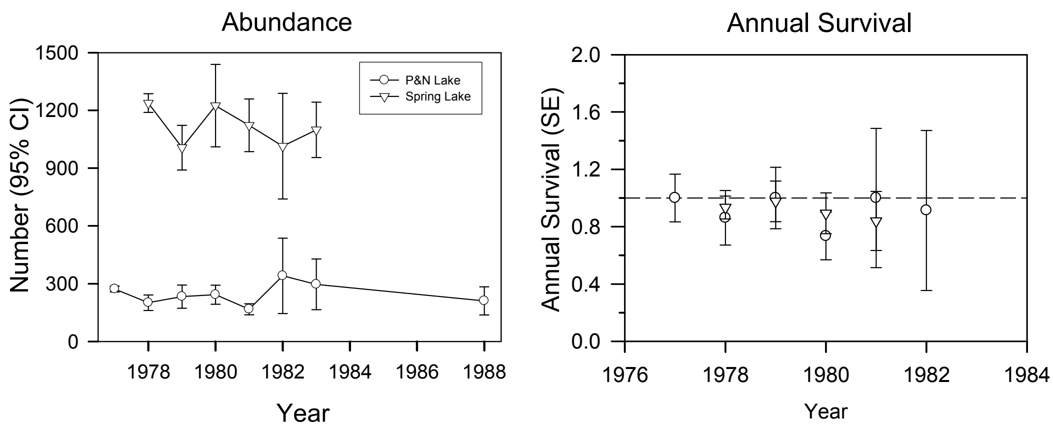

Figure 1. Lake trout abundance and annual survival estimates and their standard errors

Lake trout condition increased in 1980 and 1981, the second and third years of fertilization, but decreased to baseline values in 1982 and 1983, the final years of fertilization (Figure 2). Although condition increased, there was little evidence that growth increased for the same years.

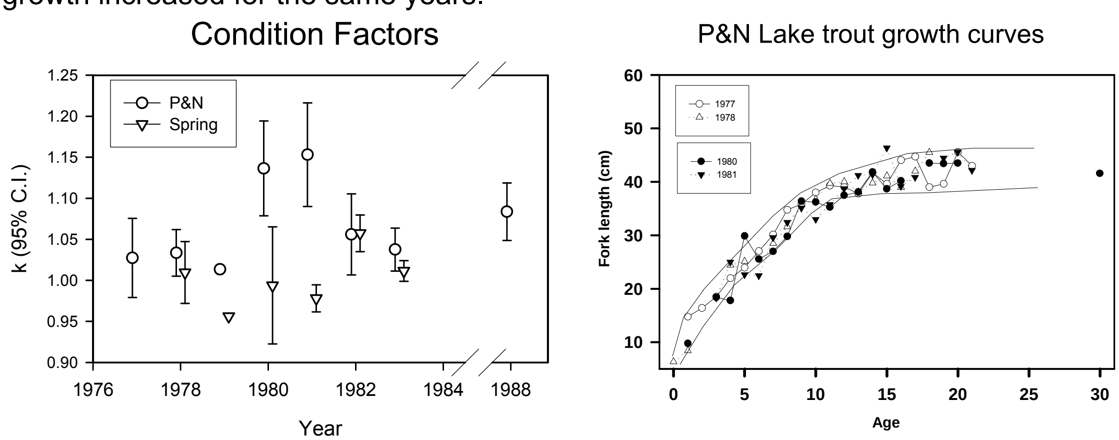

Figure 2. Lake trout condition (k) and growth curves.

Discussion

We were surprised that growth did not increase during the years of fertilization of P&N Lake. This experiment was based on another lake fertilization study conducted at the Experimental Lakes, Ontario where lake whitefish growth, condition, recruitment, and abundance increased during lake fertilization at slightly higher rates than those used in P&N Lake (Mills and Chalanchuk 1987). In a recent study of impact of rainbow trout cage culture on a lake population at the Experimental Lakes Area (Mills et al. 2006), growth and condition of lake trout increased when nutrient supply to the lake increased due to excreta of the caged trout during the second and third seasons of cage culture. In an experiment where nutrient loading remained constant, but lake trout abundance decreased (Mills et al. 2000), lake trout growth increased as a response to the decreased abundance. Langeland (1982), in another Arctic whole lake fertilization study, found that increased growth was one of the primary responses of brown trout (*Salmo trutta*) to fertilization. It is not clear at this time why lake trout growth did not increase in P&N Lake. Abundance of their primary food organisms, zoobenthos, increased during the fertilization. Our results are very different from those of Lienesch et al. (2005), who fertilized a small Alaskan lake where lake trout were very abundant. They believed that lake trout growth increased, but this may be due to impacts on lake trout reproduction because of winter anoxia in portions of the water column. They did not calculate changes in lake trout condition, but did find that individuals were heavier during years of fertilization. This is qualitatively similar to our results.

A very big difference occurred in the fish communities between our experiment and that of Lienesch et al. (2005). Arctic char were present in P&N lake, and their abundance tripled during the years of fertilization. The diets of the Artic char and lake trout were very different in P&N Lake; Arctic char ate a higher proportion of chironomids, which increased dramatically in P&N lake during fertilization (Welch et al. 1988). This was also the primary food group utilized by lake whitefish during the fertilization of Lake 226 (Mills 1985). There was no evidence that lake trout recruitment increased during years of fertilization. Electroshocking the shoreline of the lake yielded young-of-the-year lake trout during years of fertilization, so we believe recruitment was not reduced during the years of fertilization, as it had in the study of Lienesch et al. (2005).

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12.1.4 Population Structure and Contributions to Local Fisheries by Lake Trout in Atlin Lake, British Columbia: a Micro Satellite DNA-based Assessment

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Abstract
Atlin Lake is the largest natural lake ecosystem within British Columbia and contains diverse aquatic resources, yet these resources are relatively understudied. Lake trout, *Salvelinus namaycush*, is one such resource that is exploited in subsistence, recreational, and commercial fisheries. To better understand the resources of Atlin Lake, the *Atlin Lake Community Biomonitoring Program* is being coordinated by the Taku River Tlingit (TRT) Fisheries Department. Our study involves a review of genetic studies of lake trout in North America and a survey of microsatellite DNA variation in lake trout from Atlin Lake.

Lake trout dispersal has been closely linked to the effects of the Pleistocene glaciations. Repeated glaciations caused the reduction of habitats and separated populations for long periods of time promoting divergence between the populations. When the glaciers retreated, refugial groups came into contact with each other contributing to intrapopulation diversity currently observed (Wilson & Hebert, 1998). Three major mitochondrial lineages have been resolved with largely allopatric distributions, suggesting dispersal from separate refugia (Wilson & Hebert, 1998). Evidence for genetic differences between glacial and non-glacial regions has been noted but currently most of these data on lake trout are from the southern portions of their range (Alfonso, 2004). It has long been noted that lake trout are phenotypically diverse not only in size and body shape, but also in their colouring, which ranges from silver to brown to even green or red. The different morphologies are usually associated with differences in habitat and behaviour (Brown et al., 1981). Of the lake trout populations studied the largest amount of phenotypic variation has been seen in the Laurentian Great Lakes (Krueger & Ihssen, 1995). There are three morphotypes commonly recognized in the Laurentian Great Lakes; “lean”, “humper” and “siscowet” morphotypes are recognized on the basis of facial characteristics, body fat content and spawning time (Burnham-Curtis & Smith, 1994). Only Lake Superior has sympatric populations of each of the three morphotypes (Krueger & Ihssen, 1995). The first documented case of sympatric morphotypes of lake trout outside the Laurentian Great Lakes was in Great Bear Lake, NWT. It contains at least two morphotypes, one of which is similar to that of the lean form found in the Laurentian Great Lakes. However, these two types are not spatially separated like those in the Laurentian Great Lakes (Alfonso, 2004). Initial evidence suggested that there is a genetic component to this differentiation and the frequency of mixed phenotypes in the Laurentian Great Lakes suggests the gene flow occurs among

the populations (Burnham-Curtis & Smith, 1994). Further studies identified substantial genetic differentiation among sympatric and allopatric populations in morphology, early developmental rate, physiology, and in allozyme and DNA-based allele frequencies (Eshenroder & Krueger, 2002). Currently only a few native populations remain in Lake Huron and Superior. In the mid 20th century a drastic reduction in population sizes and diversity occurred in the Great Lakes due to overfishing, sea lamprey (*Petromyzon marinus*) predation, and habitat destruction (Guinand et al., 2003). As a result of the attempt to restore the diversity of lake trout in the Great Lakes many genetic studies on the populations have been conducted to reconstruct the past to better understand and, therefore, restock the present populations. Microsatellite analyses of young-of-the-year lake trout have provided robust estimates of strain-specific reproductive success in restoration programs in the Great Lakes (Page et al., 2003). Generating guidelines for the restocking of exploited populations is one of the reasons why knowledge on the diversity of lake trout is important. Diversity within a species allows for restoration of threatened or at-risk populations, adaptation to changing environments, survival from predation, and use of all possible habitats. Diversity should also be conserved for its inherent value as reflecting the evolutionary legacy of a species; however, current knowledge of lake trout diversity is incomplete across the range. Genetic diversity can be used as a measure of long-term population health and establishing a baseline of genetic diversity can aid in determining if any change requires conservation attention.

Our microsatellite study of Atlin Lake lake trout populations will allow us to answer three questions: (i) how many genetically-distinct populations exist in Atlin Lake, (ii) do distinct populations make different proportional contributions to fisheries, and (iii) is there any association between distinct phenotypes of lake trout (e.g., based on colour, body shape, depth distribution) and genetic differentiation? We have collected lake trout tissue samples from throughout Atlin Lake, from Tagish Lake, and from two Pacific Basin watershed lakes (Trapper and Tatsamenie lakes, Taku River) from 2000 to 2003. From these data, effective population sizes can be estimated, as well as temporal variation in allele frequencies and the percentage composition at different spawning areas. Previous analysis of lake trout mitochondrial DNA indicated that fish from northwestern BC and the southern Yukon near Atlin Lake probably recolonized these areas postglacially from two Wisconsinan glacial refugia: the Nahanni refuge located in the Nahanni River Valley, and from a portion of the Beringian refuge (i.e., an unglaciated area north of the Brooks Range in Alaska). Preliminary analyses of microsatellite variation in western lake trout indicate good potential for population differentiation and identification in and around Atlin Lake. Thus far we have screened eighteen loci, ten of which amplified clearly (seven polymorphic, three monomorphic). The level of genetic diversity ranges from fifteen to two alleles across all loci in Atlin Lake populations compared to the five to two alleles found in the other lakes in the region. With the use of microsatellite data we hope to differentiate between various morphologies and identify the number of distinct genetic populations in the lake. The data collected will also aid in determining which population(s) contribute to the fisheries and in what proportions. This is important from a management standpoint because if one population is contributing more than the others there is a possibility of reducing genetic diversity through overexploitation of less productive populations.

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12.1.5 Latitudinal and Longitudinal Differences in Mercury Levels in Lake Trout in Northern Canada: Possibilities for the Future

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Abstract

Lake trout have a broad distribution across northern Canada and are important domestic, sports, and commercial fisheries. Recent studies, conducted mainly in the northern provinces and the Northwest Territories, have determined that elevated mercury concentrations are a common occurrence in lakes in the more northerly regions of Canada. Twenty-two percent of lake trout populations sampled in lakes along the Mackenzie River Basin (MRB) had mean mercury concentrations which exceeded 0.5 µg/g, the guideline for the commercial sale of fish. Higher mercury concentrations were strongly associated with the relatively old age of MRB lake trout in these lakes. In contrast, none of the lake trout sampled in eight lakes further south in northern Saskatchewan and Alberta had mean mercury concentrations >0.5 µg/g; fish also were younger (mean age 6 yr for the 8 lakes). Mercury concentrations in MRB fish generally increased with fish length, age, and trophic feeding although the nature of these relationships varied with the lake. Mercury concentrations tended to be higher in lake trout in smaller versus larger lakes and as a probable consequence of higher summer epilimnion temperatures, which favour a higher net methylation rate, and higher mercury and methyl mercury concentrations in water which enter these lakes from the watershed. Increasing fishing pressures on MRB lakes may be a means of reducing mean fish age, improving growth rates, and decreasing mercury body burdens. However, because lake trout begin first reproduction at a later age than in the southern portion of their range, caution must be exerted in enhancing fishing pressures. Increased global warming may result in higher mercury concentrations in fish through increased water temperatures, a longer ice free season, and increased release of stored mercury from the watershed into these lakes. Higher mercury levels in lake trout in Labrador may be related to atmospheric mercury sources.

13 Contributed Papers

13.1 Concurrent Session #5 – Land Use and Climate Change

Session Chair – Erik Madsen, Diavik Diamond Mines Inc.

13.1.1 Projected Impacts of Climate Warming on Production of Lake Trout in the North

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Introduction

Fish are heterothermic ectotherms and are known to behaviourally thermoregulate in order to remain within an optimal temperature range where activity and growth are maximized. For lake trout (*Salvelinus namaycush)*, this optimal range has been identified as 10 ± 2^{o}C (Christie and Regier 1988; Magnuson et al. 1990). Volume of water in a lake within this optimal range (thermal habitat volume) is a strong predictor of lake trout yield (Christie and Regier 1988) or potential harvest (Payne et al. 1990). As climate warming continues to alter availability of optimal thermal habitat for lake trout, production will also change. Decreases in production in the southern areas of the lake trout's range (Shuter and Lester 2004) will likely be coupled with increases in production in northern areas as availability of suitable thermal habitat increases.

An understanding of how climate change could alter lake thermal characteristics and lake trout production has important management implications, but limited meteorological data in northern regions limits the use of complex lake warming models. Our objectives, therefore, were to *i)* develop a method to describe current lake thermal profile characteristics and approximate how thermal properties could be affected by climate warming given the limitations in meteorological data, *ii)* estimate current availability of lake trout thermal habitat and changes in habitat availability under warmer mean annual air temperatures, and *iii)* estimate relative changes in lake trout potential harvest (production) under climate warming.

Methods

Potential effects of climate warming on lake thermal characteristics were evaluated from a data set of 33 Yukon lakes of various morphometries located predominantly in the southwestern portion of the Territory between 59 and 63º N latitude. Our analyses only included lakes for which a mid-summer thermal profile (late July to early August, warmest part of summer) and a previously digitized bathymetric map in Geographic Information System (GIS) format existed. We developed a model (Mackenzie-Grieve and Post *in press*) to describe current thermal characteristics of study lakes (surface temperature, thermocline depth, bottom temperature), and used methods established by Shuter et al. (1983) to assess how increases in mean annual air temperature (*TEMP*) of 2, 4, and 6˚C would influence lake surface temperature and thermocline depth. Methods described by Payne et al. (1990) were used to assess thermal habitat volumes (*THV*) and lake trout production (*H*). A complete description of methods is provided in Mackenzie-Grieve and Post *in press*.

Results and Discussion

Study lakes were classified into one of four groups. Group 1 lakes (n=3) are currently isothermal and have no optimal thermal habitat for lake trout in summer. Group 2 lakes (n=4) currently contain no thermal habitat warmer than the upper optimal limit (12˚C). Group 3 lakes (n=5) currently contain no thermal habitat colder than the lower optimal thermal boundary of 8˚C. Group 4 lakes (n=21) currently contain habitat warmer and colder than the lake trout optimum range.

In Group 1 lakes, any increase in *TEMP* leads to further increase in lake temperature (Figure 1A) which is coupled with further decrease in lake trout *H* (Figure 2). In Group 2 lakes, small *TEMP* increases increase *THV* in some of the lakes (Figure 1 B), but larger *TEMP* increases lead to large decreases in *THV* coupled with large decreases in *H* (Figure 2). In Group 3 lakes, changes in *THV* with increasing *TEMP* are small (Figure 1 C) and increase slightly, on average, with increasing *TEMP*. Changes in *H* follow this trend (Figure 2). In Group 4 lakes, increasing *TEMP* leads to decreasing *THV* (Figure 1 D) and decreasing *H* (Figure 2) in all cases.

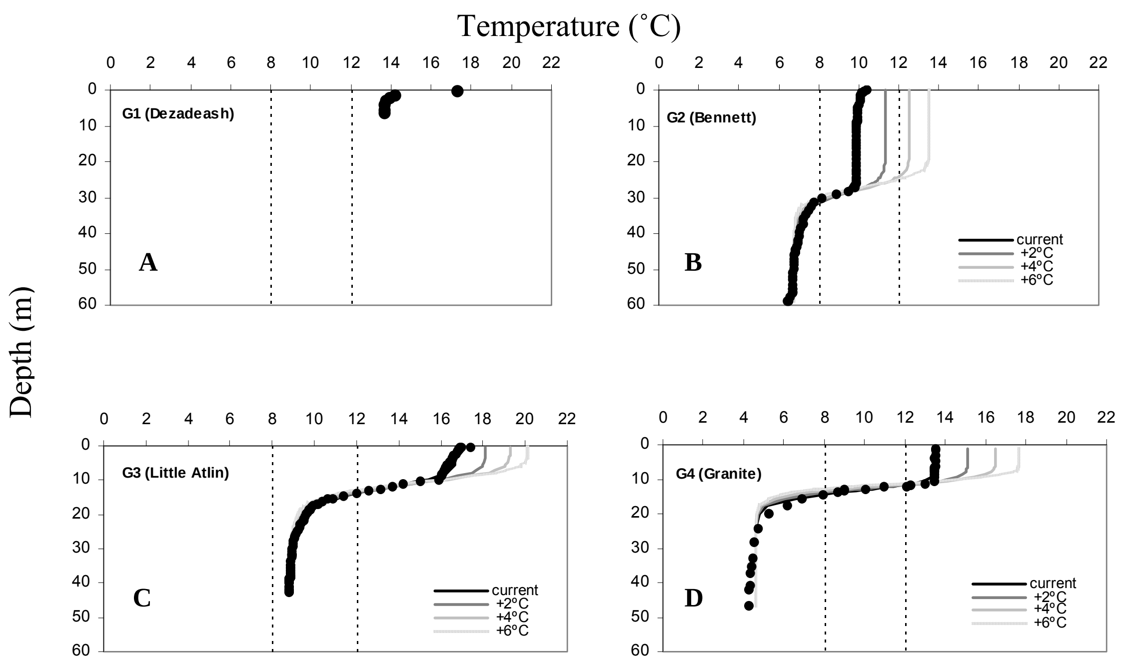

Figure 1. Empirical temperature data, fitted current thermal profiles, and warmed mid-summer thermal profiles for four Yukon lakes typical of each of the four groups. Upper (12˚C) and lower (8˚C) optimal thermal habitat boundaries are indicated by dashed vertical lines.

In addition to warmer lake temperatures, our analyses predict shallower thermoclines, consistent with observations of King et al (1997) and with results of Magnuson et al. (1990). In stratified lakes, thermal habitat is essentially vertically 'squeezed' as temperatures increase. In isothermal lakes (Group 1), increasing *TEMP* not only increases lake temperatures, but will likely extend the duration of the summer where no optimal thermal habitat exists for lake trout, having dramatic consequences on lake trout production in lakes of this type. Schindler (1997) suggests that a temperature increase of only a few degrees could lead to population extirpation of lake trout in lakes of this type.

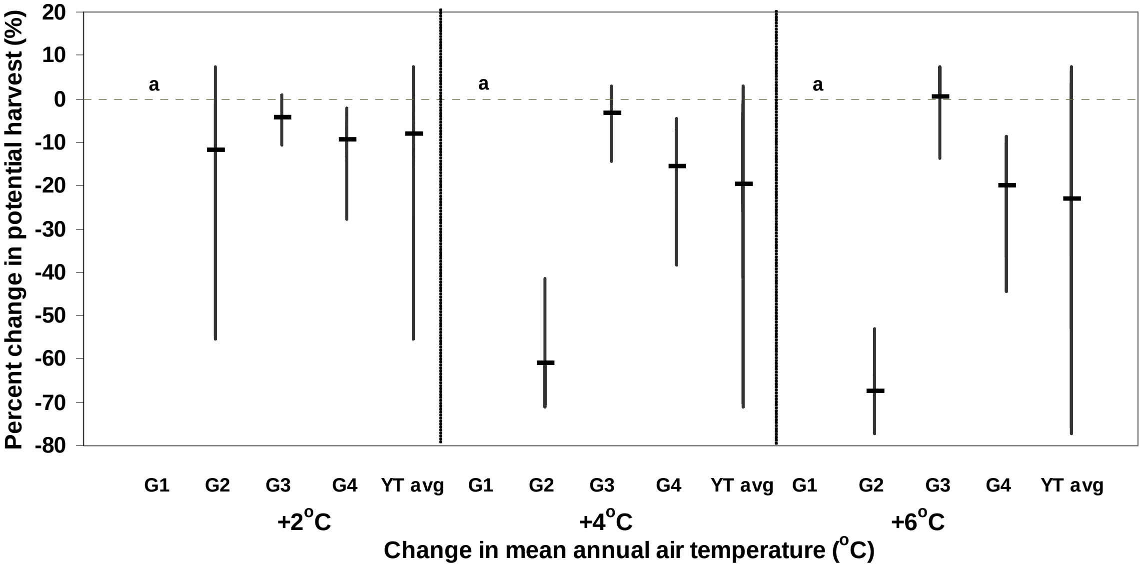

Figure 2. Predicted percent change in potential lake trout harvest (*H*) for 33 Yukon lake trout lakes with increasing mean annual air temperature shown as four groups where group means and ranges of percent change in *H* are shown.

Analyses by Minns and Moore (1992) suggest that the areas which currently support the highest fish yields will become the areas with low or marginal yields under climate change, and areas with the highest yields will be relocated northward. Our analyses suggest that this increase in lake trout productivity will be further north than the southern Yukon since an overall decrease in optimal thermal habitat (and production) is predicted. Range shifts for lake trout are also likely in the long term, provided previously unusable habitat becomes accessible.

Even though there are uncertainties involved in predicting the magnitude of climate change, managers of renewable resources, including fisheries, must assess the scope of potential impacts of global warming and prepare for a range of future conditions (Minns and Moore 1992). This study provides a framework for continued analyses, and identifies southern Yukon lake trout populations and lake types that could be at the greatest risk from climate warming.

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13.1.2 Effects of Explosives on Incubating Eggs of Lake Trout in Lac de Gras, NWT.

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Abstract:
Industrial development in Canada's North has resulted in an increased use of explosives in and near fish habitat. Blasting guidelines exist for both over-pressure and peak particle velocity (PPV) to protect fish and their incubating eggs, respectively. Many studies have focussed on how over-pressure causes mortality in fish, however no studies have examined effects of PPVs from explosives on fish eggs. We exposed lake trout eggs to blasts at Diavik Diamond Mine's A154 pit on Lac de Gras, NWT. Plexiglas incubators, containing recently spawned and fertilized eggs were placed in the substrate of the lake, along with blast monitoring equipment, at four sites. Three sites were within the blast zone, 0-220 m from the pit's dike, where PPVs were predicted to exceed guidelines, while a reference site was located over 2 km away. Substrate at one of the blast-zone sites was composed of material used in dike construction, whereas all other sites were on natural spawning shoals. To assess if mortality occurred early in development, when the eggs are most sensitive, half of the incubators were retrieved after 3 weeks of exposure, while the other half were retrieved at ice-off. After 3 weeks, one blast-zone site had slightly higher (3%) mortality, while 2 sites had lower mortality than the reference. In spring, one (different) blast-zone site had higher (10%) mortality than the reference, however, this site was the only site composed of non-natural spawning substrate. In neither case could increased mortality be attributed to measured blasting exposure, but likely resulted from site-specific characteristics. The largest blast exposure (28.5 mm/s) was more than double the current guideline for protecting spawning shoals (13 mm/s), suggesting that this guideline provides ample protection under these blasting conditions. The margin of this protection, however, remains unknown.

13.1.3 Acute and Chronic Toxicity of Nitrate to Early Life Stages of Lake Trout

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Abstract

Nitrate is the most oxidized form of nitrogen present in the environment. It is naturally produced and also found in various human-made sources such as mine effluent. The nitrate from mine effluent is derived from explosives and referred to ANFO, which is a mixture of ammonium nitrate (AN) and fuel oil (FO). The main objective of this study was to assess the acute and chronic toxicity of nitrate to early life history stages of a fish species that resides in northern Canada using standard laboratory protocols. The Canadian Council of Ministers of the Environment has derived a water quality guideline for nitrate based on a species not found in northern Canada, the Pacific treefrog. The acute and chronic toxicity of nitrate to the embryos, alevins and swim-up fry of lake trout were tested in laboratory aquaria. Survival, time to development, incidence of deformities and abnormal behaviour, and length and weight of fry were recorded for the chronic tests, and survival was measured for the acute tests.

The acute (96-h) LC50 for alevins and swim-up fry were 2,343 and 1,121 mg/L NO_3-N, respectively. The chronic (~150-d) LC50 for the embryo to swim-up fry survival was 190 mg/L NO_3-N. Sublethal effects on development timing and fry body size were observed at chronic concentrations of 6.25 mg/L NO_3-N. These results confirm that the Canadian nitrate water quality guideline of 2.9 mg/L NO_3-N, is applicable to the early life stages of an Arctic fish species for a chronic exposure. However, it does not support the use of the guideline for situations that involve acute exposures.

13.1.4 The Effects of Multiple Source Stressors on a Small Tundra Fish Community in the Northwest Territories, Canada

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Introduction

Kodiak Lake is a small, clear, oligotrophic tundra lake 300 km northeast of Yellowknife, Northwest Territories in the upper Coppermine River watershed. Six species of fish inhabit the lake. Lake trout (*Salvelinus namaycush*), round whitefish (*Prosopium cylindraceum*), and Arctic grayling (*Thymallus arcticus*) are the most abundant large-bodied species. In 1997, as part of the BHPBilliton Diamonds Inc. Ekati Diamond Mine plan to establish open-pit mines in the two lakes immediately upstream of Kodiak Lake, the upper watershed discharge was diverted around the lakes through the Panda Diversion Channel (PDC) into the northeast corner of Kodiak Lake. In the same year, BHPBilliton was licensed to discharge treated sewage effluent (TSE) from the mining camp into Kodiak Lake. As a condition of that license, BHPBilliton commissioned a study to monitor the lake for potential effects. Because of the proximity of Kodiak Lake to mine development activities, it was essential to identify any other potential stressors that may affect monitoring results.

Since the construction of an exploration camp 1993, development activities at the Ekati Diamond Mine have provided a variety of potential stressors to the Kodiak fish community. Potential stressors were grouped into three categories based upon the potential effects: 1) fishing pressures; 2) sediment inputs; and, 3) eutrophication. Fishing pressures were applied to the fish community through recreational and assessment/monitoring fishing. Recreational fishing began in 1993 and continued through 1996, until BHPBilliton imposed a fishing ban for mine personnel on the claim block. Assessment/monitoring fishing began in 1994 and eventually resulted in nine fishing programs by 2003. The majority of sediment deposited in Kodiak Lake was the result of an unexpected event. Sediment inputs began in 1995 with the construction of the PDC. The channel, blasted through bedrock and frozen overburden, was constructed to divert the upper watershed around the two lakes immediately upstream of Kodiak Lake. The PDC was completed in 1997 and in the spring of that year, paleosediment deposits adjacent to the channel were mobilized as a result of permafrost degradation. The sediment was transported down the channel to Kodiak Lake. The sediment buried spawning and foraging habitat throughout the lake. The resulting high turbidity persisted through the open-water period. Nutrient inputs to Kodiak Lake increased as soon as development in the area began to disturb the soil. As the scale of mine development increased, nutrient inputs from blast residue were transported down the PDC to the lake. However, the greatest source of nutrients was the direct discharge of TSE into Kodiak Lake between 1997 and January, 1999.

Methods

The Kodiak Sewage Effects Study was a multidisciplinary project. Water quality and chemistry, primary and secondary producer communities, and the fish community were surveyed. Fish community surveys of the large-bodied fish species were initiated in 1994. Standardized methods were introduced in 1996 and maintained until 1999. Small mesh gill nets (1.5” stretched) set for short periods were used to capture fishes. This method was used to reduce handling mortality of lake trout and round whitefish. Fish community surveys were conducted during the last week of August using established gill net locations. Fishes were weighed, measured for length, and age was determined using the appropriate aging structures. Where tagged fishes were recovered, growth rates were determined.

Results and Discussion

Because the initial purpose of the study was to monitor the effects of TSE discharge on the Kodiak Lake ecosystem, it was important to consider all other potential stressors to isolate the effects of the TSE. Fishing pressures were identified as a potential historic stressor. As the closest sizable lake to the exploration camp, Kodiak Lake had been regularly fished from 1993 to 1996 by camp personnel. Annual assessment/monitoring fishing began in 1994. In some years, lake trout and round whitefish were sacrificed to collect tissue samples for analyses of trace metals. During all fish community surveys, handling mortality of round whitefish was high. The introduction of index gill nets using short-term sets reduced lake trout mortality but mortality of round whitefish remained high. The fishing pressures resulted in a steady decline in lake trout and round whitefish abundance.

The discharge of sediment into Kodiak Lake in 1997 was an unexpected event and introduced another potential stressor. A delta was formed at the mouth of the PDC, fish habitat was buried to various depths throughout the lake, and turbidity was elevated through the open-water season. The potential effects included interference with benthos production due to a constant rain of sediment and the inability for the phytoplankton to reach maximum potential production due to the reduced light transmission from the increased turbidity. The sediment discharge from the PDC therefore had the potential to affect the ecosystem components that were monitored during the Kodiak Sewage Effects Study. As a result, once the field component began there were multiple potential stressors which could possibly interact to an unknown degree. This was compounded by the lack of a solid baseline dataset and the reliance for some components on time-series data. However, even though it was not possible to isolate effects of specific stressors with a high degree of confidence, the study was continued and the results suggested a complex set of linkages between the stressors and ecosystem components.

The most straight forward relationships occurred among sediment, eutrophication, phytoplankton, zooplankton, and Arctic grayling. The most significant contributing stressor was the TSE discharge from 1997 to January, 1999. Using the 1996 data as a reference point (collected prior to both TSE and sediment discharge), phytoplankton abundance almost doubled by 1997 and peaked in 1998 at over three times the reference point. The delay in peak phytoplankton abundance may indicate that high turbidity from the PDC sediment event played a role in mitigating the effects of nutrient inputs. After TSE was discontinued, phytoplankton abundance immediately dropped back to reference levels in 1999 and has continued to oscillate around the reference in subsequent years. This suggests a direct linkage between TSE and phytoplankton abundance. Zooplankton abundance appeared to follow phytoplankton abundance almost precisely. Zooplankton abundance in 1997 was higher and then peaked in 1998. In 1999, abundance declined significantly and by 2000 was one-half and one-third the 1997 and 1998 abundances, respectively. Though zooplankton had not been surveyed prior to 1997, zooplankton abundance appeared to follow phytoplankton abundance closely during the monitoring study. Therefore, for the purpose of this study it was assumed that the steady 1999-2003 abundance levels reflected normal zooplankton abundance. Interestingly, immediate responses were observed in grayling growth and appear to be linked to the changes in zooplankton abundance. Using 1996 as a reference point, the growth rate in grayling, particularly the juveniles, increased in 1997 and peaked in 1998. Growth rates then began to decline until 2000 when juvenile grayling were smaller than in 1996. For example, 2+ fish in 1997 were 1.28% larger than the same age class in 1996. In 1998, the difference had increased to 13.42% but declined to 7.35% in 1999. By 2000, the 2+ fish were 7.97% smaller than in 1996. Other stressors, such as fishing and sediment, did not appear to have direct affects.

A more complex interaction was observed in relationships between round whitefish abundance and eutrophication, sedimentation, benthos, and fishing. Extensive baseline data do not exist for benthos. However, using the latest dataset, 2003, as a reference point, 1997 benthos mean density was one-third that of 2003. In 1998, mean density had increased to nearly five times 2003, and peaked in 1999 at nearly six and a half times 2003. Subsequently, mean densities declined to two and a half times during 2000 and 2001 from the 2003 value. The very low mean density in 1997 and the year lag in response to increased primary production is likely a response to the constant deposition of sediment through the open-water season in 1997. It is also interesting to note that in subsequent years, macrophytes began to appear in the dredge hauls indicating a persistent increase in available substrate nutrients. The response in round whitefish was more dramatic and complex. The growth of juvenile round whitefish followed the increase in benthos density, increasing in 1998, peaking in 1999 and declining to reference rates by 2003. For example, 4+ fish in 1997 were 11.19% larger than the same year class in 1996. By 1999, the 4+ year class was 20.56% larger than the reference. By 2003, the difference was only 1.38%. Adult round whitefish growth also displayed increased growth but beginning a year ahead of the juvenile fish growth response and benthos density increases. The adult round whitefish growth rate began to increase in 1997, peaked in 2000, and began to decline in 2003. A comparison of the von Bertalanffy growth curve for round whitefish in Kodiak Lake with curves for other populations in nearby lakes confirms that growth in Kodiak fish was significantly different. A possible explanation for the extended and sustained increased growth rate observed in adult round whitefish is that the high mortality rates from annual fishing depleted the larger, older segment of the population. What was observed was therefore the rapid growth of younger adults to fill the vacant top positions in the population.

Interestingly, there do not appear to have been any direct effects on lake trout. Juvenile trout showed no increase in growth rate. However, like round whitefish, adult trout showed an immediate increase in growth in 1997. A comparison of a Kodiak trout von Bertalanffy growth curve with curves of populations in nearby lakes was not significant but a graph of the curves does suggest a higher rate of growth in the adult Kodiak trout population. Other corroborating information was provided by analysis of aging structures and calculating growth rates from tag returned fish. Aging structures displayed wider annuli in recent years indicating growth had increased. A comparison of mean growth of tag recovered trout in Kodiak Lake to trout from nearby, pristine lakes showed that Kodiak fish had a much higher growth rate. Similar to round whitefish, a possible explanation for the increased growth rate observed in adult trout is that fishing depleted the adult trout population and that what was being observed was the rapid growth of younger adults to fill the vacant top positions in the population.

In summary, sediment effects appeared to partially mitigate the secondary producer response to increased nutrients while limiting the benthos response to increased primary productivity. Secondary producer response appeared to be closely linked to primary producer response. The fish community, particularly juvenile fishes, showed a rapid response to changes in secondary productivity. Adult fishes appeared to show a growth response as a result of fishing pressures.

Acknowledgements
I would like to thank BHPBilliton Diamonds Inc., particularly Mr. Chris Hanks, for allowing me to conduct this study and for providing support during the production of this presentation. I would also like to acknowledge my former colleagues at Rescan Environmental Services Ltd., particularly Dr. Deborah Muggli, who continue to monitor Kodiak Lake and provided the von Bertalanffy growth curves.

13.1.5 Lake Trout Recruitment Failure – A Case Study

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Abstract
The absence of young lake trout was first noticed when the results of the 2001 Spring Littoral Index Netting (SLIN) showed no fish under 11 years old. This was abnormal for Red Lake, a pristine lake trout lake in Northwestern Ontario.

In October 2002, a spawning assessment confirmed the absence of younger fish and indicated a decline in the lake trout population. Only 7 of the 147 fish captured were less than 13 years old. These results indicated a dramatic age distribution shift in the lake trout population within the last ten years. A dive confirmed that the spawning habitat was plentiful and had excellent quality. However, the eggs showed a 60 to 80 % mortality rate at all sites within two weeks of the spawn.

A spawn collection was undertaken in 2003. Egg development was monitored during the incubation at the Hatchery. The incubation was successful and no developmental problems were identified, nor did the eggs show any signs of disease or thiamine deficiencies. Egg survival was also tested in-situ by placing incubation trays on four known spawning shoals within the main spawning basin (Pipestone Bay) and in another location on Red Lake. Upon retrieving the trays in the spring, there was extreme mortality (99.97%) in Pipestone Bay; but the control site had similar survival to the hatchery setting.

Preliminary data from a more intensive incubator study in 2004 confirmed past findings, as only the site within Pipestone Bay had a high mortality rate. Unfortunately, the radio-tagging study showed extensive use of this basin during the spawn by lake trout.

From the results gathered to date, it appears the recruitment problem is attributable to conditions within Pipestone Bay. This bay is at the top of the watershed in a pristine area, but it has been subject to impacts from a small mining operation in the 1930's along the shorelines of the bay, a small mining operation in the mid 1980's within the immediate watershed, a forest fire on the northern shore in the mid 1980's, and mining exploration projects. Various environmental testing is underway to determine the cause of the mortality and a rehabilitation strategy for the lake trout stock is being implemented.

13.1.6 Construction and Monitoring of an Artificial Lake Trout Spawning Reef in a Sub-Arctic Lake

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Abstract

An artificial reef was constructed in Snap Lake, NT, to create spawning habitat for lake trout. In the summer of 2000, a bare bedrock shelf was chosen for placement of the reef within Snap Lake. The shelf was selected as the best available location that would provide the physical conditions required for lake trout spawning habitat (i.e. slope, aspect). The reef was constructed in March 2001, by placing inert rock on the ice over the shelf in a 20 m x 5 m x 1m pile. The rock pile dropped onto the bedrock shelf maintaining much of the original configuration. Egg traps installed on the reef in 2001 and 2002 were unsuccessful in capturing lake trout eggs, however, evidence of lake trout spawning activity on the reef in 2002 was documented as divers observed cleaned rock areas on the reef, and adult lake trout in spawning condition were caught near the reef. A different design of egg nets was successfully used in 2003 to capture lake trout eggs. Lake trout eggs were also observed in the interstices of the artificial reef, indicating that lake trout found and utilized the artificial reef in 2003. Gross examination of the development of 9 of the lake trout eggs suggested that lake trout deposited eggs on more than one occasion. Physical measurements of the reef were documented and fall within the range of characteristics identified in the primary literature as preferred lake trout habitat. Sedimentation rates on the reef were lower than rates observed at a natural reef. Juvenile burbot, lake chub and slimy sculpin were captured in minnow traps set on the reef, indicating small-bodied fish use of the reef habitat. Results of the study indicate that artificial reefs can be used successfully in sub-arctic lakes to create fish habitat.

14 Contributed Papers

14.1 Concurrent Session #6 – Lake Trout Biology (Part Three)

Session Chair – Peter Cott, DFO

14.1.1 How Environmental Variation may Drive Life History Parameters in Lake Trout

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ABSTRACT
Lake trout exhibit substantial life history variation across their range. Populations at the northern and southern extremes of the distribution are markedly different, but considerable local variation also occurs. This observed life history variation makes it difficult to build models for predicting sustainable levels of fishing pressure and effective harvest regulations. Three hypotheses have been developed to account for the observed life history variation in lake trout: (1) the colder temperatures at higher latitudes are responsible for most of the variation across the range, (2) differences in the diets of lake trout populations from different lakes are responsible for most of the variation (planktivory versus piscivory) within regions, and (3) life history characteristics vary between populations as a function of lake area and total dissolved solids.

To address these hypotheses, multivariate statistical techniques (Procrustean Analysis and Canonical Correlation Analysis) were applied to 120 lake trout lakes from Quebec to Yukon to summarize life history variation (age and length at maturity, maximum length and age, growth, and condition factor) and relate these patterns to climate, lake morphology, and water quality.

The results showed a significant association between climatic conditions and lake trout life history characteristics ($p=0.0001$). Data on lake morphology and water quality were sparse across the range. Thus, we were only able to access these parameters for two regions: (a) British Columbia and (b) Ontario and Quebec. The relationship between water quality and life history characteristics was not significant for either region, however lake morphology was significant for the Ontario and Quebec region ($p=0.02$) but not British Columbia ($p=0.3$). The information from this study could be incorporated into existing lake trout life history models, thus extending their applicability to encompass a broader geographic range.

14.1.2 Adaptation and Latitudinal Variation in Growth of a Northern Ectotherm, the Lake Trout, *Salvelinus namaycush*

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Introduction

Organisms rely on their environment for essential resources such as shelter, food, and water (Campbell *et al.* 1999). This dependency means that environmental changes may cause the life history traits of organisms to change (Stearns 2002). This phenomenon is particularly pronounced in ectothermic organisms where their metabolism is driven by ambient temperature and other environmental factors, and results in a large range of inter-population variation.

There are two theories that account for the distribution of inter-population variation in life history traits. The first theory is that as latitude increases, growth rates decrease. It is believed this occurs because at higher latitudes the climate is cooler and there is a shorter growing season (Phillips 1990). The second theory is that within an organism's geographic distribution, there is an ideal niche beyond which peripheral populations are less well adapted. This second theory is a consequence of allopatric speciation (Mayr 1963), where species evolve in isolated populations and become well adapted to specific habitats. As species gain access to other habitats, their distribution can be extended although they are better adapted to their original habitat.

To better understand how external environmental factors influence life history traits, we first need to identify the key factors that influence these traits. This can be done by finding correlations between life history traits and environmental trends.

The primary objectives of this study were to examine inter-population variation in lake trout and to assess the effects of climatic and lake size changes on lake trout growth rates. The secondary objective was to determine which of the two aforementioned theories on life history variation best applied to lake trout.

Lake trout is a good model species for testing the effects of climate variation over a latitude gradient as it has a wide distribution across North America (Scott and Crossman 1990), and is known to be temperature sensitive (Evans *et al.* 1991) and long lived (Schram and Fabrizio 1998).

Methods

For this study lake trout data were collected from six locations (11 lakes): Great Bear Lake (65° 49’ N/120° 44’ W), The ECOL lakes (60° 40’ to 60° 45’ N/ 114° 5’ to 114° 15’ W), Great Slave Lake (62° 49’ N/ 133° 49’ W), Peter Lake (63° to 63° 30’N/ 92° 30’ to 93° W), The Experimental Lakes Area (ELA) (49° 30’ to 49° 45’ N/ 93° 03’ to 94° 00’ W), and Lake Superior (48° 1’ N/ 86° 59’ W) (Fig 1).

Figure 1: Map of Canada with the 6 study sites identified. 1: Great Bear Lake; 2: Experimental Croppings of Lakes; 3: Great Slave Lake; 4: Peter Lake; 5: Experimental Lakes Area; 6: Lake Superior.

Most of the data were compiled from existing data bases, with the exception of Peter Lake. The Peter Lake samples were processed for length and age as well as other biological information. Fish were aged from fin-ray sections. Fin aging and sectioning followed methods outlined by Mills and Chalanchuk (2004). Fish size was determined from fork length (mm).

The size-at-age of the individual lake trout populations were compared and correlated to the length of growing seasons (e.g. the number of days per year above 0°C and 10°C). This comparison was used to test whether growing season length and/or ambient temperature influenced lake trout growth. In addition, the size-at-age of the individual lake trout populations were grouped by lake size and compared to test whether habitat size influenced lake trout growth.

Results and Discussion

We found that lake trout growth rates varied among the populations. A one-way ANOVA of mean fish length factoring showed there was a significant difference ($p < 0.001$) between populations. These results were consistent with other studies (Vander Zanden *et al.* 2000) and with other freshwater species (Tallman 1997). This variation is believed to be a result of individual niche adaptations to individual niche variation.

The hypothesis that lake trout growth was correlated to latitudinal position was not supported (ANOVA, p = 0.213). There was no pattern between latitudinal position of the population and mean fish length. No difference in the rate of growth between northern and southern populations of lake trout was observed, which is a contrast to the results of Healey (1975), based primarily on scale ages.

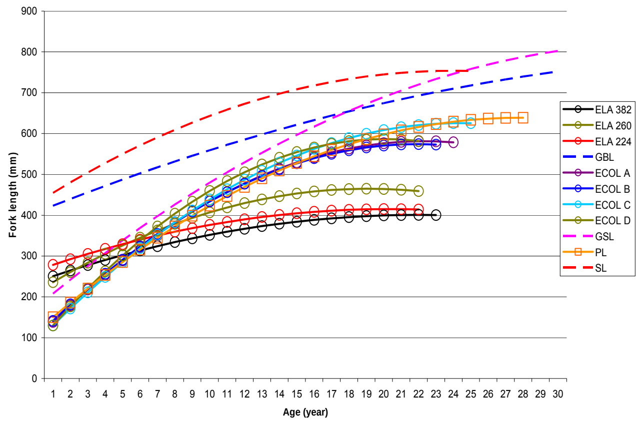

Figure 2: Quadratic linear regression of lake trout growth for individual lakes grouped according to lake size. --- Large lakes; □ Moderate lake; ○Small lakes Large sized lakes: GBL: Great Bear Lake; GSL: Great Slave Lake; SL: Lake Superior; moderate sized lake: PL: Peter Lake; small sized lake: ECOL A: Alexie; ECOL B: Baptiste; ECOL C: Chitty*; ECOL D: Drygeese; ELA 382; ELA 260 and ELA 224.

However, the hypothesis that lake size was an influential factor was supported (p= 0.001). It appeared that bigger lakes had faster growing lake trout populations (Fig. 2). The data showed a positive correlation between lake size and mean fish length (r=0.658). These results were consistent with the results of Shuter *et al.* (1998) who reported that lake trout populations from large lakes exhibited larger size and growth rates. Benoit and Power (1981) also reported that lake trout growth varied with lake size.

Summary/Conclusion

Lake trout populations examined in this study had significant variation in growth rates. This variation did not correlate to climate (latitudinal position), but did correlate to lake size. This is contrary to the first theory to explain life history variation. Lake trout in larger lakes have faster growth rates and a larger mean fork length. There are many potential reasons why larger lakes had faster-growing fish, as there are many confounding factors which can change with increasing lake size (e.g. dissolved oxygen, water composition, food web dynamics and habitat availability) (Pielou 1998). For this study, water temperature, dissolved oxygen, and water composition were not considered influential factors because they were similar among all study lakes. However, food-web dynamics and habitat availability for each of the study lakes was not well known and may be an influential factor of lake trout growth.

The second theory to explain life history variation is supported if large lakes are considered the central niche for lake trout. However, further studies are needed in a wide variety of lakes to confirm this second theory.

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14.1.3 Patterns and Processes Shaping Parasite Communities of Lake Trout

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Abstract
Factors shaping parasite communities of fish are still controversial with some researchers suggesting that phylogenetic relationships of host species is the key factor while others suggest that it is primarily due to ecological associations or historical ecology. Lake trout are an interesting model species to study these associations as they occur from the Arctic islands associated with another closely related taxon, Arctic charr (*Salvelinus alpinus*) and as far south as the Great Lakes, as part of more complex fish communities. Furthermore, lake trout belong to a relatively small clade of fishes consisting of brook trout (*Salvelinus fontinalis*), bull trout (*S. confluentus*), and Arctic char and dolly varden (*S. malma*). The parasites species *Discocotyle sagittata*, *Crepidostomum farionis*, *Cyathocephalus truncatus*, *Diphyllobothrium dendriticum*, *D. ditremum*, and *Eubothrium salvelini, Echinorhynchus salmonis* and *Cystidicola farionis* have wide holarctic distribution in chars. Throughout lake trout range in North America a total of 33 species of parasites have been reported, many of which are also associated with other fish species. Of the 33 species, three species are found in trout and indicate that phylogenetic and coevolutionary processes helped shape this component of the lake trout parasite community. *E. salmonis*, common in lake trout, appears to be tied to the historical ecological association of lake trout with coregonids. Two common parasite species, *Crepidostomum farionis* and *Proteocephalus spp*. appears to be correlated with the salmoniformes, indicating a phylogenetic association at a higher taxon level. Most of the remaining species are the result of historical and present day ecological associations and are indicative, to a large extent, of current feeding patterns of lake trout. It is well documented that fish are a key component of lake trout diet but their parasite communities indicates that invertebrates, including plankton, are also important components of lake trout diets.

14.1.4 Assessing Patterns of Use and Productivity of Shallow-water Spawning Habitat by Lake Trout – Do Great Lakes Lake Trout Have it Right After All?

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The goal of spawning habitat selection by lake trout is to optimize individual recruitment; however, the interplay of physical, chemical and biological factors and their effect on habitat choice, embryo survival, and ultimately recruitment is unclear. In the Great Lakes, selection of shallow-water spawning habitat by lake trout occurs but its contribution to recruitment relative to other habitat is unclear. Using a shallow-water reef in Lake Champlain with high spawner abundance, we investigated the relationship between spawning habitat use, egg survival, egg predator abundance in egg nets, and currents. Egg density was assessed by collecting eggs in buried egg nets. Egg survival was assessed from naturally deposited eggs and the displacement of plastic beads having similar settling velocities to eggs. As the beads behaved as egg surrogates we used them to calculate pre-displacement egg densities. We also used them to infer the potential for accumulation of fine sediments that would be more readily displaced than the beads. Relative amount of current on different parts of the reef were measured using erodable plaster of Paris blocks that were attached to individual egg nets. We also measured currents throughout the water column using an acoustic Doppler current profiler. Lake trout appeared to select intermediate depths on the reef that had the highest currents and caused maximum displacement of eggs and (presumably) fines. Survival of non-displaced eggs was high. Abundance of the egg predators (sculpins and crayfish) was relatively low and did not show any relationship with water depth, egg abundance or potential for egg displacement. Our results suggest that selection of shallow-water spawning habitat is a strategy that, while causing high egg loss due to displacement, may result in increased survival of entrained eggs primarily by reducing the accumulation of fines; suppression of predator abundance and foraging may also be involved.

14.1.5 The Effect of Climate Variation on Lake Trout Habitat and Behaviour in a Small Canadian Shield Lake

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ABSTRACT

Model predictions have shown that suitable habitat for cold-water stenotherms can be significantly reduced under climate warming scenarios. We used three years (2002, 2003, and 2004) of acoustic telemetry data, to define the thermal habitat boundaries of lake trout, *Salvelinus namaycush*, and examine the effect of climate variation on habitat variability and behavior. All data were collected in a small boreal shield lake (Lake 373, Area = 27.3 ha, Max depth = 20.8 m) at the Experimental Lakes Area in northwest Ontario. Telemetry data were collected using depth-sensing transmitters that were continuously monitored. Movements and behaviour of acoustic-tagged fish were recorded over considerable year-to-year variation in air and epilimnetic temperatures (~4°C), encompassing about half of the variation in temperature observed over the long-term record (1986-2001). We also observed differences in depth of the summer thermocline (~1–2 m) during the two climatically different years. Lake trout were distributed over a broad range of temperatures, suggesting that the use of a “classic” thermal habitat boundary (8-12°C) does not adequately define the pelagic distribution of lake trout. Variation in the pelagic distribution of lake trout among years was primarily associated with temperature-mediated changes in the depth of the hypolimnion. Our analysis presents the first empirical estimate of lake trout behaviour relative to thermal stratification and habitat boundaries, and provides information on lake trout behaviour during different climatic conditions.

14.1.6 Trace Element Distributions in Lake Trout Otoliths: Indicators of Life Histories and Environmental Conditions?

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Introduction

Otolith microchemistry can be used to determine life histories of, and environments occupied by, fish. Strontium (Sr) concentrations correlated with annual otolith growth increments have been used to distinguish between migratory and non-migratory behaviour (Babaluk et al. 1997) and trace elements in otoliths have been used to differentiate fish stocks (Campana et al. 2000). In this study, laser ablation microprobe inductively coupled mass spectrometry (LAM-ICP-MS) was used to analyze and map the distribution of Sr, zinc (Zn), lead (Pb), manganese (Mn) and barium (Ba) in otoliths from lake trout (*Salvelinus namaycush*) from two lakes adjacent to mining operations and one lake with no mining activities. The objectives of this study were to (1) determine the optimum instrumental conditions for analysis of this suite of elements; (2) compare and contrast trace element content with respect to time, individuals and location (in this case including lakes proximal to orphaned tailings and active mining and smelting); and (3) ascertain if there were, and what constitutes any characteristic patterns or anomalous concentrations of trace elements.

Otolith collection, preparation and analysis

Lake trout otoliths were collected from Athapapuskow and Kississing lakes in north-west central Manitoba (near mining operations) and Indian House Lake in eastern Quebec (control, no mine). Otoliths were prepared as described in Babaluk et al. (1997). LAM-ICP-MS analysis was done using a Thermo Finnigan Element 2 ICP-MS coupled to a Merchantek LUV 213 Nd-YAG laser. Samples were ablated in an Ar-He carrier gas and optimum laser beam conditions (in terms of sensitivity) used a 30 μm diameter beam traveling at 2 $\mu m s^{-1}$ across the otolith. A laser power setting of 80% was used resulting in an incident pulse energy of ~0.020 mJ and an energy density on sample of ~6.22 $J cm^{-2}$. Calcium (as 56 wt. % CaO) was used as an internal standard and external calibration standardization was done using NIST glass 610.

Results

Figures 1a & 1b show the results of a laser scan across an otolith from Indian House Lake. Strontium, Ba, Zn and Mn all show periodic, oscillatory patterns that correspond to annuli, with concentrations ranging between 800 – 2000 parts per million (ppm), 5 – 70 ppm, 2 – 200 ppm and 0.1 – 10 ppm, respectively. All otoliths showed broadly similar general patterns, however, the scans did differ in some of their details in that the concentration maxima are different and the maximum amounts of Zn can occur at different ages in the sequence of annuli. The otoliths from Indian House Lake lake trout (i.e., those farthest from any potential anthropogenic influence) had the highest overall Zn content. Similarly one fish from Kississing Lake showed a different Ba distribution (Figure 2). Barium is found in greater concentrations in three annuli in the middle third of the otolith; this also corresponds with three prominent Sr peaks (not shown). The Zn (not shown) and Mn peaks in this region are offset from the Sr (not shown) and Ba peaks (Figure 2). Lead contents ranged from 0.1 to 3 ppm in fish from Athapapuskow Lake; in

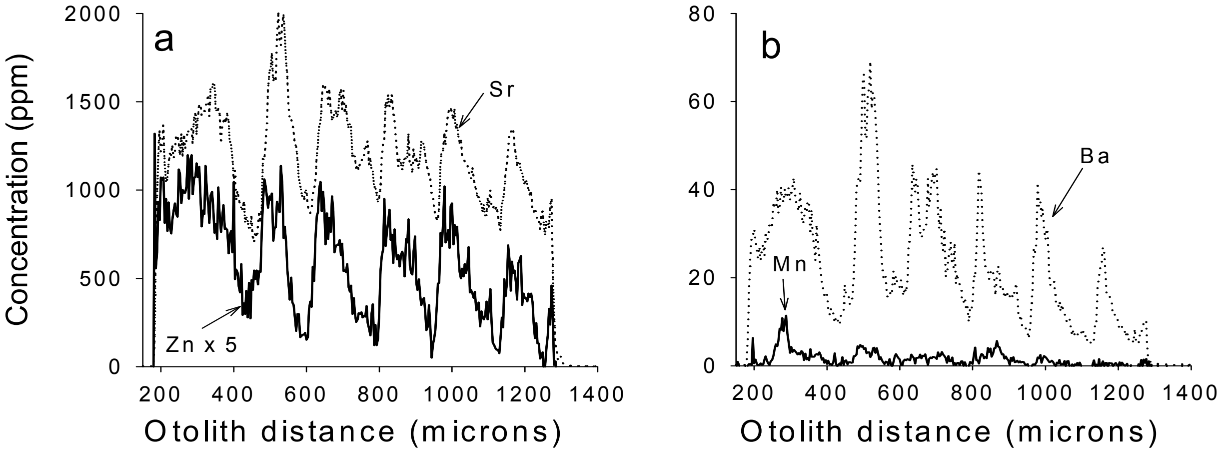

Figure 1: Typical trace element distribution profiles from a LAM scan of a lake trout otolith from Indian House Lake.

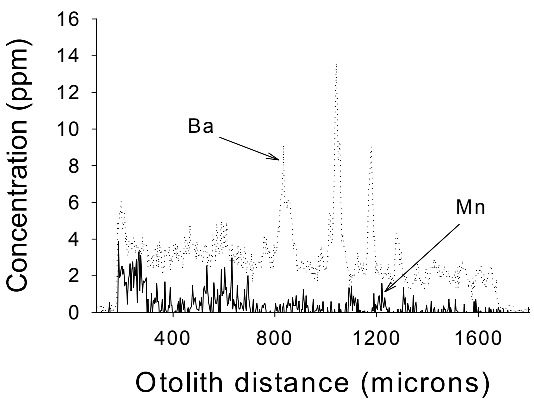

Figure 2: Ba and Mn distribution profiles from a LAM scan of a lake trout otolith from Kississing Lake.

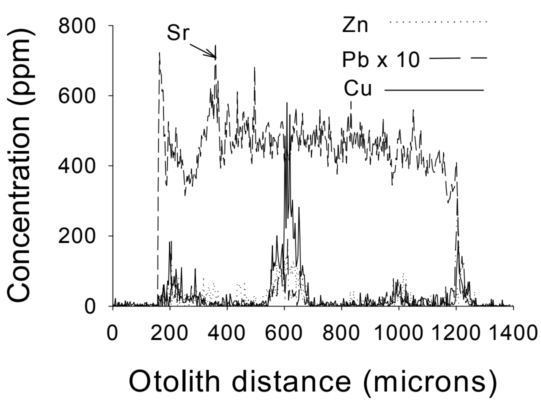

Figure 3: LAM scan of an Athapapuskow Lake lake trout otolith showing anomalous Cu-Pb-Zn peaks.

Kississing Lake, Pb levels were between 0.2 ppm and 0.7 ppm and in Indian House Lake levels were around 0.1 ppm. Lead does not show a regular periodic distribution that could be linked to the annular structure. While the patterns of Sr, Ba, Zn and Mn for the Athapapuskow Lake fish shown in Figure 3 could be described as typical, anomalous patterns for Copper (Cu) and Pb were evident. Using the Sr content for reference (flat with a weak periodic pattern and an overall concentration of ~ 500ppm) at about 575 microns along the transect from the otolith core to the outer edge there were prominent Cu, Pb and Zn peaks and there was second smaller group of Cu, Pb and Zn peaks at about 1000 microns. Corresponding peaks are not seen in the Sr, Ba (not shown) or Mn (not shown). Copper, Pb and Zn concentrations reach ~550 ppm, ~180 ppm and ~12 ppm respectively. Anomalous concentrations similar to those shown in Figure 3 associated with distinct growth increments were observed in two other trout otoliths from Athapapuskow Lake.

Discussion

In this and other studies (e.g., Halden et al. 2000) we have shown that Sr and Zn have periodic, oscillatory distributions in otoliths. While the movements of fish between marine and freshwater environments can be shown by the periodic, oscillatory distribution of Sr and the Sr uptake process is basically understood, the pathway by which Zn and other metals are incorporated into fish is likely to be different and is less well understood. Moreover, the interpretation of the concentrations and significance of the periodic nature of the patterns of Zn and other trace metals remains to be established.

Options for the incorporation of trace metals such as Zn include absorption from water through the gills or ingestion as part of their diet (c.f. Renfro et al., 1975; Bradley & Sprague, 1985). We showed that Mn and Ba have distinct periodic signatures corresponding to otolith annuli which indicate that their availability and uptake are periodic. Overall, the differences in concentration may be attributed to different lakes (i.e., environments) while differences in the periodicity in the patterns within a lake may be attributed to different behaviors, nutrition, movement or changes in habitat occupied. If the uptake of Zn is linked to nutrition then this would be consistent with higher concentrations being detected in summer growth increments (i.e., period of most active feeding).

We were also able to distinguish anomalous trace element signatures. In some Athapapuskow Lake fish, single annuli sometimes contained significantly elevated concentrations of Cu, Zn and Pb. This might indicate that at some time the fish encountered elevated concentrations of these elements. The higher levels could be achieved by the fish moving into areas where Cu, Zn and Pb levels were high. Geochemical coherence of Cu, Pb, and Zn is expected because these elements occur together in sulphide minerals. Sulphide minerals are common in rocks and therefore the surrounding environment (i.e., lake). It would be reasonable to expect some levels of these elements to be constantly present as background. The rather sudden appearance of elevated Cu, Zn and Pb could indicate that the Athapapuskow Lake fish had come in contact with tailings effluence or possibly some atmospheric fallout, effectively a point source in space and or time. There is no direct contact between the tailings of the nearby active mine and Athapapuskow Lake. However, there are abandoned mines and tailings in the area which are in direct contact with Athapapuskow Lake.

Geochemical coherence might also be expected of Sr and Ba. Because of charge and ionic radius they are very likely substituents for calcium (Ca) (main constituent of otoliths) and are commonly found in carbonate and phosphate minerals. Their presence in lakes is expected and concentrations are likely to be high where the watershed encompasses rocks containing carbonate minerals such a limestone or easily weathered plagioclase feldspar. Limestone outcrops are prominent features at the southern end of Athapapuskow Lake and given that trout movements can be on the order of 10s or 100s of km (Schmalz et al., 2002), trout could easily have encountered both tailings at the northern end of the lake and limestones at the southern end. This preliminary study indicates a variety of environmental conditions may be reflected in otolith microchemistry.

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15 Poster Presentations

Session Chair: Erin Hiebert

15.1 Management & Co-management

15.1.1 Evaluation of Offshore Stocking to Mitigate Piscivore Predation on Newly Stocked Lake Trout in Lake Ontario

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Abstract:
In Lake Ontario, survival of stocked lake trout declined sharply in the 1990's relative to levels measured in the 1980's. These declines are believed due, in part, to increased predation on newly stocked fish by large salmonids. Large salmonids congregate near shore in spring because the shallow water warms before the deeper open lake water. Prior to the 1990's, the movement of vast schools of alewives shoreward in spring coincided with the release of hatchery lake trout effectively buffering newly stocked fish from large predators. Since the early 1990's, declines in alewife abundance coupled with a deeper distribution in spring is believed to have resulted in increased predation on newly stocked lake trout.

We evaluated the relationship between location (offshore vs. onshore) and timing (May vs. June) of stocking to the survival of hatchery lake trout in Lake Ontario. Relatively simple changes in stocking practices such as those examined in this study may provide cost-effective alternatives to enhance survival of stocked fish. By April of each year from 2000 to 2002, six experimental lots of 40,000 age-1 Seneca strain lake trout (240,000 total) were marked with coded wire tags and adipose fin clips. Each year, the six experimental lots were stocked at two sites by three methods: offshore in May (over 55 m), from shore in May, and from shore in June. Preliminary results through 2004 indicate that the combined age-2 through age-5 returns favor offshore stocking over stocking from shore in either May or June by a 2.0 : 1.0 : 1.2 margin (n = 79, 40 and 49 respectively).

15.1.2 Management and Monitoring of Lake Trout (*Salvelinus namaycush*) in Cold Lake, Alberta

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Abstract

Cold Lake, Alberta is home to endemic and introduced populations of lake trout (*Salvelinus namaycush*), and is one of the few lake trout fisheries readily accessible by road in Alberta. In the early 1900's the lake received heavy commercial and recreational fishing pressure directed towards lake trout. The fishery subsequently collapsed in the 1940's. Commercial fishing re-commenced in 1955 with reduced quotas. To support recovery, supplemental stocking was begun in 1965 that continued annually until 1987. This was confounded, however, by the impacts of DDT being applied in the watershed by the Department of National Defence. The population began to stabilize when lower tolerance limits were established, however, the population exhibited no sign of return to historical densities. The lake trout population remained this way until the 1990's when management changes, prompted by the public, began a move towards improving the recreational fishery and gaining a better understanding of the lake trout stock. Reduced bag limits, size limits, and season closures on lake trout and the gradual elimination of the gill net fishery on the Alberta portion have given the fishery the opportunity to recover.

Current monitoring programs have included experimental test netting, mark-recapture population estimates of adult lake trout using such techniques as dorsal scarring and VIE injection, and angler surveys (summer/winter) in order to determine lake trout harvest and fishing effort. Monitoring of the domestic fishery still remains an unresolved issue. Many issues remain regarding the long term recovery and sustainability of the lake trout population including: increasing angler effort and harvest, increasing domestic harvest, an expected increase of Metis harvest due to new fishing rights, continued inter-provincial cooperation with Saskatchewan, and increasing urbanization and industrial development in the watershed.

15.1.3 Effectiveness of Slot-Size Regulations and Stocking for Management of High Fishing Demand and Conservation of Wild Lake Trout Stocks

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Abstract
The study objective was to test the effectiveness of slot-size regulations and supplemental stocking for management of high fishing demand for lake trout populations in Ontario lakes. The slot-size regulation specifies non-harvest of lake trout 40-55 cm total length to prevent recruitment over-fishing. In contrast, supplemental stocking addresses high fishing demand by artificially enhancing production. Our 2x2 nested study design incorporated two lakes that were stocked and two in which slot-size regulations were removed. The lakes are located in south-central Ontario and have surface areas of 220-360 ha, maximum depths of 30-50 m, and similar water chemistry and fish assemblages. Baseline studies were completed during 2000 and 2001 to determine fishing effort, catch and harvest, and abundance, age and size structure of the lake trout populations, prior to removal of the slot-size regulation in 2002. Stocking of yearling lake trout of native origin was initiated in two study lakes in 2000 and was continued annually to 2005. Roving creel surveys were conducted annually to monitor the winter and spring fisheries. After removal of slot-size regulations angler effort in the winter fishery increased two-fold to 10-20 angler hr ha^{-1}, harvests increased 3-3.5 fold and yields increased 3.4 and 4.7 fold to 1.09 and 1.65 fish ha^{-1} yr^{-1}. Effort, catch and harvest were unchanged in the control lake where the slot-size regulation remained in place in the absence of stocking. Harvest and yield increased with stocking in the presence of the slot-size regulation. Hatchery fish comprised 42% of the catch after only three years, but stocking appeared to suppress natural recruitment. Fishing effort, harvest and mortality was much lower with slot-size regulations in place thereby allowing recreational fishing opportunity while providing protection for the wild stocks. Experimental removal of slot-size regulations has confirmed the need for strong regulation of harvests to harmonize fishing demand with conservation needs for sustainability of wild stocks.

15.1.4 Lake Trout in Québec: Diverse Management Strategies for Sustainability

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Lake trout in Québec: Population Diversity

In Québec, the lake trout (*Salvelinus namaycush*) is found in at least 1,014 lakes covering a total area of 26,523 km^2. North of 49˚, distribution is extensive, the inventory is incomplete and little is known about the biological characteristics of lake trout populations.

In Southern Québec, population features vary significantly. Lakes are usually small (mean = 488 ha, median = 127 ha). Populations in waters under 300 ha are mainly planktivorous, while those in larger lakes are usually piscivorous. Planktivorous populations are characterized by slow growth (L_∞ = 43 to 55 cm), reach sexual maturity at a small size (L 50% sexual maturity = 27.5 to 37.5 cm) and often yield more than 1 kg/ha/year. Piscivorous populations can grow to larger sizes (L_∞ = 60 to 104 cm), sexual maturity is reached at a large size (L 50% sexual maturity = 38.5 to 51.5 cm) and yields are low (0.4 to 0.6 kg/ha/year).

In Northern Québec the species is fished extensively, both by Native people for subsistence purposes and by tourists for sport. Further south, pressure from fishing can be significant, ranging from 2 to 20 rod hours/ha. The lake trout is not fished commercially in Québec.

Limited v. Unlimited Access Fisheries.

Fish stocks are a common property resource. Fishing regulations (season, catch and possession limits, size limits, etc.) help distribute the harvest between users but do not limit the fishing effort (Olver et al. 2004). Yet, the lake trout is very sensitive to fishing mortality (Martin and Olver 1980), which is directly linked to the fishing effort. A quota system is therefore the only means of avoiding overfishing (Olver et al. 2004).

Accordingly, the Québec government has created areas where access to the resource can be limited. There are three types of such areas, namely wildlife reserves, controlled exploitation zones (ZECs) and outfitters with exclusive rights.

All three types share the same goals of protecting indigenous populations of lake trout (and other species), guaranteeing sustainable harvesting and providing fair access to the resource. Being linked to fishing pressure, limited access fisheries have been created near the main human population centers where demand is high.

Limited Access Fisheries in Southern Québec
Wildlife Reserves.

Québec's 17 wildlife reserves cover a total area of nearly 67,000 km^2. Activities within a wildlife reserve are managed by a public corporation. A catch quota is set for every lake, and mandatory registration of catches as fishers leave the reserve territory enable harvest to be monitored on a permanent basis. Fishing is prohibited when a preset quota is reached. This information also allows the quota to be adjusted annually, according to the productivity of each population. Fishers have access to the wildlife reserves on a first-come, first-served basis, and must pay an entrance fee.

Controlled Exploitation Zones (ZEC).

Québec's 63 ZECs range from 200 to 2,500 km^2 in size and cover a total area of some 48,000 km^2. Fishing is managed in a similar way to the wildlife reserves, except that activities (harvest monitoring, road maintenance, etc.) are overseen by a non-profit association. The association's officers are all volunteers and are elected democratically. Anyone may join the association by purchasing an annual membership card. To fish in a ZEC, a person needs only to pay the required fees; it is not necessary to be a member of the association. The powers of the associations and the fees they may charge are regulated by order-in-council of the government. A ZEC's fees are approved annually by a general assembly of its members. Because the lakes are often small, the catch quota can be reached within a few days; the fishing season on a lake can be extended by applying conditions to reduce catch rates (late opening date, fly fishing only, etc.).

Outfitters with Exclusive Rights.

An outfitter with exclusive rights is a commercial operation to which the Québec government grants exclusive wildlife harvesting rights over a given area. Fishing is possible only with the permission of the holder of the rights. The outfitter supplies services and monitors harvests within its territory. Wildlife harvesting activities are regulated by a three-year management plan established jointly by the ministry and the leaseholder. In all, Québec has 193 outfitters with exclusive rights covering an area of approximately 25,500 km^2.

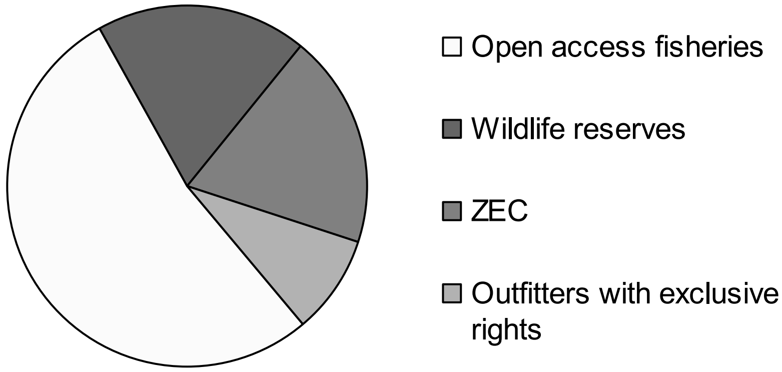
Limited Access Fisheries in Northern Québec

The situation is very different north of 49˚. Here, agreements have been entered into with the First Nations to limit non-Native access to certain areas. In a portion of the territory, the fisheries are reserved for exclusive use by the First Nations. In a second portion, non-Natives must obtain a right of access issued by the Native community in order to be able to fish. The rest of the territory is freely accessible. Given that harvesting is extensive, the risk of overfishing is low, except locally. The harvest control approach is designed to ensure management of fishing quality, whereas the wildlife reserves and outfitters are geared more towards tourism development.

A Winning Equation: Open Access + Limited Access = Comprehensive Management

By creating a network of areas where access to the resource can be controlled, it is possible, at provincial level, to protect a significant percentage of the lake trout population from overfishing and ensure sustainable harvesting. It is also possible to provide a range of fishing opportunities at varying costs, to meet the needs of different client groups. The creation of the ZECs and outfitters with exclusive rights has helped develop co-management of the resource.

Proportion of lake trout lakes by access type



As far as the open access fisheries are concerned, stock conditions vary according to fishing pressure. Closing of winter lake trout fishing and the introduction of size limits (minimum size or protected slot, depending on population characteristics) have significantly reduced overfishing and have allowed a significant proportion of populations to recover.

Acknowledgments
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15.2 Effects of Land Use Activities on Lake Trout and Their Habitats

15.2.1 Enhanced Growth and Condition of Lake Trout in a Small Ontario Lake during Cage Aquaculture of Rainbow Trout

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Introduction

Salmonid aquaculture is now one of the most important seafood industries in Canada. More than 25% of all the economic value of fish and seafood in Canada is from aquaculture, and about 90% of this value is from saltwater and freshwater salmonid aquaculture (OCAD 2001). Although seawater culture of Atlantic salmon dwarfs freshwater production, freshwater production is not insignificant at approximately 5.5 million kg yr^{-1} and a value of more than $16M CAD yr^{-1}. There is still great controversy about the impacts of freshwater cage culture in the Great Lakes, and this is one of the reasons that growth in the industry has stagnated in recent years. The purpose of this study was to determine the impacts of rainbow trout (*Oncorhynchus mykiss*) cage culture on lake trout (*Salvelinus namaycush*) in a small Ontario lake.

Methods

We studied the impacts of rainbow trout cage aquaculture on the fish populations of Lake 375, the Experimental Lakes Area, Ontario (Cleugh and Hauser 1971), during two yearly production cycles. Approximately 10,000 rainbow trout were cultured in one pen in Lake 375 in 2003 as well as 2004. Fingerlings were added to the pen each spring and fed commercial fish pellets until they were harvested in the fall. Lake 375 has a typical community for a small lake trout lake in this region of Canada: lake trout, white sucker (*Catostomus commersoni*), slimy sculpin (*Cottus cognatus*), pearl dace (*Margariscus margarita*), fathead minnow (*Pimephales promelas*), and redbelly dace (*Phoxinus eos*). We had an extensive baseline of 15 years of data for the fish populations of Lake 375 prior to the years of cage culture, as well as similar data for two nearby natural, undisturbed lakes.

We monitored abundance, annual survival, recruitment, growth, and condition of lake trout in all three lakes. We captured lake trout in trap nets and short sets of small mesh gill nets (minimal mortality) each fall. We determined abundance and annual survival of lake trout using the Jolly-Seber (Jolly 1965, Seber 1982) model, and aged fish using fin-ray sections (Mills et al. *these proceedings*). Using length-at-age data, we formed growth curves and using length and weight data, we calculated condition (k) factors.

We used catch-per-unit effort of fathead minnow and pearl dace to monitor changes in the abundance of these species. Trap nets were set along the shoreline of the lake and emptied every 2-3 days. All fish captured in the trap nets were released live to the lake.

Results

No changes occurred in the abundance, annual survival, growth, or condition of lake trout during the first year of rainbow trout production, but when algal productivity increased in the lake during second year of cage culture, lake trout growth and condition increased (Figure 1). Growth and condition of Lake 375 lake trout increased above previous values for Lake 375 lake trout, and similar increases did not occur in other nearby lake trout populations in unaltered lakes. Increased growth of Lake 375 lake trout occurred in age classes prior to sexual maturity. The increased growth and condition of lake trout was probably due to the increased abundance of fathead minnow and pearl dace in Lake 375 that occurred during the second year of cage culture (Figure 2). Fathead minnow abundance in Lake 375 during fall 2004 was particularly high due to the very successful year class produced during that year.

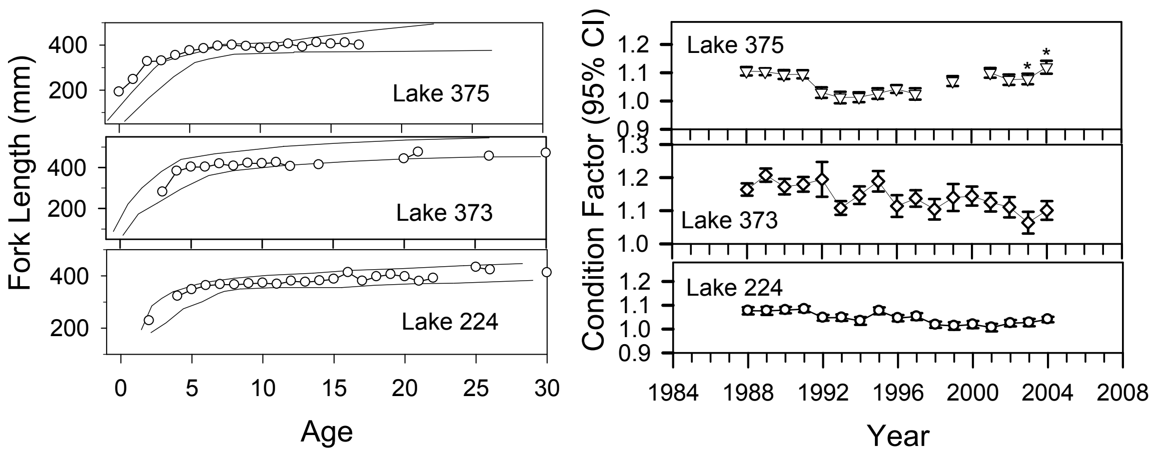

Figure 1. Growth curves and mean condition factors for lake trout in Lakes 375, 373, and 224. The upper and lower limits of growth for each population prior to the years of cage culture are indicated in the growth figure. The growth curve for 2004 for each population is presented. Mean condition values for the years of cage culture in Lake 375 are indicated by “*”.

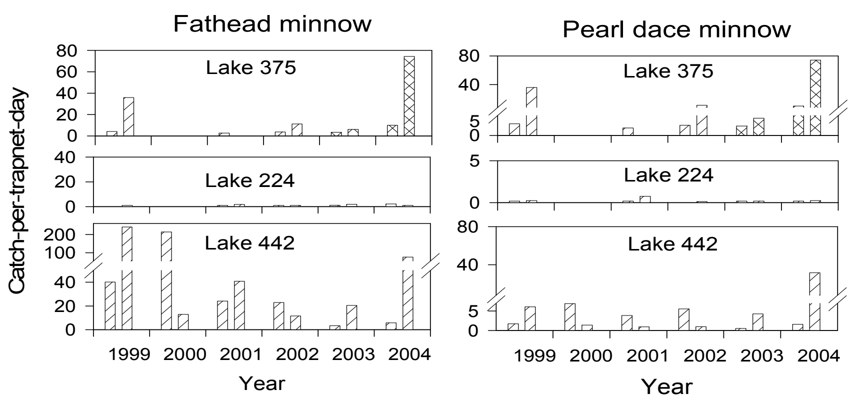

Figure 2. Trap net catch-per-unit-effort in spring and fall sampling of fathead minnow and pearl dace in Lakes 375, 224, and 442. Years of cage culture in Lake 375 are indicated by cross-hatching in the bars for 2003 and 2004.

Discussion

We were not surprised that growth and condition of lake trout in Lake 375 did not increase the first year of fertilization. In other experiments where fertilizer was added directly to a lake, there was no response the first year (Mills 1985; Lienesch et al. 2005; Martin et al. *these proceedings*). Frequently, there is a lag of one year for a change in nutrient loading to cause changes at higher trophic levels (Mills 1985). We were surprised that minnow catches increased so rapidly the second year of cage culture, and that this was evident in catches of trap nets set along the shore of the lake. At the same time catches increased along the littoral zone, minnows congregated near the pen in the pelagic zone of the lake (P.J. Blanchfield, unpublished data). We know from other experiments at the Experimental Lakes Area (Mills et al. 2000), that lake trout condition can change quite rapidly in response to changes in prey abundance, so the increase in condition was not unexpected.

After two years of cage aquaculture in Lake 375, we have not identified any negative impacts on the fish populations. There has been little degradation in hypolimnetic oxygen values during either year as well as little change in the anoxic zone of the lake during winter. As cage culture continues, lake trout could be squeezed into smaller zones of the lake during summer and winter, although the nutrients in fish faeces below the culture pen are being released at a very low rate. We suspect, based on a previous fertilization experiment conducted at the ELA (Mills 1985, Mills and Chalanchuk 1987) that growth and condition of lake trout will continue to increase for a number of years if cage culture is continued.

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15.2.2 Baseline Lake Trout Population Characterization and Health Surveys in Three Sub-Arctic Lakes

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Abstract

Adult lake trout and round whitefish were sampled in three sub-arctic lakes (Snap Lake, Reference Lake, and Northeast Lake) in August 2004, as part of the baseline inventory required for future monitoring at the Snap Lake Project, NT. Gill net and angling techniques were used to capture fish for the study. Fork length, weight, and age information were collected from all sampled fish. Sacrificed lake trout were additionally sampled for sex, state of maturity, liver weight, gonad weight and fecundity. The gonads were sectioned for histological examination to confirm the state of maturity. In addition, parasite load and stomach contents were also examined. Lake trout were generally old, slow growing and late to mature. Growth rates were similar between lakes. Age class distribution was similar between the Northeast Lake and Snap Lake lake trout populations; however, the population in the Reference Lake was, on average, represented by younger individuals. The presence of resting female and males is indicative of the low productivity of these lakes. Females may be spawning in alternate years. Fecundity was variable within- and between lakes. Histological examinations of female gonads showed that not all ovaries were developing eggs at the same rate. Lake trout from all three lakes most commonly consumed fish, followed by invertebrates and zooplankton on occasion. The most common parasites found in lake trout included tapeworms and flukes. More baseline data collections from sub-arctic lakes are required for a better understanding of the general ecology of lake trout populations at northern latitudes if they are to be considered for monitoring potential effects due to development.

15.2.3 The Long-term Recovery of a Lake Trout Population in Lake 223 Following Acidification

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Introduction

Anthropogenic acidification was an important aquatic issue in the 1970s and 1980s. One of the important experiments that conclusively demonstrated the impacts of acidification on North American lake ecosystems was the acidification of Lake 223 (Schindler et al. 1985), the Experimental Lakes Area, northwestern Ontario. During this intentional acidification from natural pH of 6.5 in 1975 to pH 5.1 in 1983 by sulphuric acid additions, lake trout (*Salvelinus namaycush*) reproduction ceased and the food web ending in lake trout collapsed. Lake trout abundance decreased by more than 50% (Mills et al. 1987, 2000). Instead of continuing the acidification until lake trout were extirpated from the lake, the lake pH was allowed to gradually recover. Starting the first year of pH recovery, the lake trout food web became re-established and lake trout recruitment returned. Pre-acidification pH was achieved in 1994, and with the exception of *Mysis relicta*, all trophic levels returned to their former community compositions. Although lake trout recruitment immediately resumed in 1984 and lake trout survival remained high, abundance of lake trout in Lake 223 had not increased to to pre-acidification values 12 years later in 1996 (Mills et al. 2000). The purpose of this study is to report on changes in the abundance of lake trout in Lake 223, and report on other changes in this population's condition, growth, recruitment, and annual survival. Similar data for the lake trout population in nearby natural pH, pristine Lake 224 will also be presented for the same years.

Methods

Lake 223 was acidified from 1976 to 1993 using electrolyte grade sulphuric acid added to the epilimnion usually twice weekly from a slowly moving boat. A target pH was established each year and additions were used to maintain the target pH. The lake was acidified in a step-wise fashion to pH 5.0 in 1981, held at this pH until 1983, and then gradually allowed in a stepwise fashion to become less acidic. Additions were terminated in fall 1993.

In-lake microbial processes continually neutralized lake acidity all years of pH additions, and when the additions stopped, these processes caused lake pH to immediately return to natural pH values in 1994. This natural pH value has continued through 2005.

Lake trout were captured in Lakes 223 and 224 in the fall of each year using trap nets, short sets of small-mesh gill nets, and angling. Angling was terminated after the first few years of study, and trap nets were not used the final years of study in Lake 223. Sets of gillnets were usually 10 – 15 minutes and almost all fish were removed live to be returned to their populations. The Jolly-Seber (Jolly 1965, Seber 1982) mark-recapture method was used to estimate lake trout abundance and annual survival. Individuals were aged using fin-ray sections and fish were assigned to year classes based on these ages to estimate recruitment. Mills et al. (2002) explain this method in more detail. Growth curves were constructed from mean length at age data and Fulton's condition factor (k) was calculated for each individual. More details are located in Mills et al. (1987, 2000).

Results

Abundance of Lake 223 lake trout gradually increased starting in 1995 (Figure 1), but is still less than prior to acidification, 1975 – 1976. Annual survival remained high during pH recovery, averaging 88% per year, and there was no trend to increased survival in the latter years of recovery to account for the increase in abundance.

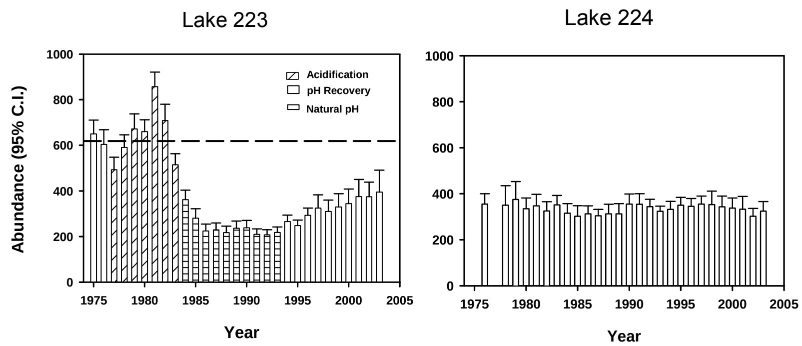

Figure 1. Jolly-Seber abundance estimates and their 95% confidence intervals for lake trout in Lakes 223 and 224. Pre-acidification average abundance is indicated by the dotted line for Lake 223.

Although lake trout recruitment resumed in 1984 (Figure 2), the number of new recruits (6) was well below the number (23) needed to sustain the already low abundance or increase abundance (above 35). Therefore, it is not surprising that abundance remained low for many years of recovery, until recruitment increased above 40 fish per year in 1990. Abundance and recruitment of lake trout were relatively stable throughout the entire period of study in nearby Lake 224.

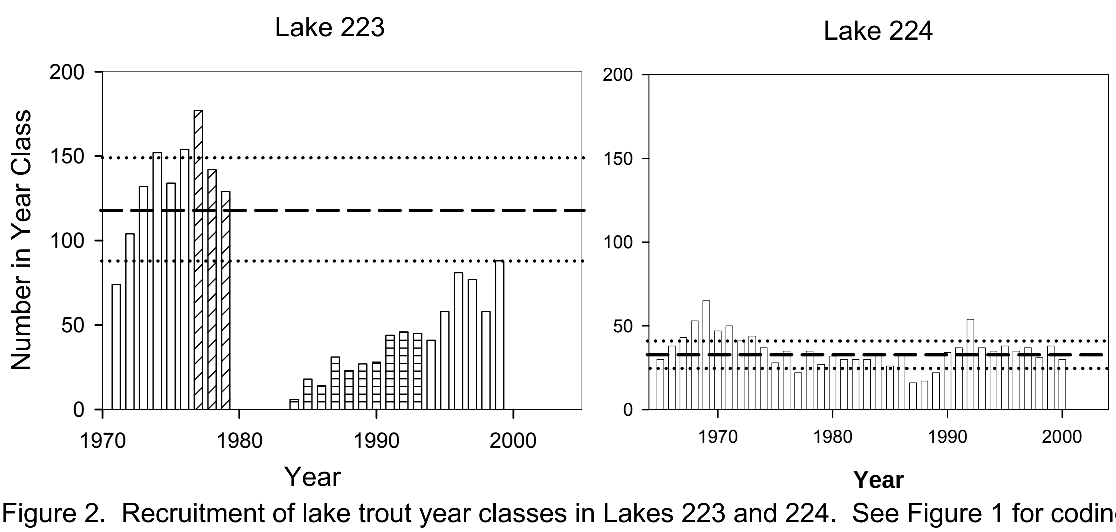

Figure 2. Recruitment of lake trout year classes in Lakes 223 and 224. See Figure 1 for coding of Lake 223 data. The dashed line for Lake 223 is the average recruitment for years prior to acidification and dotted lines are the 95% confidence interval. The dashed line for Lake 224 is the long term average; dotted lines as in Lake 223 panel.

During years of pH recovery, growth of new Lake 223 recruits was greater than that prior to acidification (Mills et al. 2000) and age of first maturity decreased (Figure 3). The combination of increased growth and decreased maturity contributed to the gradual increase in recruitment in Figure 2. Although abundance of Lake 223 lake trout has not yet returned to pre-acidification values, we believe the steady increase in recruitment and continued high annual survival will cause abundance to continue to increase and eventually achieve pre-acidification values.

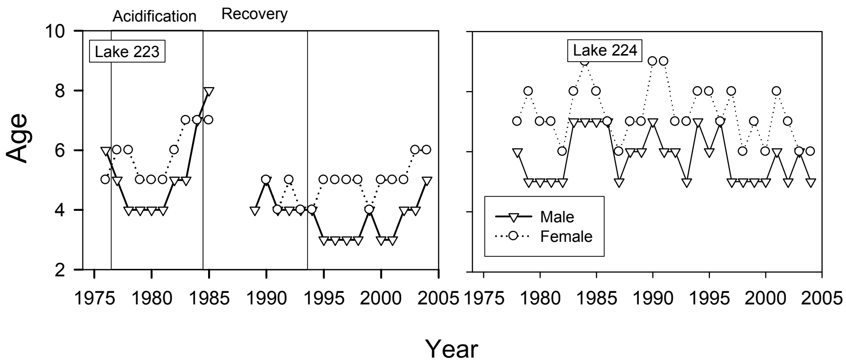

Figure 3. First age of maturity for Lakes 223 and 224 lake trout.

Discussion

When we started the recovery portion of the Lake 223 experiment, we expected the lake trout population to recovery as quickly as other biotic components in this lake. Lake trout abundance has increased very gradually, and actually continued to decrease in the early years of pH recovery because yearly recruitment was so low. Abundance has only started to increase as recruitment has increased above 40 individuals per year. Although this may seem very low, it is similar to average yearly recruitment for other ELA populations (Mills et al. 2002). We do not know whether the absence of critical prey species during the early years of pH recovery were responsible for the slow build-up of recruitment. Species were extirpated at all trophic levels during the acidification phase of the experiment, and they gradually colonized the lake during pH recovery. *Mysis relicta*, an important lake trout prey species is still absent from Lake 223, but there are other lake trout lakes in the ELA that lack *Mysis*, and the lake trout populations have average recruitment and growth compared to other close-by populations.

The prolonged period of recovery may not be too surprising. Unlike many other fish species, there may be no compensatory recruitment for lake trout (Walters et al. 1980, Mills et al. 2002) as frequently documented for other species such as lake whitefish (*Coregonus clupeaformis*) (Healey 1980).

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15.2.4 The Effects of Discharge of Effluent from Small-Diameter Mineral Exploration Drilling to Arctic Lakes

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Abstract
Extensive mineral exploration occurs in the NWT, often involving diamond drilling through lake ice. Return water from the drills may contain rock fines, which may affect areas of fish habitat in the vicinity of the drill hole. This research evaluated the impacts of discharging diamond drilling wastes into lakes, at the scale of first stage mineral exploration drilling. Three field programs monitored impacts to water quality, sediment quality, and benthic biota: 1) The Great Slave Lake drilling program involved release of small quantities of rock fines, and affected benthos within 15 m of the discharge point. Volumes of solids were too small to effect measurable changes to particle size structure and sediment chemistry, with the exception of increased calcium concentrations. 2) The Baton Lake drilling program involved greater quantities of drilling effluent. Water chemistry changes were observed after drilling, but these did not persist beyond the first year, with the exception of manganese in the bottom waters above the discharge site. Total suspended solids concentrations during drilling remained low. The layer of drill fines overlying the sediments had a maximum depth of 7 mm; this was sufficient to measurably increase levels of aluminum, magnesium, potassium and sodium in the sediments and decrease organic carbon and nitrogen. One year after effluent release there were no detectable differences in the benthic invertebrate population when compared to pre-release. 3) The Lac de Gras drilling program involved release of kimberlite effluent containing polyacrylamide additives. Water quality monitoring identified elevations in some metal parameters in the lower water column during drilling only. Numbers of individuals and species richness dropped right after drilling, but had rebounded one year later. Changes to sediment chemistry were observed, with increases in aluminum, magnesium, manganese, calcium, potassium, sodium, carbon and ammonia.

15.3 Stock Assessment

15.3.1 A Calibrated Summer Assessment Methodology for Lake Trout

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Abstract
Summer Profundal Index Netting (SPIN) is a calibrated index fishing method that was developed to monitor the status of lake trout populations in Ontario. The method employs a random series of mixed mesh gillnet (8 x 8m = 64m total net length) which catches lake trout greater than 300 mm fork length. The operational window for the protocol is June to mid-September when lakes are thermally-stratified. Nets are set on the bottom for two hours during the day at depths ranging from 10 to 40m. This depth range is divided into three 10m strata and the number of samples in each stratum is proportional to stratum area and the cumulative daily stratum catch-per-unit-effort (CUE). The catch of lake trout is adjusted for gear selectivity and an index of lake trout abundance is obtained using the area weighted geometric mean CUE. In 2003 and 2004, this index was calibrated by studying a number of lakes where lake trout density was estimated either by mark-recapture or life history analysis. Results of this work have demonstrated that five times the corrected CUE provides a reasonable approximation of lake trout density (number per hectare). The application of this method in reporting on the state of the lake trout resource in Southern Ontario will be discussed.

15.3.2 An Update on the Status of Lake Trout Stocks in Great Bear Lake, NWT: Are Existing Management Strategies Suitable for Maintaining a Trophy Sport Fishery?

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Abstract:
Although Great Bear Lake represents one of the two major sport fisheries for lake trout in the Canadian north, there has been no stock assessment research and minimal monitoring of the fishery over the past 15-20 years. Lake trout stocks were last assessed in 1984-85, at which time a series of management decisions were implemented with the goal of maintaining a world class trophy fishery. Total allowable harvest levels were set by geographic area under the assumption that lake trout do not move extensively, daily catch and possession limits were decreased and a moratorium was placed on further lodge development. We initiated a stock assessment study in 2003 with the following objectives: 1) to provide up to date biological information on trout stocks in each of the 4 management areas traditionally fished by the lodges; 2) evaluate the success of the current management strategy; 3) test the assumption that trout do not move between management areas through the use of molecular genetic techniques. Our results to date show that although there is considerable variation in biological traits between management areas, the size and age structure along with rates of growth and mortality have remained stable over the last 20 years suggesting that current lodge practices under the existing management scheme are sustainable. Analyses of genetic stock structure from microsatellite DNA indicates a high degree of separation between lake trout from different management areas suggesting there is a low degree of mixing between stocks in different regions of the lake. We suggest the allocation of specific management areas to individual lodges has probably encouraged lodge owners to manage their designated areas carefully and has allowed the fishery to remain stable with relatively little enforcement.

15.3.3 Distinguishing Between Wild and Stocked Lake Trout: Evidence from Otolith Carbon and Oxygen Stable Isotope Values

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Abstract
We investigated the potential for using carbon and oxygen isotope values of otolith carbonate as a method to distinguish naturally produced (wild) lake trout (*Salvelinus namaycush*) from hatchery-reared lake trout in Lake Ontario. We determined $\delta^{13}C_{(CaCO3)}$ and $\delta^{18}O_{(CaCO3)}$ values of otoliths from juvenile fish taken from two hatcheries, and of otoliths from wild yearlings. Clear differences in isotope values were observed between the three groups. Subsequently we examined otoliths from large marked and unmarked fish captured in the lake, determining isotope values for regions corresponding to the first year of life. Marked (i.e. stocked) fish showed isotope ratios similar to one of the hatchery groups, whereas unmarked fish, (wild fish or stocked fish that lost the mark) showed isotope ratios similar either to one of the hatchery groups or to the wild group. We interpret this data to suggest that carbon and oxygen isotope values can be used to determine the origin of lake trout in Lake Ontario, if a catalogue of characteristic isotope values from all candidate years and hatcheries is compiled.

15.3.4 Making the Most of Mixtures: Resolving Ambiguous Ancestries in Mixed-Stock Inland Lake Trout Populations

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INTRODUCTION

A traditional management treatment for declining populations in valued fisheries is supplementation with hatchery-source fish. Often, the source strains employed share a distant evolutionary relatedness to the native stocks they are mixed with during the rehabilitation process. While the actual effectiveness of this approach is still a matter of debate, it is established that this type of management action can lead to detrimental effects on wild native lake trout populations (Evans and Willox 1991). In regions with long-term historical stocking programs, such as southern Ontario, unambiguous identification of native wild lake trout populations can be particularly difficult. An understanding of how evolutionary history and contemporary population genetic structure enables resolution of ambiguous ancestries is essential for conservation of native lake trout and other exploited northern aquatic species.

Ontario's inland lake trout populations have experienced over a century of supplemental stocking with non-native strains (Kerr 2001). This facilitated gene flow has effectively ended thousands of years of evolutionary isolation in hundreds of native populations. In recent recorded history, many of these stocking events have involved putting hatchery strains with Great Lakes ancestry into small, genetically divergent inland populations. In all of these cases, the opportunity for loss of native genetic diversity arises through 1) numerical displacement of native lake trout with repeated stocking of reproductively unsuccessful hatchery fish, or 2) replacement of native lake trout by introgression and/or successful natural reproduction of hatchery fish (Evans and Willox 1991).

Molecular genetic techniques are ideal for evaluating the degree of admixture in wild populations that have been stocked with non-native hatchery fish. Genetic analysis of Ontario broodstocks developed for inland lake stocking has revealed a high genetic diversity resultant from their shared ancestry with Great Lakes stocks. In contrast, low genetic diversity inland populations show clear evidence of their reciprocal isolation following deglaciation (Ihssen et al. 1988, Wilson ahd Hebert 1998). We are using this genetic diversity differential and contemporary statistical techniques to discriminate among the genetic signatures of inland lake trout stocks with native, hatchery, and mixed ancestries.

RESULTS AND DISCUSSION

The historical post-glacial migration of lake trout into the study area has been resolved by allozyme, mitochondrial DNA, and other analyses (Ihssen et al. 1988, Mandrak and Crossman 1992). Low genetic diversity lake trout that survived in a southern Mississippian refuge dispersed during early glacial retreat to colonize much of the pro-glacial Great Lakes region, including southern Ontario 14,000 years ago. A later migration of lake trout from the Atlantic glacial refuge increased the genetic diversity of the pro-glacial Great Lakes populations. Immigrants from both evolutionary clades were subsequently able to colonize the upper regions of southern Ontario (the Algonquin and Haliburton Highlands) during a brief window of time when the Fossmill Outlet drained glacial Lake Algonquin (Mandrak and Crossman 1992). The third and fourth major lake trout clades present in the Great Lakes region arrived late in the formation of the contemporary Great Lakes. These fish used the extensive western network of pro-glacial lakes to migrate from a northern Beringian and a separate western Nahanni glacial refuge into Lake Superior (Ihssen et al. 1988). They did not successfully colonize the lower Great Lakes, and almost all migration into the study region ended approximately 6000 years ago. High levels of natural genetic diversity present in sympatric Great Lakes stocks persisted while low genetic diversity inland lake trout populations diverged from one another in reciprocal reproductive isolation (Ihssen et al. 1988).

For this study, I used a PCR-based restriction fragment length polymorphism method to evaluate pro-glacial evolutionary relatedness among different representative populations. I also used a suite of ten highly variable microsatellite loci to track more recent population genetic changes. This combined mitochondrial and microsatellite analysis revealed limited gene flow from potential Great Lakes source populations into stocked inland lakes (Figure 1).

Palmerston and Kingscote Lakes, ON exhibited a native genetic signature even though both were stocked extensively (50+ years) with Great Lakes source strains over the last century. The retention of native genetic diversity following extensive supplementary stocking was also observed in an earlier study of the only two known native Wisconsin lake trout populations (Piller et al. 2005). Trout Lake and Black Oak Lake currently support native lake trout populations although both lakes have been supplemented with lake trout of Great Lakes origin for decades. Native lake trout stocks of the Great Lakes evaluated in this study have retained high genetic diversity, as observed by Ihssen and others (Ihssen et al. 1988).

The lake trout of Miskwabi Lake, ON were confirmed as an introduced population. They are probably derived from Lake Manitou lake trout, an Ontario broodstock that has been stocked into Miskwabi Lake on many occasions, although further genetic analysis may reveal multiple hatchery source origins. The genetic signature of this population is similar to that of lake trout in Big Green Lake, WI and Lewis Lake, WY. Not only are both Big Green Lake and Lewis Lake known lake trout introductions from a Lake Michigan source, but they are also located outside the southern limit of the species range (Piller et al. 2005). All three populations have a higher genetic diversity than can be accounted for by natural post-glacial migrations followed by reproductive isolation.

Lake trout of mixed genetic ancestry remain a challenge for genetic characterization. Inland populations in Killala and Mishibishu Lakes, ON have been stocked with Lake Superior lake trout before their induction into the Ontario hatchery system (OMNR 2003). The Killala Lake broodstock evaluated in this study has been developed from wild remnant inland natives persisting in reproductive isolation from stocked fish. While this hatchery strain appears native by our standard genetic analyses, a finer individual-level analysis may reveal Lake Superior source introgression. Mishibishu Lake hosts a mixed-ancestry introduced lake trout population (OMNR 2003). Known potential sources were from different regions of Lake Superior, which likely supported separate genetic stocks. As expected, the Mishibishu broodstock shows a Great Lakes genetic signature. Their complicated ancestry is under investigation as part of an ongoing genetic evaluation of the Ontario hatchery system.

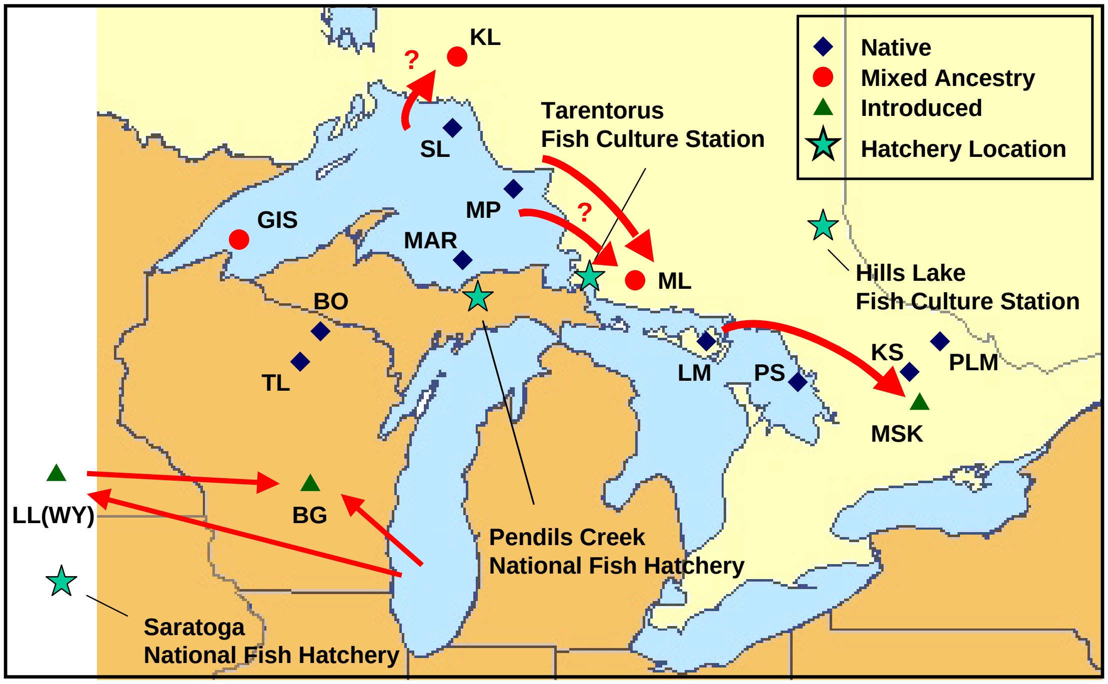

Figure 1. Contemporary patterns of facilitated gene flow. Populations are as follows: KS, Kingscote; PLM, Palmerston; MSK, Miskwabi; LM, Lake Manitou; ML, Mishibishu Lake; SL, Slate Island; MP, Michipicoten Island; KL, Killala; and PS, Parry Sound populations were evaluated in this study. BG, Big Green; LL, Lewis Lake; TL, Trout Lake; BO, Black Oak; MAR, Marquette; and GIS, Gull Island Shoal populations were evaluated in ref. 6. GIS was identified as a mixed stock of native and MAR ancestries in Guinand et al. (2003).

In summary, our combined molecular genetic analysis of mitochondrial DNA and microsatellite DNA enables the following diagnostic goals: 1) resolution of ancestries in wild populations, 2) detection of remnant native populations, 3) determination of the extent of hatchery genetic contribution to mixed-ancestry populations, and 4) evaluation of stocking success and divergence among stocked populations derived from the same ancestral hatchery source. We are using the information gained from these analyses to evaluate the rehabilitative potential of captive Ontario lake trout broodstocks and to develop a generalized genetic diversity model for lake trout conservation and management.

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15.3.5 Phylogeographic Information Content of Mitochondrial Genes for Reconstructing Ancient and Recent Population Histories

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Abstract
Despite the long history of research on lake trout, remarkably little is known about their genetic structure and diversity. This is a critical information gap, as understanding the species' evolutionary and adaptive history is key to predicting their ability to respond to present and future challenges.

Both historical events (isolation in glacial refugia and recolonization during glacial retreat) and contemporary factors (volume and quality of available habitat) have had substantial influences on genetic diversity and adaptive potential of lake trout populations. Lake trout were subjected to repeated displacement and bottlenecks caused by Pleistocene glaciations, with subsequent secondary contact among refugial groups as the glaciers retreated. As glacial races in isolated refugia would have been exposed to different selective pressures for tens of thousands of years, it is likely that survival in these different arenas conferred different adaptive abilities on phylogeographic groups. Conversely, population sizes and genetic diversity of modern populations significantly influence their ability to respond or adapt to contemporary ecological and environmental pressures.

Although previous phylogeographic studies have resolved the broad-scale evolutionary and glacial history of the species, more detailed information is needed to address the historical demography and adaptive potential of extant populations. We investigated the utility of different mitochondrial DNA (mtDNA) genes for detecting the phylogeographic ancestry and contemporary genetic diversity within and among lake trout populations. Co-amplification and restriction digests of two mtDNA regions enabled the simple and inexpensive identification of the major phylogenetic groups within lake trout. Amplification of additional amplicons allowed further identification of refugial groups within phylogenetic lineages, and assessment of intrapopulation diversity. A useful application of the method is the ready identification of introduced or stocked populations, providing a rapid assessment method for determining the ancestry of lake trout populations with unknown histories.

15.3.6 Status of Lake Trout (*Salvelinus namaycush*) in Accessible and Exploited Small Lakes of BC's Skeena Region

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INTRODUCTION

The Skeena Region of BC covers an area of 29.5 million ha (3.5x the size of the Province of New Brunswick; Figure 1) and contains 81 lakes known to contain lake trout. The majority of the Region's lakes that support lake trout are inaccessible and virtually unexploited; however, numerous small lakes (< 5,000 ha) in the Skeena and upper Fraser watersheds provide popular recreational and in some cases First Nations food fisheries for lake trout. Exploited lake trout populations first assessed between 1989-92 were found to be experiencing over-harvest based primarily on survival and CUE (overnight gill-netting) indices (deLeeuw 1991). Creel surveys of large (Babine & Francois lakes) and small lakes (Tchesinkut, Uncha & Binta) indicated some lakes were being harvested at theoretical maximum sustainable yields (Healey 1978) while others were not (Hatlevik 1982; Maniwa et al. 2001). Beginning in 2001, sampling was conducted on lakes originally sampled in 1989-92 to determine trends in survival and abundance in order to examine population status from a landscape perspective; results are summarized in this poster.

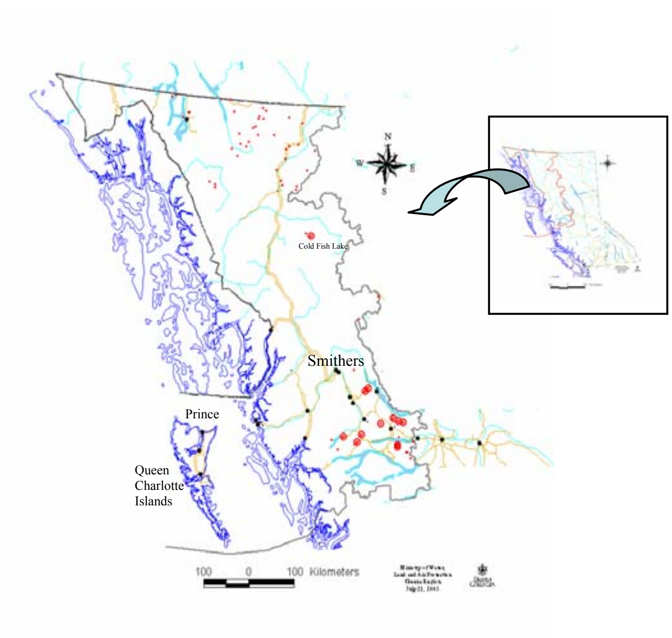

Figure 1: Map of lake trout populations recently assessed (circles) and known lake trout populations (dots) in Skeena Region, BC. Inset Map: Skeena Region within BC.

STUDY AREA

Exploited and previously sampled lake trout populations were chosen for assessment from the southern portion of the Region near population centers. One unexploited population (Cold Fish Lake) was assessed in 2005 as a control; it is situated in a protected area where angler effort and harvest is monitored. Assessed lakes range in area from 105 to 3380 ha in area with TDS concentrations from 42 –to- 98 mg/l. Detailed descriptions of Skeena's lake trout populations are described by DeGisi (in prep).

METHODS

During the initial year of sampling, five populations were sampled with an emphasis on the collection of biological samples and net methodology evaluation (Giroux 2003). In subsequent years, spring littoral index netting procedures (SLIN; Hicks 1999) were applied exclusively. For non-standardized netted lakes (*n*=5), daylight short-set 45 and 90 m netting catch results were used to approximate SLIN CUE. All lakes were sampled during May and early-June. Lake surface water temperatures rarely exceeded 13^{o}C. Lake trout population life history parameters (L∞, ω, *K, M, F, Z*) were derived using methods described in Payne et al. (1990) and Shuter et al. (1998). Abundance estimates followed methods described by Janoscik and Lester (2002), whereas methods described by Lester and Dunlop (2004) were used to approximate population exploitation levels. The mean of the sampled lakes area (ha) and TDS (mg/l) was used to estimate Fmsy, Nmsy and MSY (Lester and Dunlop 2004). Lake trout harvest (kg/yr) and yield (kg/yr/ha) estimates were obtained from creel surveys and a mail-out survey completed in 1994 (ARA, 1994)

RESULTS

The majority of Skeena Region's small accessible lakes with lake trout populations have abundance and fishing mortality indices below sustainable threshold levels as established by Lester and Dunlop (2004) for Ontario's lake trout populations (Figure 2). Two SLIN assessed lakes were found to have abundant lake trout. However, only the unexploited and inaccessible population (Cold Fish Lake) was clearly classed as *healthy* (Figure 2). Analysis of current and historical individual lake lake trout yield data indicates that recreational harvest is exceeding maximum sustainable levels (Figure 3). Abundance index netting, mortality indices and angler harvest data for lake trout populations generally correspond with exploitation levels assigned by Lester & Dunlop (2004; Figures 2 & 3).

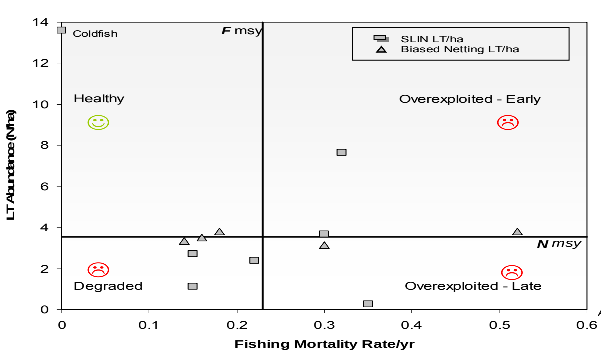

Figure 2: Lake trout population fishery development for 12 small lakes in Skeena Region. Lake trout abundance (N/ha) assessed by spring littoral index netting (SLIN; squares) and biased netting (converted to SLIN CUE; Triangles) are plotted against fishing mortality (*F*). Lakes to the right of the vertical reference line = F_{msy} are exceeding sustainable levels; lakes below horizontal reference line = N_{msy} are not meeting expected abundance levels for sustainable harvested lakes with an area of 1000 ha and TDS of 70 mg/l. Figure adapted from Lester and Dunlop (2004).

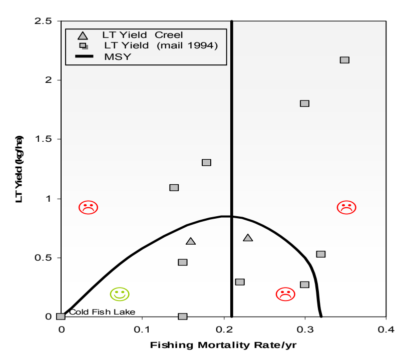

Figure 3: Lake trout creel estimated yield (kg/ha) plotted against fishing mortality for 12 small lakes in Skeena Region. Tchesinkut Lake yield estimate is approximated by ground based roving creel survey. Remaining lakes yield approximated from mail survey completed in 1994 (ARA, 1994). Lake trout maximum sustainable yield curve presented for a 1000 ha, 70 TDS lake. Lakes plotted below curve and to the left of the F at MSY are sustainable. All other points, exceeding MSY. Figure adapted from Lester and Dunlop (2004).

CONCLUSIONS

Present Status & Threats

- Present lake trout recreational harvest regulations appear to provide marginal protection for the majority of Skeena Region's assessable and exploited small lake, lake trout populations.
- Observed population status for many lakes is likely the result of excessive past recreational harvest. For example, in the early 1970's as many as 30 lake trout could be harvested per angler without length restrictions.
- Lakes with all-season road access, close proximity to urban centers, small lake area (i.e. < 500ha), competing fish species and commercial recreation opportunities appear to be most vulnerable to over-exploitation.
- Populations with the very low lake trout abundances (n=2/ha) and in small lakes (<200 ha) have been closed to lake trout angling. Lakes with populations approaching depressed abundance levels will be monitored and will have harvest concerns addressed by a Province wide lake trout conservation strategy (see *Future Work* below).

Future Work

- In 2004, the Provincial Biodiversity Research Branch and Regional Fish & Wildlife Sections, initiated the BC Lake trout Conservation Strategy. The goal of this project is to compile and review lake trout life history for all known lake trout populations in BC to develop biological reference points for the management of lake trout in BC. The primary objective is to create recreational harvest regulations based on best available information. It is intended that regulations will approximate sustainable harvest levels for populations and will remove the need for lake-by-lake regulation consultation and changes. The 2005/06 fiscal year is the anticipated completion date for this project.

ACKNOWLEDGEMENTS

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15.3.7 Lake Trout Spawning Locations and Spawning Site Fidelity in Small Ontario Lakes

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Introduction

Lake trout spawning usually occurs in shallow, inshore areas of small lakes (Sly & Evans 1996; Gunn & Sein 2000; Ellrott & Marsden 2004; Benoit & Legault 2002). Although inshore spawning occurs in the Laurentian Great Lakes (Bronte et al. 2002, Reid et al. 2001), deep-water shoals are thought to be more important (Bronte et al. 2002; Desorcie & Bowen 2003; Eshenroder & Amatangelo 2002). One of the reasons that lake trout lakes have a shoreline buffer area that is protected during timber-harvesting is to, theoretically, protect the spawning sites. These sites are frequently located in very shallow water, less than 2 m, and are located close to lake shores in wind-swept areas. Spawning areas are often assumed to be a limiting factor for reproduction of fish populations. The purpose of this study was to determine the number of lake trout spawning locations in some small Ontario lakes, and to determine if the number of sites and usage of sites change from year-to-year in an intensive study of two lakes.

Methods

We determined the spawning locations of natural, un-stocked lake trout (*Salvelinus namaycush*) populations in 12 small lakes at the Experimental Lakes Area, Ontario (Cleugh and Hauser 1971). Spawning locations were determined by systematically examining the entire shoreline of each lake immediately after dusk from 1977 to 2004 during the early October spawning season to locate spawning aggregations. The diffuse light of a Coleman® lantern mounted on a stand in a slow-moving motorboat was sufficient to locate, but not disturb, spawning lake trout. We confirmed these spawning locations by gillnetting lake trout on spawning locations for mark-recapture studies (Mills et al. 2002). We found that lake trout were aggregated during spawning so that netting on spawning areas yielded many lake trout, but netting on non-spawning areas yielded only an occasional lake trout. All lakes were unaltered by experiments or other disturbances except Lakes 223 and 239. Lake 223 was intentionally acidified and then allowed to chemically recover (Mills et al. 2000). The lake trout population in Lake 239 was reduced by more than 60% prior to monitoring spawning sites starting in 1986 (Mills et al. 2002).

During our long-term studies of lake trout population dynamics (Mills et al. 2002), we became aware that spawning sites of lake trout changed in Lakes 223 and 224 more than in other small lakes. We used site-specific netting data collected during the spawning season of each year to identify the number of fish caught on each spawning site. We initiated a study of spawning site fidelity in Lake 224 in 2001 using tag capture-recapture data collected through 2004 to track how spawning site selection changed for individual lake trout. We captured lake trout on the various spawning sites in the lake during the spawning period, sexed and tagged each fish with an individually numbered tag and released the fish back into the lake. We continued capturing, marking, and recapturing lake trout each subsequent year at the spawning sites during spawning. We used the individually numbered tag on each fish to tabulate a history of individual spawning site use from 2000 to 2004. We counted the number of fish each year from 2002 to 2004 that were recaptured on the same site as the previous capture at a spawning site, and the number recaptured at a different site from that where the individual was last captured.

Results

Lake trout utilized from one to seven different spawning sites in each of the 12 lakes (Table 1). There was no clear relationship between number of spawning sites utilized by lake trout in a lake and the surface area of the lake.

Table 1. Number of spawning sites used by lake trout in 12 Lakes at the Experimental Lakes Area, Ontario.

Lake Number	Surface Area (ha)	Number of Years of Observation	Total Number Identified in lake	Maximum Number used each year	Minimum Number used each year
442	15	11	1	1	1
260	17	16	2	2	1
375	19	13	1	1	1
224	26	22	5	4	3
223	27	22	7	5	3
373	28	15	2	2	1
626	28	1	1	1	1
622	36	1	2	2	2
382	37	16	3	2	2
305	52	8	3	2	2
239	56	15	2	2	1
468	301	4	5	4	4

Lake trout usually spawned within 5 m of the shoreline of each lake in water less than 2 m deep. The exception occurred in Lake 373, where the site was in water 3 – 4 m deep and located approximately 9 m from shore.

When lake trout utilized more than one spawning site in a lake, some sites were not used each year. The largest number of spawning sites in a lake occurred in Lake 223, the lake that was acidified and allowed to chemically recover. Lake trout used the same 3 spawning sites throughout the 8 years of acidification, but spawning locations changed during chemical recovery, and changed again in the years following chemical recovery (Figure 1). Lake trout did not return to one of the original primary spawning sites used prior to acidification until 8 years after complete chemical recovery of the lake had occurred.

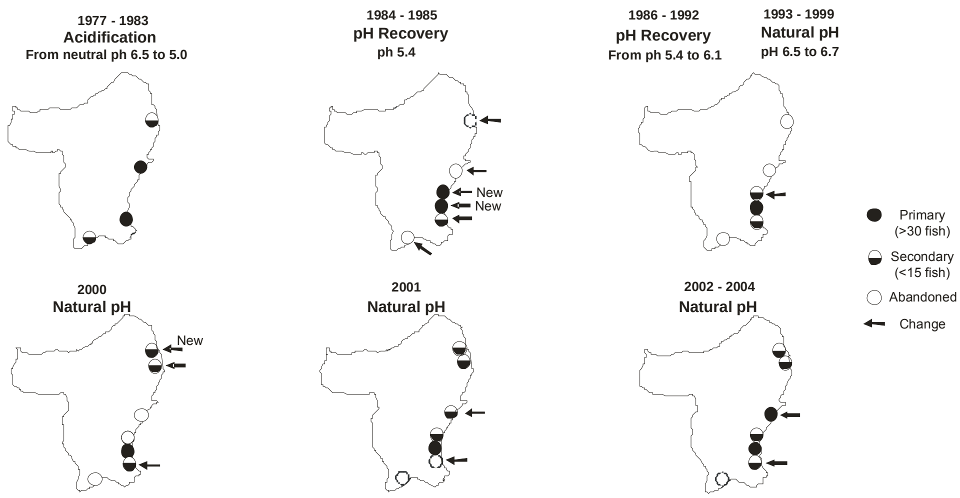

Figure 1. Spawning locations of lake trout in Lake 223 from 1977 to 2004 and number of fish captured at each site from 1977 to 2004.

Lake trout in Lake 224 utilized 5 different spawning sites through the 26 years of monitoring on this lake (Figure 2). There were obvious differences in the number of lake trout that used the sites each year, particularly from 2000 to 2004.

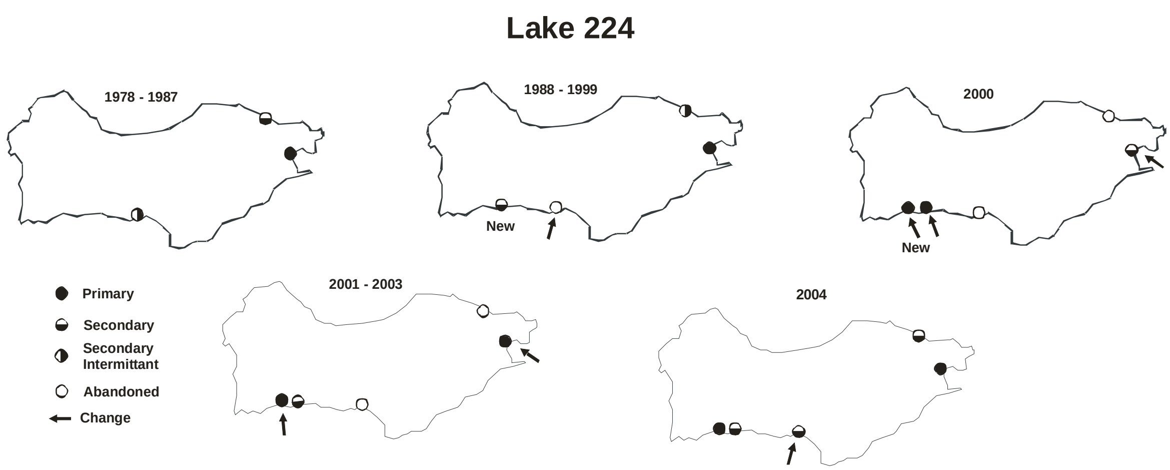

Figure 2. Location of spawning sites and relative number of lake trout captured on each site from 1978 to 2004 in Lake 224.

Sixty percent of lake trout recaptured at spawning sites in Lake 224 from 2002 to 2004 were captured at the same spawning site used previously, and 40% were recaptured at a different site (Table 2) although there were great differences among the three years of recaptures. In two of the years, the number of fish recaptured at the same site was ≥ twice the number recaptured at alternate sites. In 2003, the reverse occurred; more fish were recaptured at sites not used the previous time we captured these fish when spawning. Although many fish were captured consistently at the same site from 2002 to 2004, some fish used one site the first year, a second site the second year, and returned to the original site the third year.

Table 2. Spawning site fidelity of Lake 224 lake trout.

Year	Recaptured at Same Site	Recaptured at different site
2002	22	11
2003	17	23
2004	32	13
Total	71	47

Discussion

Gunn and Sein (2000) showed that lake trout would utilize alternate spawning sites if the original sites were covered by plastic tarpaulins. An implicit assumption in their study was that lake trout returned to the same spawning sites each year regardless of the presence or absence of the coverings. We have shown that lake trout do return to the same spawning sites each year in some lakes (Table 1), but this is not true for all small lake trout lakes. We have shown that there are other lakes where the spawning locations can change without being artificially disturbed, such as Lake 224 (Figure 2). In the case of Lake 223, the changes in spawning locations might be linked to the changes in habitat caused during lake acidification, recovery, or post-recovery. In Lake 224, a natural undisturbed lake, the changes occurred without the disturbances. A crucial question that remains unanswered at the present time is whether these changes affect recruitment. Gunn and Sein (2000) believed that the changes in spawning sites caused by forcing fish to utilize alternate areas had no impact on lake trout abundance. Lake trout abundance is a combination of the number of fish already present in the population, their annual survival which does vary slightly from year-to-year (Mills et al. 2002), and whether all fish of a year-class are recruited at the same time into the portion of the population that is included in the mark-recapture study. Although mark-recapture abundance estimates can be similar during a number of consecutive years, there can be changes in recruitment and survival that occur but not be apparent in abundance estimates. Decreased survival could be balanced by increased recruitment or the reverse. Therefore, a better method to determine whether changes in spawning locations affects recruitment is to assess the recruitment using methods based on fish ages. When a large proportion of a year class is captured and aged, this can give an appropriate estimate of annual recruitment (Mills et al. 2002).

The unanswered question for Fish Habitat Managers in their evaluations of changes to shoreline habitat in lake trout lakes is whether these changes can impact lake trout recruitment. Based on the results of our studies at the ELA, there is no simple answer to this question. It is clear from our studies that spawning occurs in small areas in each lake, and there are lakes where all the spawning can occur at one or two sites in a lake. There are other lakes where a larger number of spawning sites are used each year, and when this occurs, a substantial portion of the spawning population does not utilize the same site each year. We believe it is much less likely that there will be an impact of shoreline alteration in a lake where a fish population spawns at multiple sites than in a lake with only one or two sites. The experiment that still needs to be conducted is the alteration of a lake trout spawning site in a lake with only one known spawning area. We suspect that the lake trout will utilize alternate areas, but we still do not know what the impact of this might be on lake trout recruitment.

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15.4 Biology

15.4.1 Lake Trout Distribution and Salinity: an Overview of the Relative Abundance and Distribution of Lake Trout throughout the Husky Lakes Drainage, 2001-2004

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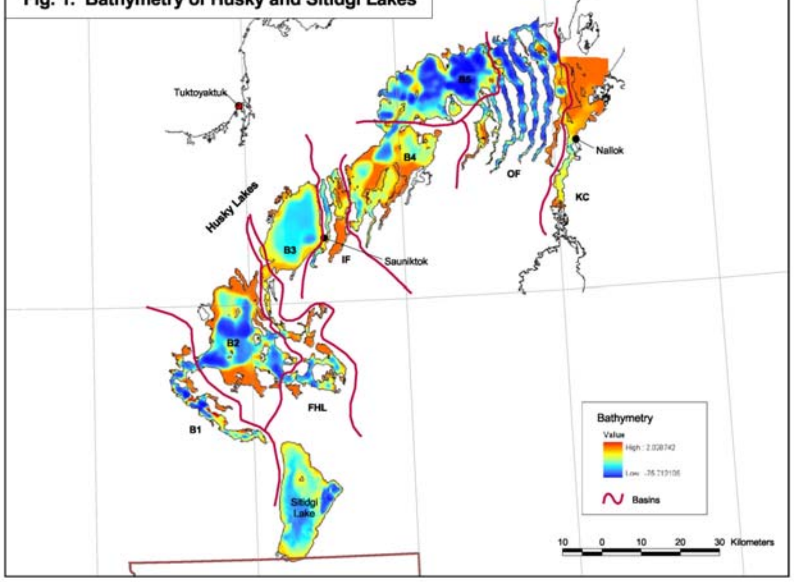
Introduction

The objective of this study was to document the size structure and types of fish, their prey, and their habitats in the Husky Lakes of the Northwest Territories. The area is a prime subsistence harvesting area for lake trout (*Salvelinus namaycush*) by the Inuvialuit of Tuktoyaktuk and Inuvik, NT. There are no commercial fisheries for lake trout in this area, although there is a recreational fishery for lake trout during the summer months. The Husky Lakes are located adjacent to an area presently subject to natural gas exploration activity, and are adjacent to a proposed transportation corridor (all weather road) between Inuvik and Tuktoyaktuk.

The Husky Lakes system consists of five connected basins (B1-B5 on Figure 1), the Five Hundred Lakes area (FHL) to the east of Basin 2, two sets of "fingers" (IF = inner fingers; OF = Outer Fingers) and the innermost lake, Sitidgi Lake. The distance from Liverpool Bay (salinity 2.07%) to the innermost Sitidgi Lake (0% salinity) is approximately 300 km. The salinity gradient is the most striking physical feature of this system.

Fig. 1. Bathymetry of Husky and Sitidgi Lakes



Methods

The study involved nine components: (1) non-destructive, small mesh (20 m panels each of 3.8, 6.4, and 7.6 cm (1.5", 2.5" and 3") gillnet sets (approx. 50 minute set times) in the five basins, the inner and outer finger areas, Sitidgi Lake, and the Five Hundred Lakes areas conducted during each July from 2001 to 2004 (586 sets in total); (2) live capture, tagging, and release of 251 lake trout ; (3) measurement of in-situ water chemistry parameters including pH, conductivity, dissolved oxygen, turbidity, water temperature, and salinity at 318 of the gill netting stations; (4) full suite of water quality variables at 11 stations throughout the system; (5) sampling of sediments and lower trophic levels at nine stations; (6) installation and operation of a water gauging station in Basin 2; (7) data collection and preparation of a bathymetric map of the entire system; (8) determination of hydrocarbon and heavy metal levels in the five main species of fish in the lakes, and (9) sampling and measuring of 903 lake trout caught in subsistence harvests from 2000 to 2004.

Results

A total of 6,216 fish representing 18 species (freshwater, marine, and anadromous) was captured over the four years of the study during test netting. Lake whitefish (*Coregonus clupeaformis*) (n=1517) was the species captured most frequently, followed by Pacific herring (*Clupea pallasii*) (n=1510) and least cisco (*C. sardinella*) (n=1075). Lake trout (n=178) was seventh in this list. A summary of the catch-per-unit-effort (CPUE) for the three species captured most frequently as well as lake trout is provided in Table 1, along with mean water temperatures and salinities for each basin.

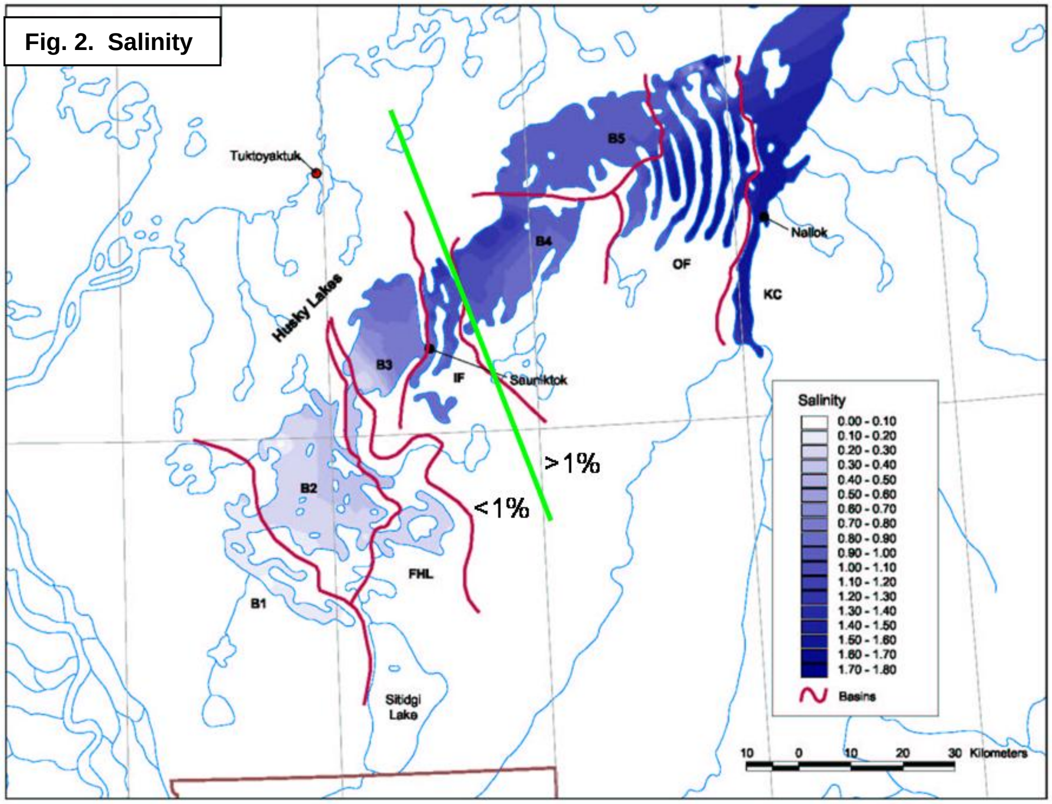
Lake trout were caught only in the inner basins (Sitidgi Lake, B1, B2, 500 Lakes, the Inner Fingers and in B3). Pacific herring, the main prey of lake trout (found in 53% of 38 stomaches that were examined), were found in most areas throughout the system, but mainly in lake B4 and the OF area.

Table 1. Distribution of lake trout across basins of Husky Lakes and Sitidgi Lake

	Catch Per Unit Effort: no. fish/test net hour/20 m panel									
Lake Trout	Sitidgi Lake	B1	B2	500 Lakes	B3	Inner fingers	B4	B5	Outer fingers	Liverpool Bay
lake trout	0.08	5.33	3.08	3.87	3.43	2.00	0.00	0.00	0.00	0.00
salinity (%)	*0.00*	*0.12*	*0.29*	*0.28*	*0.68*	*1.11*	*0.91*	*0.90*	*1.19*	*2.07*
temperature (^oC)	*13.7*	*13.77*	*10.3*	*11.6*	*7.94*	*7.7*	*10.64*	*10*	*8.7*	
Other predominant species										
lake whitefish	0.20	12.00	28.00	20.73	22.86	6.79	9.00	9.82	8.00	8.00
least cisco	0.08	1.20	5.14	7.00	1.00	3.16	6.55	8.73	19.64	7.38
Pacific herring	0.00	1.33	1.00	4.00	0.00	7.20	33.75	7.11	24.00	94.00

The salinity of the Husky Lakes system ranged from 0% in Sitidgi Lake, to 2.07% in Liverpool Bay (Figure 2). The approximate location of the 1% boundary of salinity is shown in green; lake trout were found throughout areas of the lakes where salinities were <1%.

Fig. 2. Salinity



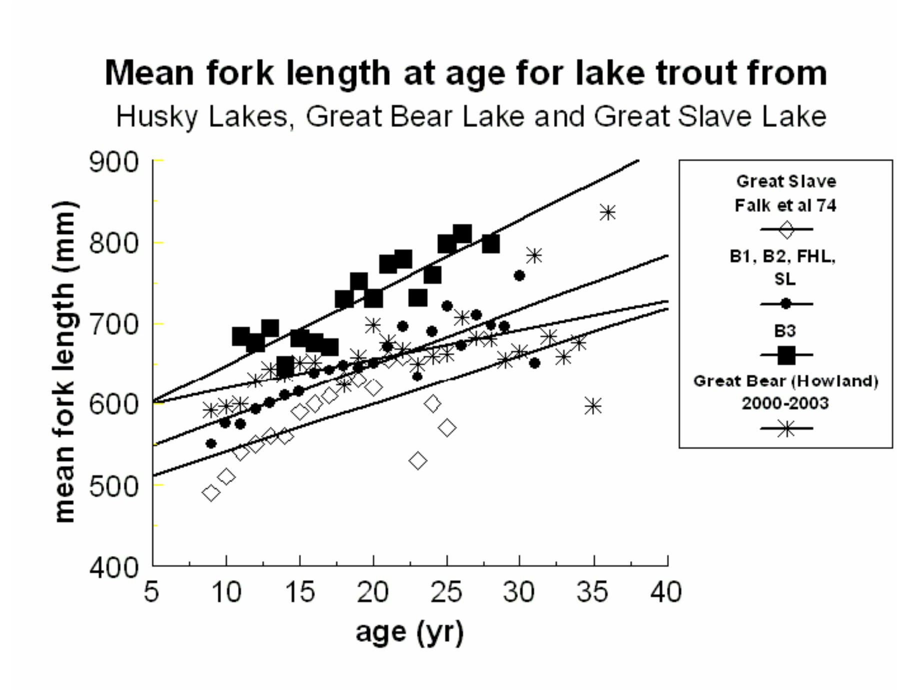
Lake trout caught in B3, the most saline of the basins where lake trout were caught but still with salinity less than 1%, were found to have statistically higher mean length, mean weight (Table 2), and growth rates (Fig. 3) than those caught in less saline areas such as B1, B2, and Sitidgi Lake.

Table 2. Mean size, age, weight, and condition of harvested lake trout from Husky and Sitidgi lakes, 2000-2004

mean	B3	n	B1, B2, FHL, SL	n	ANOVA	
fork length (mm)	709	145	656	758	F=11.46 p< 0.0001	***
age (yr)	18.20	105	18.40	449	F=0.11 p=0.7380	ns
weight (kg)	4.20	145	3.60	757	F=9.52 p<0.0001	***
condition (K)	1.16	145	1.24	753	F=3.61 p=0.0577	ns

Growth rates for B3 lake trout were also greater than that for lake trout from B1, B2, FHL, and Sitidgi Lake, as well as for large lakes in central and southern NWT such as Great Bear Lake (Howland, K., DFO, unpublished data) and Great Slave Lake (Falk et al. 1973) (Figure 3).

Fig. 3.



Conclusions

Community-based test netting and montioring of the community subsistence fishery provides an excellent means for long-term, cost-effective monitoring of lake trout stocks in Husky Lakes. This work has contributed to the establishment of a diverse data base which will be used for assessing potential impacts of development on the ecosystem.

Lake trout of Husky Lakes appear to be taking advantage of a rich and abundant marine food resource (Pacific herring) which in turn has led to faster growth rates than counterparts in less saline areas of Husky Lakes, and in lakes to the south including Great Bear Lake and Great Slave Lake, NWT.

Acknowledgements

We acknowledge the efforts of Joseph Felix Jr., Freddie Gruben, Douglas Panaktalok, Joseph Illasiak Jr., Todd Slack, Kyle Kisoun, Clarence Mangalena, and Forrest Day for the field work. We also thank Alan Udell, Victory Point FX, Yellowknife for preparation of the figures; Gary Carder, Yellowknife, and Paul Graveline, Winnipeg, for aging of the otoliths; Ken Mills (DFO) for aging fins; Kim Howland (DFO) for data from Great Bear Lake, and Martin Curtis(DFO) for stomach content analyses. Funding for this study was provided by the Fisheries Joint Management Committee, Panel on Energy Research and Development (PERD), Devon Canada, ConocoPhillips, and the Dept. of Fisheries and Oceans, Arctic Research Division.

Literature Cited

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15.4.2 Aging Lake Trout using Fin rays

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Synopsis

Historically, lake trout (*Salvelinus namaycush*) have been aged using scales employing criteria for determining annuli described by Cable (1956). More recently, otoliths have become the accepted method for aging lake trout (Dubois and Lagueux 1974; Johnson 1976; Power 1978; Burnham-Curtis and Bronte 1996). Individual fish must be killed so otoliths can be extracted, so this is not a suitable technique when fish must be returned alive to a population after sampling. Cuerrier (1951) showed that cross sections of fin rays could potentially be used to age lake trout. Removal of rays does not require the death of a fish. The purpose of this study was to (1) assess the validity of the fin-ray method for aging lake trout and (2) to compare ages determined from fin-ray sections to those determined from otoliths.

We conducted mark-recapture studies in 6 lakes at the Experimental Lakes Area (ELA), Ontario (Cleugh and Hauser 1971), to evaluate the validity of fin-ray ages for lake trout. Lake trout were captured in the fall of each year using trap nets and short sets of small-mesh gill nets. We marked each fish with a numbered Carlin (White and Beamish 1972) and/or a visible implant (V.I.) (Haw *et al.* 1990) tag. We removed 2 to 3 fin rays from the leading edge of a pectoral fin when a fish was first captured, and removed a similar number of the leading rays from the opposite pectoral or a pelvic fin when individuals were recaptured one to 17 years later. Fin rays were dried, mounted in epoxy, and then sectioned with an Isomet® thin sectioning machine. We counted the annuli on the sections at 63 – 320x using transmitted light. Circular annuli (Figure 1) were identified as clear bands and were similar to those described by Cuerrier (1951), Mills and Beamish (1980), and Chalanchuk (1984).

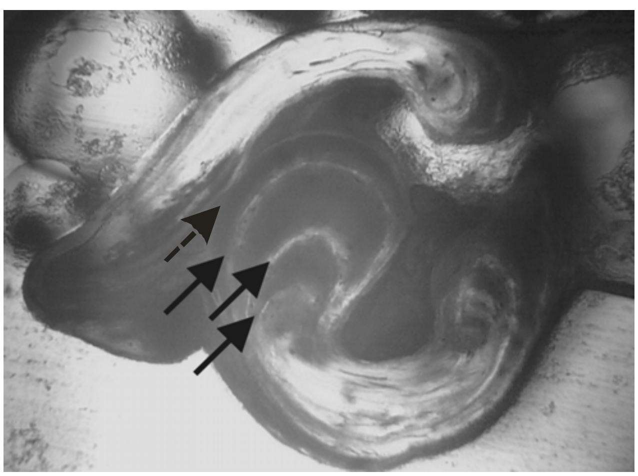

Figure 1. Fin-ray sections from an age 3+ lake trout. Annuli are indicated by arrows with solid tails. Edge of fin ray indicated by arrow with dashed tail. Fish captured in fall.

We compared the ages determined from recaptured fish with a predicted age, calculated as the sum of the age determined at marking plus the number of winters between marking and recapture, to validate the fin-ray ages. The ages predicted for the recaptured fish were identical to the ages determined at recapture for 73% (968 of 1331) of the age pairs (Figure 2). When differences occurred between predicted and actual ages for recaptured fish, the difference was 1 year for 48% of the cases and there was no tendency (t test, P > 0.75) for recapture ages to be greater or less than predicted ages.

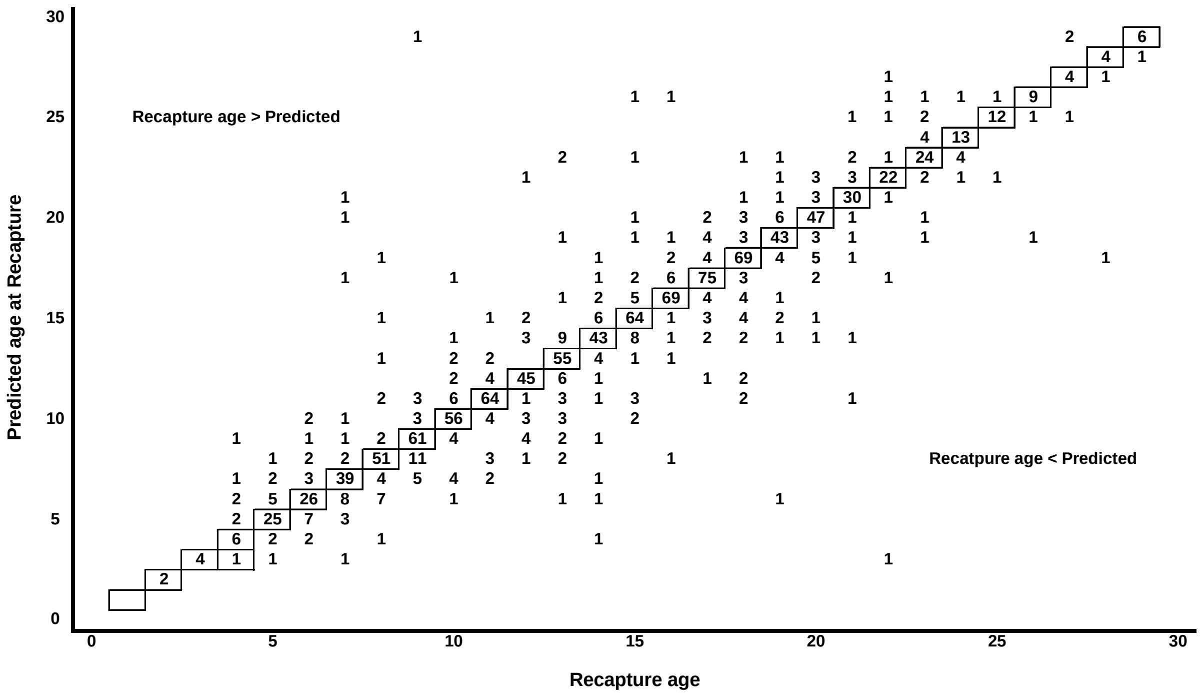

Figure 2. Comparison of age at marking and predicted age at recapture for ELA lake trout from Lakes 223, 224, 260, 373, 375, and 442. A predicted age at recapture was the sum of age determined when the fish was first marked and the number of winters between marking and recapture when additional fin rays were removed for aging. The number of years between marking and recapture varied from 1 to 17 years. Numbers in the rectangles are individuals whose age at recapture equaled the number predicted from the earlier age at release. Numbers above the line are individuals whose ages at recapture were greater than predicted, and numbers below the line are individuals whose ages were less than predicted.

We compared fin-ray and otolith ages using samples obtained from lake trout in ELA Lake 468 and Great Bear Lake, Northwest Territories. Fin rays were removed and processed as described above. Otoliths were removed from individual fish and were mounted and sectioned in the same manner as the fin rays. Annuli on otoliths appeared as clear bands when viewed using a compound microscope. We used the criteria of Beamish (1979) to identify annuli on otolith sections. There was no significant difference between fin-ray and otolith ages for the combined data set of Lake 468 and Great Bear Lake ages (P = 0.14), although there was complete agreement between ages for only 40 of the 106 pairs of ages. There was no tendency for ages using one method to be greater or less than ages using the other method (31 cases where fin-ray ages were greater than otolith ages and 30 where otolith ages were greater than fin-ray ages).

Cuerrier (1951) predicted that fin rays could be used to age lake trout, and we have successfully applied this method to our studies for more than 20 years. Through the years, we have progressed from cutting fins by hand using jeweler's saws with very fine blades to modified Isomet® rock cutting machines. The critical step in the production of sections is ensuring that the sections are exactly, or almost exactly, cut perpendicular. Sections produced from angled cuts obscure annuli. Whole fins need not be removed for aging; only the first 2-3 leading rays from a fin are necessary. It is important to cut the ray from a fish as closely as possible to the base of the fin. The first cm of fish fin ray is the area with greatest separation between annuli on the fin. In our studies, we wanted to kill as few lake trout as possible during experiments because the populations in our study lakes were relatively small. It is faster to remove rays in the field than to extract otoliths, and in situations where it is desireable not to mutilate fish, this is a promising method of aging lake trout.

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16 Symposium Program

August 16, 2005
Arrival & Registration Day

- Registration: 13:00 – 20:00 at the Explorer Hotel Katimavik Rooms foyer
- Poster and Trade Show Set up: 13:00 – 18:00 - Explorer Hotel Katimavik A
- City of Yellowknife Tours: 13:00 and 14:30, depart from Explorer Hotel Lobby
- Welcome Reception at Dept. of National Defense Raven's Nest 18:00 -21:00

August 17, 2005 – Day One
Katimavik B & C, Explorer Hotel

Coffee and Registration 08:00 – 09:00

Opening Prayer 09:00

Welcome Panel 09:05 – 09:30

Session Chair: Ron Allen, Area Director, Western Arctic Area, DFO

Honourable Ethel Blondin Andrew, MLA and Minister of State (Northern Development)
Mr. Gordon Van Tighem, Mayor, City of Yellowknife
Mr. Fred Carmichael, Chair, Aboriginal Pipeline Group
Mr. Frank Pokiak, Chair, Inuvialuit Game Council
Dr. John Colford, Government of the Northwest Territories
Dr. John Cooley, Department of Fisheries and Oceans

August 17, 2005 – Day One
Katimavik B & C, Explorer Hotel

Lake trout across the Range:

An Overview of the Distribution, Harvesting and Issues Relating to Lake trout - Katimavik B & C

Session Chair: TBA

1. Alaska – John Burr 09:30-09:45
2. NWT and NU – George Low 09:45 -10:00
3. Yukon – Susan Thompson 10:00-10:15
4. BC – Ted Down 10:15 10:30

Coffee 10:30-11:00

Poster Viewing and Trade Show: Open 10:30 – 17:00 – Katimavik A

5. Prairies – Doug Leroux 11:00-11:15
6. Ontario – Nigel Lester (& co-author Warren Dunlop) 11:15-11:30
7. Great Lakes – John Fitzsimons 11:30-12:00

Lunch Provided – 12:00 – 13:30 - Melville Room - 2 sittings, 12:00 and 12:45

Fisher's Panel - Katimavik B & C 13:30

Session Chair: George Low, DFO

1. Inuvialuit – Max Kotokak, FJMC 13:30-13:40
2. Gwich'in – John Carmichael, Aklavik RRC 13:40-13:50
3. Sahtu – Paul Modeste, Deline RRC 13:50 – 14:00
4. GSLAC – Sports and Traditional Fisheries – Arthur Beck 14:00-14:10
5. GSLAC – Fishermen's Federation – Bert Buckley 14:10-14:20

Coffee 14:20-14:50

6. GSLAC – Traditional Fisheries – Diane Giroux 14:50-14:30
7. Deh Cho – Dennis Deneron, Trout Lake – 14:50-15:00
8. Tlicho (North Slave) – 15:00-15:10
9. Sport Fishing Lodge Rep –15:10-15:20

Fisher's Panel Discussion & Questions: 15:20-15:50

Transition – 15:50-16:00

Day One – August 17, 2005
Explorer Hotel, Katimavik B & C

Day One Plenaries (16:00): Introductions/Session Chair: Ron Allen, DFO

Theme: Lake Trout Biology and Habitat

Plenary Speaker #1: Dr. David Evans 16:00-16:30
Ontario Ministry of Natural Resources and Trent University
Peterborough, Ontario

Title: Thermal Niche and Oxygen Requirements of Lake Trout With Reference to Fishery Yields in Changing Environments

Highlights: Temperature and dissolved oxygen are perhaps the two most basic parameters that define habitat quality for lake trout. The directive, controlling, limiting and lethal effects of these factors not only delimit the habitat but also in large measure set the productive capacity of the lakes within which this species resides. This paper explores the influence of these factors on the biology of lake trout and demonstrates linkages to production and fishery yield. Implications for conservation of lake trout stocks and management of lake trout fisheries in changing regional and global environments will also be discussed

Theme: Contaminants in Lake Trout

Plenary Speaker #2: Dr. W. Lyle Lockhart 16:30- 17:00
Aquatic Biologist/Toxicologist
North/South Consultants, Winnipeg, Manitoba.

Title: Mercury in Edible Muscle of Lake Trout From Sites in Northern Canada

Highlights: For over 30 years mercury has been measured in edible muscle of lake trout and several other species of fish from northern Canada. This has been driven mainly by the need to know whether the fish can be eaten safely by people and also by a need to understand the dynamics of mercury in the North. Almost 2000 lake trout from 108 locations have been analyzed from across the Yukon, Northwest Territories and Nunavut and one site in northern Quebec.

END OF DAY – SUMMARY REMARKS
Ron Allen

Day Two – August 18, 2005
Explorer Hotel, Katimavik B & C

Coffee 08:00-08:30

<u>Day Two Plenaries (08:30)</u>: Introductions/Session Chair: Lois Harwood, DFO

Theme: <u>Co-Management Regimes & Harvesting</u>

Plenary Speaker #3 : Dr. Brian Shuter 08:30-09:00
Department of Zoology
University of Toronto, Toronto, Ontario

Co-author Dr. Nigel Lester
Ontario Ministry of Natural Resources, Peterborough, Ontario

<u>Title</u>: Lake Trout in The South and The North: Growth and Sustainable Yields

Highlights: North American lake trout populations exhibit considerable variation in their life time growth patterns and this variation is associated with environmental differences among lakes. Life history data from over 100 lake trout populations are used to illustrate the differences in growth and longevity that exist between southern and north populations.

Theme: <u>Stock Assessment</u>

Plenary Speaker #4: Dr. Michael J. Hansen 09:00-09:30
Professor of Fisheries
College of Natural Resources
The University of Wisconsin – Stevens Point

Title: Stock Assessment of Lake Trout: From Field Sampling to Population Models, With Examples from the Great Lakes

Highlights: Dr. Hansen will summarize stock assessment methods for lake trout, including field sampling methods and population modeling methods. This presentation will rely on examples from the Great Lakes stock assessment programs.

<u>Poster Viewing and Trade Show</u>: Open 09:00 – 17:00 – Katimavik A

<u>Dedicated Poster Session</u>: 09:30-10:30 – Katimavik A
Presenters to be beside their posters.

Coffee 09:30 -10:30

Day Two – August 18, 2005
Explorer Hotel

CONTRIBUTED PAPERS

Concurrent Session # 1 Harvesting & Co-management Contributed Papers: 10:30-12:10

Location: Katimavik B & C
Session Chair: Dr. Burton Ayles, FJMC

1. Co-occurring management strategies and ecosystem change have impeded assessment of lake trout restoration in Lake Ontario – B. Lantry and S. Prindle 10:30-10:50
2. Efforts to suppress a lake trout population outside its native range - B. Hansen 10:50-11:10
3. Fair share in lake trout fisheries. N. Lester 11:10-11:30
4. Sampling of Lake trout Subsistence Harvests In The Husky and Sitidgi Lakes in Canada's Western Arctic– L. Harwood 11:30-11:50
5. Process and product: co-operatively managing Great Bear Lake and Its watershed. K. LeGresley-Hamre. 11:50-12:10

Lunch 12:10 – 13:40 – On your own

Concurrent Session # 2 Stock Assessment Part One Contributed papers: 10:30 – 12:10

Location: Melville Room
Session Chair: Yukon Government Rep

6. Composition and yield potential of lake trout in Paxson Lake, Alaska. B. Scanlon 10:30-10:50
7. Identification and assessment of lake trout spawning habitat through underwater surveys using volunteer scuba divers. B. W. Corbett and L. Parsons 10:50-11:10
8. Using population-level risk and uncertainty as a basis for lake trout management in Banff National Park. A. Paul, C. Pacas, M. Sullivan, N. Lester, J. Post 11 :10-11 :30
9. The winter habitat of lake trout in a small boreal lake. P. Blanchfield, L. Tate and J. Plumb 11:30-11:50
10. Comparison of population estimate model accuracy in four closed fish communities in the NWT. W. S. Macneill 11:50-12:10

Day Two – August 18, 2005
Explorer Hotel

Concurrent Session #3: LT Biology (Part One) Contributed papers: 13:40-15:20

Location: Katimavik B&C
Session Chair: Dr. Charles Kruger

11. Phenotypic diversity of lake trout in Lake Mistassini. C. Kruger, M. Zimmerman, and R. Eshenroder 13:40-14:00
12. Phenotypic diversity of lake trout in Great Slave Lake: differences in morphology, buoyancy, and habitat depth. M. Zimmerman, C. Krueger, and R. Eshenroder 14:20-14:40
13. Differentiation of lake trout forms: a working hypothesis. R. Eshenroder, C. Krueger, and M. Zimmerman. 14:00-14:20
14. Phenotypic diversity of lake trout in Great Bear Lake, NWT. K. Howland, R. Tallman and K. Mills 14:40-15:00
15. Niche selection and phenotypic variation in lake trout. R. Tallman and K. Howland 15:00-15:20

Concurrent Session #4: Stock Assessment (Part Two) & Mercury Contributed papers: 13:40-15:20

Location: Melville Room
Session Chair: Dr. Terry Dick

16. Lake trout movements and habitat use in a small northern lake. T. Dick, C. Gallagher and A. Yang. 13:40-14:00
17. Hydro acoustic assessment of lake trout populations in small inland lakes. T. Middel, N. Lester, B. Shuter, L. Rudstam 14:00-14:20
18. Effects of lake fertilization on lake trout populations at Saqvaqjuac, Nunavut. K. Martin, K. Mills, and H. Welch. 14:20-14:40
19. Population structure and contributions to local fisheries by lake trout in Atlin Lake, British Columbia: a micro satellite DNA-based assessment. S. Northrup, M. Connor, and E. Taylor 14:40-15:00
20. Latitudinal and longitudinal differences in mercury levels in lake trout in northern Canada: possibilities for the future. M. Evans, L. Lockhart, G. Low, D. Muir, L. Dotezel, K. Kidd. 15:00-15:20

Day Two – August 18, 2005
Explorer Hotel

COCKTAILS (cash bar) 18:00 – 19:00 Explorer Hotel
GALA BANQUET 19:00 – 22:00 Katimavik B & C

Day Three - August 19, 2005
Explorer Hotel

Day Three Plenaries: Introductions/Session Chair: Ron Allen, DFO

Theme: Land Use Activities And Climate Change Effects On Lake Trout And Their Habitats – Katimavik B& C

Plenary Speaker # 5: Dr. Michael Papst 08:30-09:00
Arctic Science, Dept. of Fisheries and Oceans, Winnipeg, Manitoba

Title: Past, Present and Future Stressors on Lake Trout and Their Habitats in the North

Plenary Speaker #6: Dr. John Casselman 09:00-09:30
Ontario Ministry of Natural Resources
Glenora Fisheries Station
Picton, Ontario

Title: Effects of Climate and Climate Change on Lake Trout Populations and Fisheries

Highlights: Global warming is occurring and affecting lake trout growth and recruitment. This is exemplified across the range of the species. Quite specifically at intermediate latitudes, long-term sampling analyzed from Ontario and Quebec confirms that with increased summer temperature conditions, year-class strength is decreasing and highly negatively correlated. Cold autumns and winters, followed by warm summers, are critically important environmental recruitment components. The former have decreased dramatically in recent years. However, at high latitudes, growth and recruitment have been enhanced by these increasing temperature conditions.

Poster Viewing and Trade Show: 09:00 – 12:00 – Katimavik A

Day Three - August 19, 2005
Explorer Hotel

Concurrent Session #5 : Land use and Climate Change Contributed Papers: 09:30-12:00

Location: Katimavik B
Session Chair: Erik Madsen, Diavik Diamond Mines Inc

21. Projected impacts of climate warming on production of lake trout in the North. J. Mackenzie-Grieve and J. Post 09:30-09:50

22. Effects of Explosives on Incubating Eggs of Lake trout in Lac de Gras, NWT – S. Faulkner and W. Tonn 09:50-10:10

Coffee 10:10-10:40

23. Acute and Chronic Toxicity of Nitrate to Early Life Stages of Lake trout. F. Landry, M. McGurk, A. Tang and C. Hanks 10:40-11:00

24. The Effects of Multiple Source Stressors on the Fish Community in a Small Tundra Lake in the Northwest Territories, Canada. D. Tyson 11:00-11:20

25. Lake trout Recruitment Failure – A Case Study. N. Thebeau 11:20-11:40

26. Construction and Monitoring of an Artificial Lake trout Spawning Reef in a Sub-Arctic lake. R. Schryer, H. Machtans, and R. Johnstone 11:40-12:00

Concurrent Session #6 : Lake trout Biology (Part Three) Contributed Papers 09:30-12:00:

Location: Melville
Session Chair: Government of the NWT Rep - TBA

27. How environmental variation may drive life history parameters in lake trout. J. McDermid and B. Shuter 09:30-09:50

28. Adaptation and latitudinal variation in growth of a northern ectotherm, the lake trout, *Salvelinus namaycush* . Z. Pawlyshyn, R. Tallman and K. Howland. 09:50-10:10

COFFEE 1010-1040

29. Patterns and processes shaping parasite communities of lake trout. I. Isinguzo and T. Dick 10:40-11:00

30. Assessing patterns of use and productivity of shallow-water spawning habitat by lake trout – do Great Lakes lake trout have it right after all? J. Fitzsimons, J. Marsden, B. Williston, and G. Williston 11:00-11:20

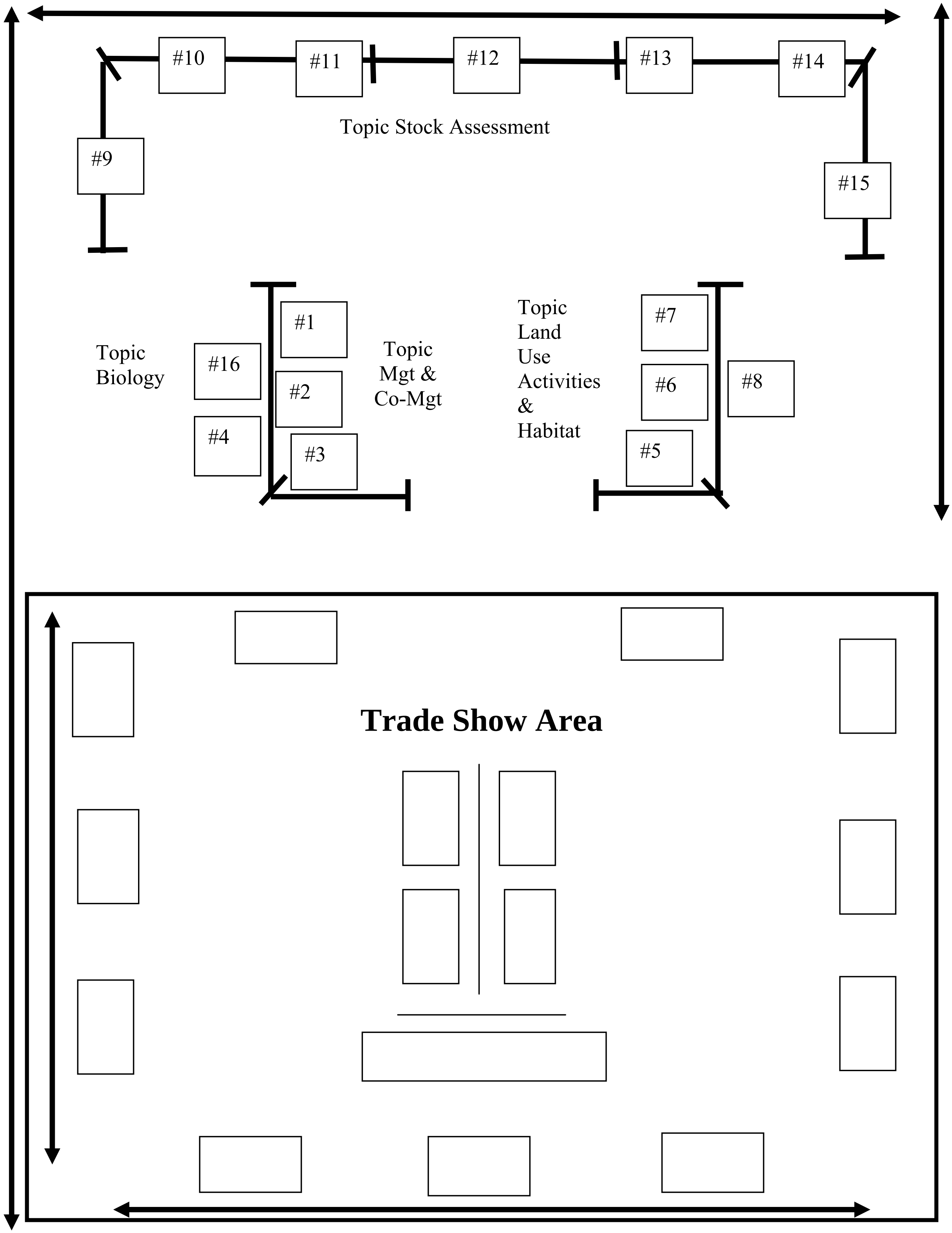
31. The effect of climate variation on lake trout habitat and behaviour in a small Canadian Shield lake. J. Plumb and P. Blanchfield 11:20-11:40

32. Trace element distributions in lake trout (*Salvelinus namaycush*) otoliths: indicators of life histories and environmental conditions. N. Halden, L. Friedrich, and J. Babaluk 11:40-12:00

CLOSING REMARKS
Ron Allen, DFO

CLOSING PRAYER

Poster and Trade Show Layout Map



17 List of Participants

Name	Title	Institution/Affiliation
Noel Alfonso	Research Assistant	Canadian Museum of Nature
Ron Allen	Area Director	Fisheries and Oceans Canada
Brendan Anderson	Fisheries Biologist	MWLAP
Gary Ash	Senior Fisheries Scientist	Golder Associates Ltd.
Burton Ayles	Member	Fisheries Joint Management Committee
David Balint	Area Habitat Biologist	Fisheries and Oceans Canada
Arthur Beck	Member	Great Slave Lake Advisory Committee
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