Pêches et Océans Canada

P. O. Box 1871 Inuvik, Northwest Territories X0E 0T0 Your file Votre référence 02/10-05 Our file Notre référence 10-HCAA-CA6-0006

Environmental Impact Review Board PO Box 2120 Inuvik, NT X0E 0T0

Sent via email: eirb@jointsec.nt.ca

March 30, 2012

Dear Mr. Nasogaluak:

<u>Subject:</u> Fisheries and Oceans Canada's Responses to Information Requests related to the Inuvik to Tuktoyaktuk Highway.

Fisheries and Oceans Canada (DFO) is pleased to provide the Environmental Impact Review Board with our responses to the Information Requests # 77, 80, 89, 119, 120 and 121.

Should the Review Board have any questions about our responses, please feel free to contact Sarah Olivier at (867) 669-4919, by fax (867) 669-4940, or email at Sarah.Olivier@dfo-mpo.gc.ca

Sincerely,

Larry Dow

A/Area Director, Western Arctic Area

Fisheries and Oceans Canada

270m

c.c.:

Corrie Gibson - DFO Julie Dahl - DFO Bev Ross - DFO Amanda Joynt - DFO Ellen Lea - DFO

DFO Response to Information Requests # 77, 80, 89, 119, 120 and 121

IR Number: 77
Source: MSES Inc.

To: Department of Fisheries and Oceans (as well as WMAC, FJMC, GNWT ENR and

Environment Canada)

Subject: Cumulative effects assessment – induced effects and increased access (EIS Section

5.3.1.2, p. 631; IR Response Round 1, IR#51

Preamble:

The Developer acknowledges that it anticipates the completed Highway will make it easier for people to access the land for their various traditional, recreational and cultural pursuits. The Developer points out that to ensure that the environment of the area remains protected, it will be important for the users of the Highway to abide by any "management restrictions" that may need to be developed for the Highway by the resource management agencies and co-management bodies in consultation with the HTCs and other interested stakeholders. The Developer has not defined what those anticipated "management restrictions" might be in the EIS. It is not clear how these potential induced environmental impacts through increases access (i.e. increased harvesting of wildlife, potential damage to vegetation, increased random camping, ect.) were quantitatively factored into the cumulative effects assessment.

MSES Inc. Request:

- 1. Please describe and explain the anticipated "management restrictions" that may need to be developed for the Highway.
- 2. Please indicate when "management restrictions" will be developed, whether they will be in place prior to Highway completion and who will be responsible for implementation and enforcement.
- 3. Please explain and justify how "management restrictions" will be evaluated in terms of their relative success at minimizing or eliminating environmental impacts.

Department of Fisheries and Oceans Response:

DFO Response 77.1

Potential management options for the Highway corridor include:

- o sport fishing regulations on specific lakes, including catch and possession limits;
- o a voluntary management plan for subsistence fishing along the corridor, which may include by-laws developed by the local Hunters and Trappers Committees (HTC).

Sport fishing regulations are developed by DFO while the guidelines are published annually in the Government of the Northwest Territories Sport Fishing Regulations Guide. Sport fishing on Inuvialuit Private Lands requires registration with the local Hunters and Trappers Committee or the Fisheries Joint Management Committee (FJMC).

If there are conservation concerns, limits could be adjusted, with subsistence fishing prioritized over sport fishing. More significant conservation concerns can warrant legislated closures of certain areas.

DFO response 77.2

Management of the highway corridor will be done in cooperation with HTCs, DFO, and the FJMC. DFO's letter of advice dated Jan 9, 2009 to the Environmental Impact Screening

Committee (EISC) regarding the development of the Tuktoyaktuk to Source 177 Road included the following statement:

"As outlined in the project description, Big Lake (Ilkaasuat) is a popular fishing location for the residents of Tuktoyaktuk and the completion of this all-weather road will allow easier access to this lake, as well as other lakes in the surrounding area. This may result in an increase in fishing, both sport fishing and for subsistence, in water bodies for which there is limited detailed scientific information. DFO Fisheries Management is concerned with the potential increase in fishing pressure in this area and will work with the Fisheries Joint Management Committee, HTCs, local resource users and other stakeholders in monitoring the use of these fisheries in the future."

The Tuktoyaktuk-Inuvik Highway Working Group (TIWG) was formed to provide guidance in the management of fisheries resources along the Highway corridor. Members include the Tuktoyaktuk and Inuvik Hunters and Trappers Committees, with one DFO participant in an advisory/observatory role. The FJMC administers the group. So far the group has carried out traditional knowledge surveys for the lakes along the corridor in the Tuktoyaktuk area, as well as identified priority lakes for DFO efforts to determine stock status and population estimates. Prior to the Highway opening, DFO and the TIWG would look at establishing management options for lakes sensitive to fishing pressure. Plans exist to create a GIS map to allow for ease of management and water body identification. Also, the TIWG will be participating as an intervener in the Environmental Impact Review Board (EIRB) review process.

Implementation of any plans would be the joint responsibility of the parties who develop the plan; most likely DFO, the Inuvik and Tuktoyaktuk HTCs, and the FJMC. The HTCs will enforce their own by-laws, and DFO will enforce the *Fisheries Act*. The management plan will be developed in conjunction with both the Tuktoyaktuk and Inuvik Community Conservation Plans.

DFO response 77.3

Management options have not yet been identified for the Highway corridor. The Tuktoyaktuk-Source 177 Road has allowed DFO to identify potential fisheries management issues that may occur along the corridor. These will be discussed within the TIWG. Any management plan for the Highway corridor will establish monitoring and evaluate all possible regulatory and management tool options. Some of the potential tools include local harvest interviews and stock assessments.

IR Number: 80 Source: MSES Inc.

To: Department of Fisheries and Oceans (as well as WMAC, FJMC, GNWT ENR and

Environment Canada)

Subject: Environmental Management Plans and Effects Monitoring (IR Response Round 1,

IR#11, 16, 55, 61, 62, 63 and 66)

Preamble:

In the response to IR #55, the developer presents its commitments (Table F) to a number of mitigation measures. However, the Developer does not respond to the questions about how the mitigation would address the potential effects of the ITH. Only at the end of the Table F, the Developer briefly refers to an "effects monitoring table". However, it is unclear how such a table would satisfy the requirement for the testing of impact predictions, developing significance thresholds, and determining adaptive measures. As per the Canadian Environmental Assessment Agency's (CEAA 2009) Operational Policy statement, Adaptive Management Measures under the Canadian Environmental Assessment Act, it is imperative to understand how and when, in relation to the construction schedule, effects monitoring programs will be developer.

Under the Operational Policy of CEAA, <u>compliance monitoring on its own does not satisfy the requirements for a follow-up program</u>. Compliance monitoring also does not adhere to the GNWT's (2006a) position statement which requires that monitoring and reporting programs need to be designed to test impact predictions. Moreover, the CEAA operational policy states: <u>"If the project implementation is likely to begin shortly after approval, the follow-up program should be fully designed and a reliable baseline established during the environmental assessment phase of the project".</u>

The Developer's response to IRs 11, 16, 61, 62, 63 and 66 are similarly deficient in clarifying how adaptive management measures will be developed in light of the CEAA's policy.

MSES Inc. Request:

For each resource and regulatory agency, please clarify your agency's role in developing an effects monitoring and an adaptive management program. Please identify:

- 1. Which programs do you anticipate to review and approve as part of your agency's mandate
- 2. What regulatory tools are available to your agency, to ensure that both compliance and effects monitoring would be in place to ensure that the effects on any given valued component will be at or below the effects predicted in the EIS.
- 3. How your agency would ensure that the above program would be designed and implemented prior to construction.

Department of Fisheries and Oceans (DFO) Response:

DFO response 80.1

DFO will review all plans and programs that include mitigation and/or monitoring of potential impacts to fish and fish habitat as well as other areas that fall within DFO's mandate. The Proponent has identified several management plans in their Information Request (IR) Response to the EIRB (IR #55), specifically in Table F. Of particular interest to DFO are the sediment and erosion control plan as well as the fish and fish habitat protection plan. DFO does not approve such plans; however we would ensure that the monitoring programs would be sufficient for detecting impacts and demonstrating effectiveness of mitigation such that unauthorized impacts are avoided.

DFO still requires additional site specific information related to all road crossings prior to being able to determine if any *Fisheries Act* authorizations are needed for the project. In the interim, DFO has identified ourselves as a potential Responsible Authority (RA) under the Canadian Environmental Assessment Act and a likely "government authority competent to authorize the development" under the Inuvialuit Final Agreement.

DFO, either as a RA or as an expert department, will work with other RAs, competent government authorities and other relevant regulators to review and ensure the implementation of all management plans.

DFO Response 80.2

DFO will review and provide comments on all monitoring plans that related to areas within our mandate and will typically approve and include certain plans as part of <u>conditions</u> of a *Fisheries Act* authorization. Monitoring can be separated into two components: construction and operation monitoring as well as compensation (No Net Loss Plan*) monitoring. In all cases, DFO would verify the effectiveness of mitigation and compliance with authorization conditions.

Monitoring during construction and operation is conducted to verify that mitigation measures are applied and are effective at avoiding impacts to fish and fish habitat. Compensation monitoring is designed to confirm that habitat compensation measures outlined in the DFO authorization are followed and assesses their effectiveness in achieving "No Net Loss" of fish habitat productive capacity over the long term.

DFO Fish Habitat Biologist and Fishery Officers may also conduct adhoc compliance monitoring site visits to ensure that all activities are in compliance with the *Fisheries Act* as well as conditions included in authorizations.

* Please refer to DFO's Policy for the Management of Fish Habitat for more details on No Net Loss (http://www.dfo-mpo.gc.ca/habitat/role/141/1415/14155/fhm-policy/index-eng.asp)

DFO Response 80.3

DFO, either as an RA or as an expert department, will work with other RAs, competent government authorities and other relevant regulators to review and ensure the implementation of all monitoring and management plans.

IR Number: 89

To: Department of Fisheries and Oceans (as well as Environment Canada and Aboriginal Affairs and Northern Development Canada)

Subject: Worst Case Scenario (EIS, Section 4.4.5, pg. 614-622; IR 69 and response)

Preamble:

The Inuvialuit Final Agreement (IFA) in paragraph 13(11)(b) requires that developers provide evidence to enable an estimate of "the potential liability of the developer, determined on a worst case scenario". This is in additional to evidence about both actual and future wildlife harvest loss which may results from a worst case scenario. Inuvialuit have a right to compensation for both actual and future harvest loss based on section 13(15) of the IFA. Further, the IFA specifies that where these are more than one developer they are jointly and severally liable. The IFA also sets out that future harvest loss includes damages to habitat and disruption of future harvesting activities.

The EIS did not provide an estimate total clean up costs of the proposed worst case scenario. The estimate of liability in the EIS is based only on losses (or replacement) of fish and some fishing gear for one season and does not address impacts on fish habitat or the effects of a spill on future Inuvialuit harvesting in the affected area or future harvest losses if Inuvialuit harvesters avoid the affected area in the future. Answer IR 69.2 provides and estimate of costs for a 5 day and a 10 day spill response event and the cost of monitoring.

MSES Inc. Request:

- 1. Please review and comment on the Developer's explanation of the likely fate of diesel spilled in the worst case scenario as set out in the EIS.
- 2. Please evaluate the impact of the worst case scenario on the fish and migratory bird habitat and populations in the streams, water courses and Husky Lakes. Provide an estimate of the cost of remediating these affected habitats.
- 3. Please provide a critical evaluation of the estimated costs for cleaning up the fuel spilled under the worst case scenario.

Department of Fisheries and Oceans (DFO) Response:

DFO Response 89.1-3

Subsection 36(3) of the *Fisheries Act* prohibits the deposit of deleterious substances into waters frequented by fish. A deleterious substance is defined by the *Fisheries Act* as any substance that, if added to water, makes the water deleterious to fish or fish habitat or any water containing a substance in such quantity or concentration or has been changed by heat or other means, that if added to water makes that water deleterious to fish or fish habitat. Environment Canada is responsible for administering this subsection of the Act and would lead on the assessment and enforcement in the event of a deposit, such as diesel fuel spills, into fish frequented waters. Please refer to Environment Canada's response to this question for a more detailed response.

DFO would also recommend that the proponent consider the potential impacts of wide-spread culvert failures on fish and fish habitat should multiple crossings be damage simultaniously due to improper installation, permafrost degradation or ground slumping, extreme events, etc..

IR Number: 119

To: Department of Fisheries and Oceans

Subject: Increased access to fisheries resources during Project operations (EIS, Section 4.2.5.1-4.2.5.3, p. 503-504, Round 1 IR #32.

Preamble:

The EIS referenced a report contracted by the Department of Fisheries and Oceans [Socio-economic Literature Review of the Impact of Linear Developments in the Northwest Territories (Nichols Applied Management and Knopp 2010. In this report, two types of management plans are briefly discussed [p.21].

DFO Integrated Fish Management Plans are used to manage a specific stock of a particular species of fish from a particular region that is under multiple fishing pressures from users from multiple locations. IFMPs involve input from all stakeholders and are used to guide the conservation and sustainable use of the resource (Fisheries and Oceans Canada 2009b). An example of an IFMP from the Mackenzie River is the "Integrated Fisheries Management Plan for Coney (Stenodus leuchicthys) in the Gwich'in Settlement Area, Inuvialuit Settlement Region, and the Sahtu Settlement Area, Northwest Territories 2000-2005" (Fisheries and Oceans Canada 2000b). The Fisheries Joint Management Committee, the Inuvialuit Game Council (IGC), the Gwich'in Renewable Resource Board and the Sahtu Renewable Resource Board (SRRB) and Fisheries and Oceans Canada all have a responsibility under their respective mandates to manage the Inconnu ("Coney") in their waters (Fisheries and Oceans Canada 2000b). This IFMP was developed to determine the best way to manage the inconnu in a way that everyone could agree on and to determine who would carry out the management of this species.

Local subsistence fisheries are monitored and managed using Community-based Monitoring Plans (CBMPs) and Fish Management Plans (FMPs). CBMPs and FMPs are put in place to maintain healthy fish stocks, maintain and manage the fishery for continued use by local communities and to encourage co-operation among all users to ensure sound management (Gwich'in Renewal Resource Board 2010).

In its response to IR 32, the Developer provided a commitment to prepare an "action plan" and indicated that an "Action Plan is the key mitigation proposed to minimize indirect residual effects on fish and fish habitat." The Developer had already committed to developing a "Fish and Fish Habitat Protection Plan" for direct impacts in the EIS and Conformity Response 2b.

Given the legislated mandate of the Department of Fisheries and Oceans and the rights assigned to the Inuvialuit under the Inuvialuit Final Agreement, it is unclear whether the Developer's commitment is additional to the fish management planning processes and regulatory processes nor is it clear how the Developer's commitment relates to the regulatory decision process of Department of Fisheries and Oceans.

GNWT Request:

- 1. Please describe the mandate and the regulatory processes of the Department of Fisheries and Oceans under the **Fisheries Act** to establish limits and restrictions on sport, subsistence and commercial fishing activities in the LSA and RSA for the Project.
- 2. Please describe the status of any relevant fisheries management plans and file copies of existing or draft fisheries management plans.
- 3. If relevant fisheries management plans are in preparation but cannot be released at this time, please provide the expected due date.

4. Please clarify and explain how the Developer's commitment to develop an "action plan" fits within the existing planning and regulatory processes to manage fish harvest by subsistence, sport or commercial harvesters as a mitigation to minimize residual impacts to fish.

Department of Fisheries and Oceans (DFO) Response:

DFO Response 119.1

Management of fisheries in the Northwest Territories is a responsibility of DFO. Fisheries management within the ISR involves actively working with co-management partners such as the Fisheries Joint Management Committee (FJMC), Hunters and Trappers Committees (HTC), Parks Canada and the Government of the Northwest Territories.

The three main priorities of DFO fisheries management are: 1) to ensure conservation of fish stocks, 2) ensure access to fish stocks for subsistence purposes and, 3) allow access to commercial, domestic, and recreational fisheries. These priorities are managed jointly with our co-management partners.

The management of fisheries tends to be a continuous adaptive management cycle (see Figure 1), and in general, the process proceeds as follows:

- Concerns regarding fish stocks are often brought forward by communities, the fishing
 industry, and/or co-management partners. These issues, if warranted, are passed on to
 stock assessment specialists (DFO staff or a co-management body) and a scientific
 sampling program is developed to investigate the concern.
- Most programs are run in conjunction with co-management partners and use community monitors. Data are compiled by stock assessment staff.
- Working group meetings are scheduled with representatives from co-management groups and DFO to discuss the results and possible management options. Recommendations from these meetings are brought back to the representative groups and communities for input through public consultations.
- A fishing plan is then developed for the fishery using the recommendations brought forward.

Fisheries management is carried out in a manner consistent with the management processes and harvesting established under the lands claim agreement. Where the processes result in a change in a quota, a change to open or close fishing seasons, or a change in a limit on the size or weight of fish under the *Northwest Territories Fishery Regulations*, DFO issues a variation order to implement it.

DFO also has the responsibility for setting and enforcing the fish harvest levels in the NWT. Harvest levels are published in the NWT fishery regulations and are enforced by the Conservation and Protection Branch (Fishery Officers).

To ensure sound management of the fisheries, commercial, domestic and recreational harvesters must obtain a licence to fish. Several categories of sport-fishing licences are issued depending on residency. Subsistence fishers do not require a fishing licence.

DFO Conservation and Protection (Fishery Officers) respond directly to public or partner agency concerns about fish habitat and fish population levels. Concerns are investigated by Fishery Officers and typically one of three resolution mechanisms are used: 1) enforcement patrols can be increased to ensure resource users are abiding by the current regulations, 2) use of variation orders to amend the allowable harvest levels for the affected water bodies, 3) close water bodies

to fish harvesting in order to rebuild fish population levels and ensure sustainable fisheries for future generations.

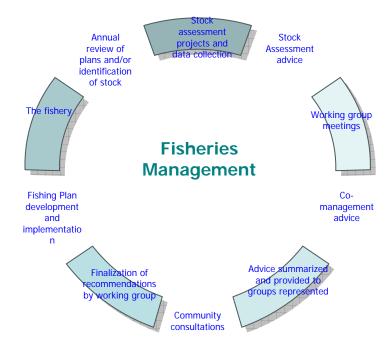


Figure 1. The cycle of Fisheries Management in the NWT.

DFO Response 119.2

A copy of the Integrated Fisheries Management Plan for Coney (*Stenodus leuchicthys*) in the Gwich'in Settlement Area, Inuvialuit Settlement Region, and the Sahtu Settlement Area, Northwest Territories 2000-2005, can be found on the following website: http://www.grrb.nt.ca/pdf/fisheries/IntegratedFisheriesManagementPlanforConey.pdf

DFO Response 119.3

The TIWG will be developing a fisheries management plan for the Highway corridor in cooperation with DFO. No date has been set for completion.

DFO Response 119.4

DFO, as part of our Information Request submission on March 1st, 2012, requested that the Department of Transportation (DoT) provide additional details related to their Action Plan. Without specifics on the Action Plan, DFO is not in a position to comment on how it might fit in with any of the existing planning and regulatory processes for the management of fish. DFO recommends that DoT discuss the details of the Action plan with the TIWG and DFO and determine how to work cooperatively on the development of a fisheries management strategy for the road.

IR Number: 120

To: Department of Fisheries and Oceans

Subject: Fisheries Research Applicable to the Project Area (EIS, Section 7.3)

Preamble:

The EIS referenced a report contracted by the Department of Fisheries and Oceans [Socio-Economic Literature Review of the Impact of Linear Developments in the Northwest Territories (Nichols Applied Management and Knopp 2010) (attached). In this report states that fish management-related studies are underway for stock structure and population analyses, community-based monitoring, climate change effects on fish, as well as Traditional Knowledge studies of fish and aquatic resources [p. 21]:

GNWT Request:

- 1. Please provide a list of the research and Traditional Knowledge studies relevant to the Project LSA and RSA. For each study, describe the study objectives and activities and indicate the status of the study.
- 2. Please file the results of completed studies.
- 3. If any research and Traditional Knowledge studies relevant to the Project LSA and RSA are in preparation but cannot be released at this time, please provide the name of the project and expected due date.
- 4. Please explain how the Developer's commitment to provide its fish and fish habitat results would assist with the ongoing research and Traditional Knowledge studies, as well as the federal government's Cumulative Impact and Monitoring Program.

Department of Fisheries and Oceans (DFO) Response:

DFO Response 120.1

The traditional knowledge study initiated by the TIWG is still ongoing and identifies the historical use of lakes within the corridor, as well as known species composition of lakes used for subsistence fishing. Upcoming work for the 2012 season is a partnership between the FJMC, DFO and University of Victoria to test a predictive model along the Tuktoyaktuk-Source 177 Road for the presence of fish. If successful, this model may be used to predict fish presence in water bodies along the entire corridor of the Highway.

DFO recommends the Developer contact individual communities and/or organizations within the Inuvialuit Settlement Region for copies or details on any relevant TK studies in the Project LSA and RSA.

DFO Response 120.2

The Northern Land Use Information Series (1981) has been digitized and placed on the website (http://sis.agr.gc.ca/cansis/publications/maps/nluis/250k/lu/index.html.) These maps outline traditional use of the area, including fishing locations and species composition of certain water bodies. In 2010, a Summer Profundal Index Netting (SPIN) study was carried out on Big Lake along the Tuktoyaktuk-Source 177 Road corridor. Results can be found in Appendix A. In 2011, a study of Lake 111 was completed. Results are also provided in Appendix A.

DFO Response 120.3

DFO Science is involved in several studies related to the ecological assessment of the Husky Lakes. A final technical report is expected in late 2012, but below is a list of other documents summarizing the preliminary results. Copies of the posters and documents can be found in Appendix B.

- Harwood, L. A. and Sparling, P. "Lake trout distribution and salinity: an assessment of the relative abundance and distribution of lake trout throughout Husky Lakes, 2001-2004." In: Mills, K. H., M. Dyck, and L. A. Harwood. 2008. Proceedings of the Second North American Lake Trout Symposium 2005, Yellowknife, Northwest Territories. Can. Tech. Report Fish. Aquatic Sci. 2778. 247
- O Christ Perin report (2007) "Fish species distribution and associated water chemistry attributes in the Husky Lake and Sitidgi Lake system, NT"
- o Marie-Julie Roux, Lois Harwood, Xinhua Zhu, Paul Sparling and Ross Tallman (2011). "Fish Assemblage Structure and species diversity with relationships to environmental variables in an arctic estuary: the Husky Lakes ecosystem, Canada." The Fisheries Society of the British Isles 2011 Annual International Conference (FSBI 2011) Fish Diversity and Conservation: Current State of Knowledge. Bournemouth, U.K. July 2011.
- o Marie-Julie Roux, Lois Harwood and Paul Sparling. (2011) "Ecological Assessment of Husky Lakes: Highlights Report".

DFO Response 120.4

Though the Developer has committed to providing fish and fish habitat results, this information would still be a requirement of the environmental assessment and must be considered in the design of water crossings, for assessing potential impacts as well as for developing appropriate mitigation measures. The baseline conditions will also assist in monitoring to confirm whether the predictions in the environmental assessment were accurate as well as to identify when additional management efforts may be required.

The fish and fish habitat data gathered along the highway corridor is of interests to DFO from a resource management and regulatory perspective. DFO expects that the baseline information gathered for this project could compliment or add to ongoing research and Traditional Knowledge studies in the area. For a list of any ongoing research and/or Traditional knowledge studies related to fisheries in the LSA and/or RSA, DFO recommends that the Developer contact the Cumulative Impact and Monitoring Program coordinator as well as individual communities or organizations directly.

IR Number: 121

To: Department of Fisheries and Oceans

Subject: Adequacy of Commitments (IR round 1 Response 55.1 Table F. Summary of Developer

Commitments)

Preamble:

The EIRB requested a complete list of all general and specific mitigation measures and commitments which the Developer provided in its Response to IR 55.1. The GNWT agrees that mitigation measures are a crucial aspect of ensuring adverse effects are avoided or minimized. However, to be fully applicable in regulatory processes, environmental and topic specific management plans, these commitments should be specific, measurable, attainable, relevant and trackable. To ensure the most appropriate wording is on record for discussion in technical sessions or public hearings, it is important for expert departments to provide feedback on the adequacy of the wording of mitigations and commitments to improve and to identify missing mitigations or commitments early in the environmental assessment process.

GNWT Request:

- 1. Please review the relevant general and specific mitigation measures provided by the Developer in IR Response 55.1 Table F and identify and confirm the adequacy of the wording of the mitigation measures or provide editorial suggestions to improve the wording to ensure the commitments are specific, measurable, attainable, relevant and trackable.
- 2. Please identify and provide wording for additional mitigation measures required to ensure the avoidance or minimization of Project impacts.

Department of Fisheries and Oceans (DFO) Response:

DFO Response 121.1-2

Commitments made during the course of this environmental assessment may help to improve the project design as well as mitigate and monitor potential impacts of the development on the biophysical and socio-economic environment. The commitments tables should reflect the information contained in the Environmental Impact Statement (EIS), supporting documents as well as any additional commitments made by the Developer over the course of the environmental assessment process including in Responses to Information Requests, Technical Sessions, Community Meetings and the final hearings. The commitments table should be a stand alone document, with sufficient detail, that it can be used over the life of the project as a record of all the relevant design considerations, mitigation measures, monitoring plans necessary to ensure the project does not cause significant adverse effects. Parties should be given the opportunity to comment on the final commitments table prior to the closing of the public registry.

The comments provided below are specific to Table F in the Developer's IR response # 55.1 with the understanding that over the course of the remainder of the EA, additional commitments may need to be added or refined:

- The Developer made commitments in the February 2012 Response to the EIRB IRs that are not reflected in Table F. These include but are not limited to:
 - Page 19 a commitment was made to measure turbidity, pH, dissolved oxygen, conductivity and temperature within 50m upstream as well as 50m and 100m downstream from each crossing. The sampling will be done in the spring and following ice-out.

- Page 160 there was a commitment to assess culverts annually for three years in fish bearing streams by a Qualified Environmental Professional to ensure fish passage, particularly during migration periods.
- Page 166 the Developer made commitments to design stream crossings with no binwalls as abutments as well as arched culverts will be used in fish habitat crossings where a bridge is not used.

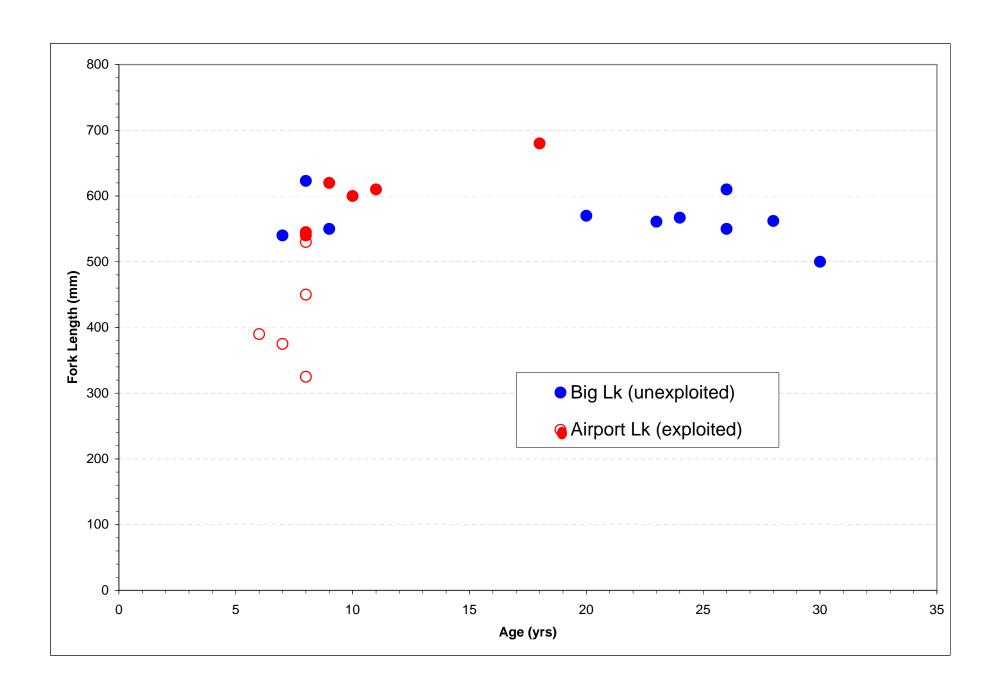
DFO would also like to make the following comments on the Commitments Table (Table F in the Developer's IR response # 55.1):

- Page 135 "The Developer will undertake further engineering, environmental and archaeological studies in areas scheduled for construction during that same year."
 Please add "or prior to that year."
- Page 139 "Appropriately sizing and installing culverts, based on hydrological assessments and local experience, to avoid backwatering and washouts". The sizing and proper installation is also to ensure fish passage.
- Page 140 "Constructing in non-fish bearing streams during winter". This commitment does not reflect the most recent discussions between DFO and the Developer during the Jan 31, 2012 meeting. Construction in frozen conditions causes fewer impacts in the aquatic environment than summer construction, in most situations; this is especially true for fish-bearing streams.
- Page 140 "Following DFO Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters (Wright and Hopky 1998)". As mentioned in our March 1st 2012 Information request submission, DFO recommends the use of a lower threshold values than indicated in our guidelines to mitigate impacts associated with the use of explosives in or near water. Other mitigation should also be employed including using a series of smaller blasts, timing, and fish exclusion measures if necessary. Two useful references are:
 - Offshore Oil and Gas Environmental Effects Monitoring: Approaches and Technologies. Edited by Armsworthy, Shelley, Peter J. Cranford, Kenneth Lee. Cott, P., B. Hanna. 2005.
 - Monitoring Explosive-Based Winter Seismic Exploration in Water Bodies NWT 2000- 2002. Cott, P., B. Hanna, J. Dahl. Canadian Manuscript Report for Fisheries and Aquatic Sciences 2648. 2003. Discussion on Seismic Exploration in the Northwest Territories 2000–2003.
- Page 141 "Creating and enforcing Regulations or guidelines on fish harvest by FJMC with input from DFO, local fisherman and Hunters and Trappers Committees;" The Developer does not have the authority to create or enforce regulations or guidelines related to fish harvest. DFO recommends the Developer change the wording to say "creating Regulations or guidelines on fish harvest in cooperation with".

DFO recommends that in subsequent versions of the commitments table, the Developer reference the reports, meeting minutes and/or transcripts where that specific commitment was made.

Appendix A

- 1. Summer Profundal Index Netting (SPIN) study carried out on Big Lake along the Tuktoyaktuk-Source 177 Road corridor.
- 2. Lake 111 study completed in 2011.



Tuktoyaktuk – Inuvik Highway Project: Summary of the Fish Assessment of Lake 111

Background

There is a potential for a highway between Tuktoyaktuk and Inuvik. Along this potential highway, there are many waterbodies. In order to protect these waterbodies the Tuktoyaktuk – Inuvik Working Group (TIWG) was created. The TIWG, comprise of the Inuvik Hunters and Trappers Committee (member), the Tuktoyaktuk Hunters and Trappers Committee (member) and the Fisheries Joint Management Council (secretariat) and it has the mandate to do a fish management plan along this highway.

In order to do a fish management plan, the TIWG need to determine what kind of species can be found in the waterbodies that will be close to the potential highway and to see if there are recreational or subsistence species of fish. The lake chosen for a community fish assessment this year is Lake 111 (figure 1). One of the reasons the TIWG chose this lake is because they cannot find any traditional knowledge (TK) on it and they are assuming that Lake Trout (*Salvelinus namaycush*) are living in it.

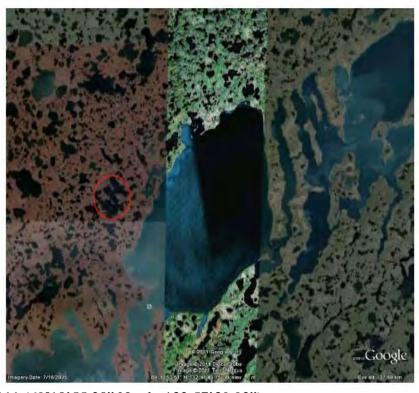


Figure 1: Lake 111 (69°10'55.20" North; 132:57'39.92")

Methodology/Results

Lake 111 was sampled on July 26-27, 2011 using minnow trap, one panel of small meshes (1.25", 0.75", 1.5", 0.5", 1.0") summer profundal index netting nets (SPIN nets) and one panel of big meshes (3.0", 4.5", 2.0", 3.5", 1.5", 5.0", 2.5", 4.0") SPIN nets. The net were set via a zodiac boat. Due to complication with the motor and the low depth of the lake, only a portion of the lake was sampled.

None of the fish capture was kept. Out of 46 fish captured, 28 percent (13 fish) died in the nets. During the assessment a total of 38 broad whitefish (*Coregonus nasus*), one artic cisco (*Coregonus autumnailis*), one grayling (*Thymallus thymallus*), four northern pike (*Esox Lucius*) and one nine stickleback (*Pungitius pungitius*) were captured. No Lake Trout was captured.

The average length and weight of the broad whitefish was 32.7 cm and 0.55 Kg. The average length and weight of the northern pike was 30.5 cm and 0.43 Kg. The arctic cisco was 24.0 cm and 0.3 Kg, the grayling was 35.2 cm and 0.6 Kg and the nine sticklebacks was 5.0 cm and 0.025 Kg.

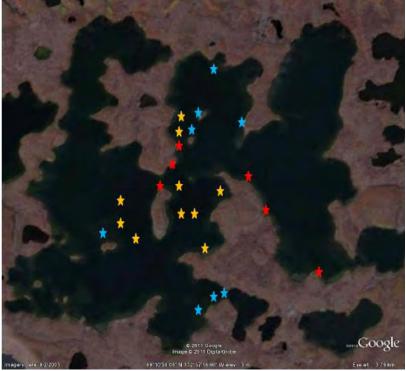


Figure 2: Sample sites. Yellow represent the big SPIN nets, blue represent the small SPIN nets and red represent the minnow trap.

Appendix B

- 1. Harwood, L. A. and Sparling, P. "Lake trout distribution and salinity: an assessment of the relative abundance and distribution of lake trout throughout Husky Lakes, 2001-2004." In: Mills, K. H., M. Dyck, and L. A. Harwood. 2008. Proceedings of the Second North American Lake Trout Symposium 2005, Yellowknife, Northwest Territories. Can. Tech. Report Fish. Aquatic Sci. 2778. 247
- 2. Christ Perin report (2007) "Fish species distribution and associated water chemistry attributes in the Husky Lake and Sitidgi Lake system, NT"
- 3. Marie-Julie Roux, Lois Harwood, Xinhua Zhu, Paul Sparling and Ross Tallman (2011). "Fish Assemblage Structure and species diversity with relationships to environmental variables in an arctic estuary: the Husky Lakes ecosystem, Canada." The Fisheries Society of the British Isles 2011 Annual International Conference (FSBI 2011) Fish Diversity and Conservation: Current State of Knowledge. Bournemouth, U.K. July 2011.
- 4. Marie-Julie Roux, Lois Harwood and Paul Sparling. (2011) "Ecological Assessment of Husky Lakes: Highlights Report".

Abstract

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 NWT. The area is a prime subsistence harvesting area for Inuvialuit of Tuktoyaktuk and Inuvik, is being considered for hydrocarbon exploration (lies near the Parsons Lake field) and eventually for an adjacent transportation corridor (all weather road) between Inuvik and Tuktoyaktuk. Relying heavily on community fisheries expertise, local knowledge and field assistance, a four years study of the Husky Lakes system was undertaken in July of each of 2001-2004. A total of +3000 fish representing 25 species were captured over the four years of the study during 578 sets, each 50-60 min in length, using 6 and 12 ft deep test nets 60 m in length, each with panels of 1.5", 2.5", 3" meshes. Water quality variables including salinity were measured. Husky Lakes itself consists of five connected basins, with a linear distance of 300 km from the most inland waters of Sitidgi Lake (0% salinity) to the brackish waters of Liverpool Bay, where salinities were as high as 2.07%. Bathymetry data were collected and a water gauge installed to monitor water levels over time. A summary of the fisheries resources throughout the lake is presented, along with an examination of the relationship between the distribution of lake trout and salinity.

Introduction

Inuvialuit fishermen from Tuktoyaktuk and Inuvik utilize the Husky and Sitidgi Lakes area. This area is extremely improtant to local culture and nutrition, offering a variety of traditional activities, including fishing, hunting, trapping and travelling. It also supports an important recreational fishery, home of the only fly-in fishing lodge in the Inuvialuit Settlement Region. There are no commercial fisheries for lake trout in this area.

This project reported here is designed to collect baseline ecological data on the Husky Lakes system, working closely with the communities involved. Information collected as part of this study will be widely available for use in future assessments, to ensure continued subsistence fishing opportunities, traditional pursuits, and developments that are conducted in a manner consistent with traditional use and ecological relationships.

The data will be helpful to communities, the Inuvialuiit and Fisheries Joint Management Committee, regulatory agencies and industry in ensuring their preparedness to plan, review and assess possible development activities in the Husky Lakes area. Husky Lakes is located east of areas presently under lease for gas exploration activites.

Study Components

- Non-destructive, small mesh gillnet sets (approx. 50 min sets) in five basins, inner and outer finger areas, Sitidgi Lake and Five Hundred Lakes areas (XXX sets);
- Tagging of xxx lake trout with floy tags; - Measurement of in-situ water chemistry parameters including pH, conductivity, dissolved oxygen, turbidity, water temperature and salinity at xxx stations:
- Full suite of water quality variables and
- samples at 11 stations;

lakes.

- Sampling of sediments and lower trophic levels at 9 stations;
- Installation and operation of a water gauging station in Basin 2;
- Data collection and preparation of bathymetric
- map of all basins; - Determination of hydrocarbon and heavy metal levels in five main species of fish in the

Field Crew

The field work was conducted by field technicians from the communities of Tuktoyaktuk and Paulatuk (Fred Gruben Sr.; Douglas Panaktalok; Joseph Felix Jr., Joseph Illasiak), an FJMC summer student, led by P. Sparling. The crew was based out of Five Hundred Lakes in 2001, Saunkitok in 2002, Nallok in 2003 and the DFO Fisheries Trailers in 2004. All work was conducted from 18' Lund boats with 40-60 hp motors, leased from community fishermen. Access to and from the study sites in summer was by float plane.

Lake trout distribution and salinity: an assessment of the relative abundance and distribution of lake trout throughout Husky Lakes, 2001-2004

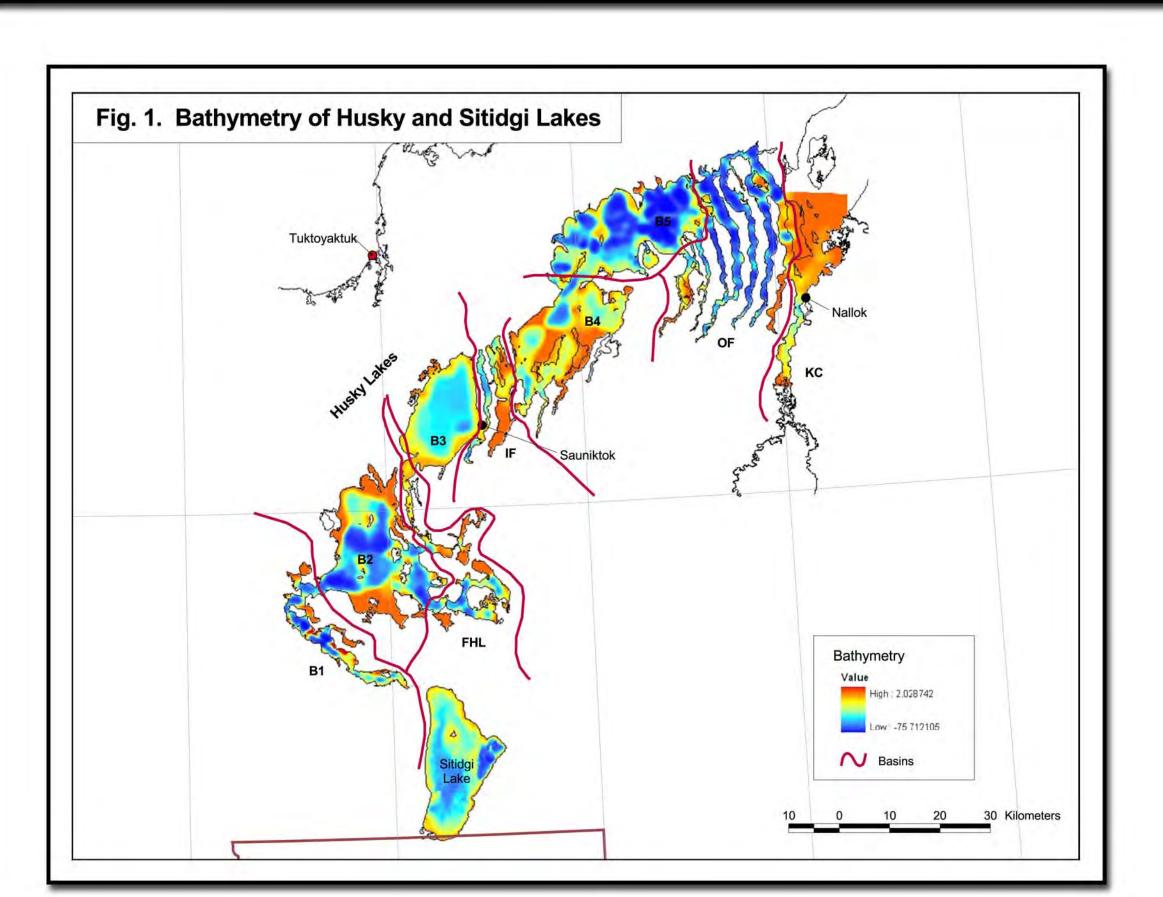
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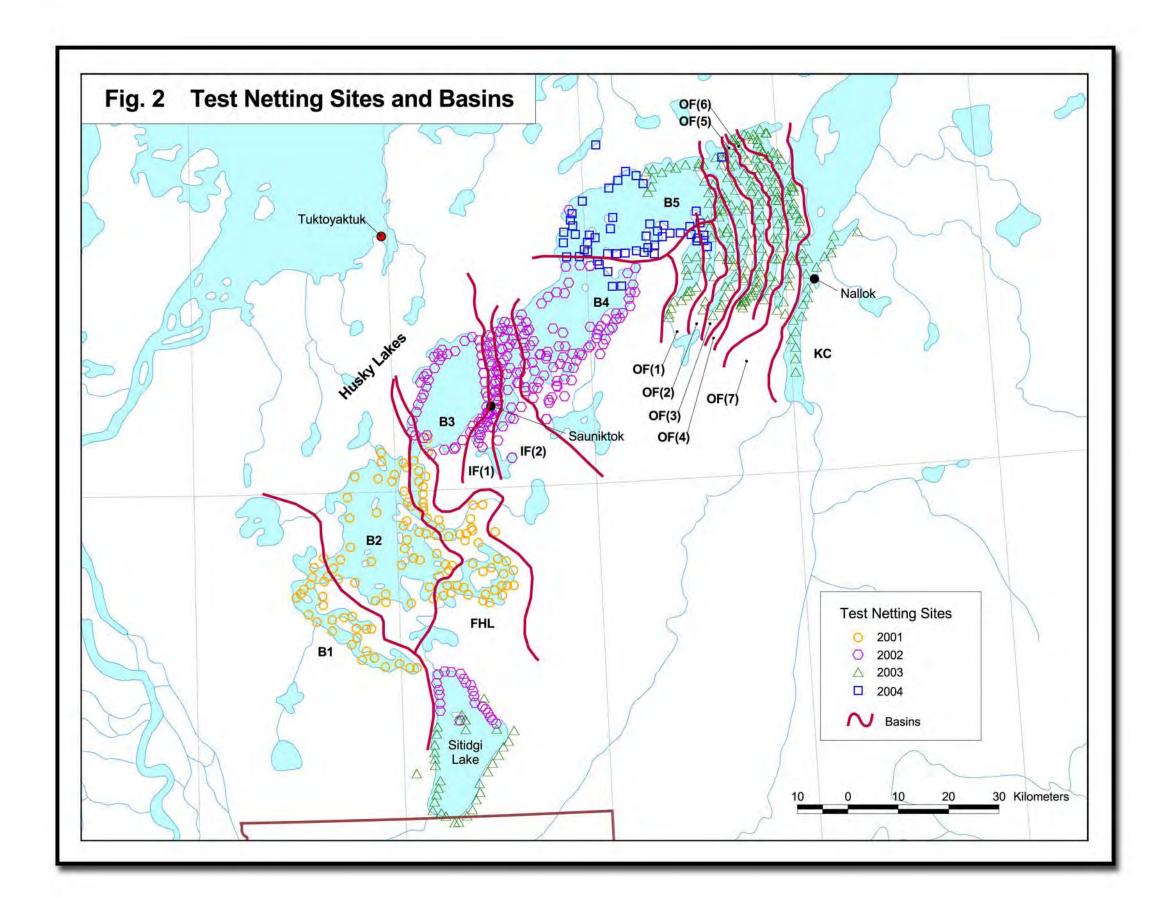
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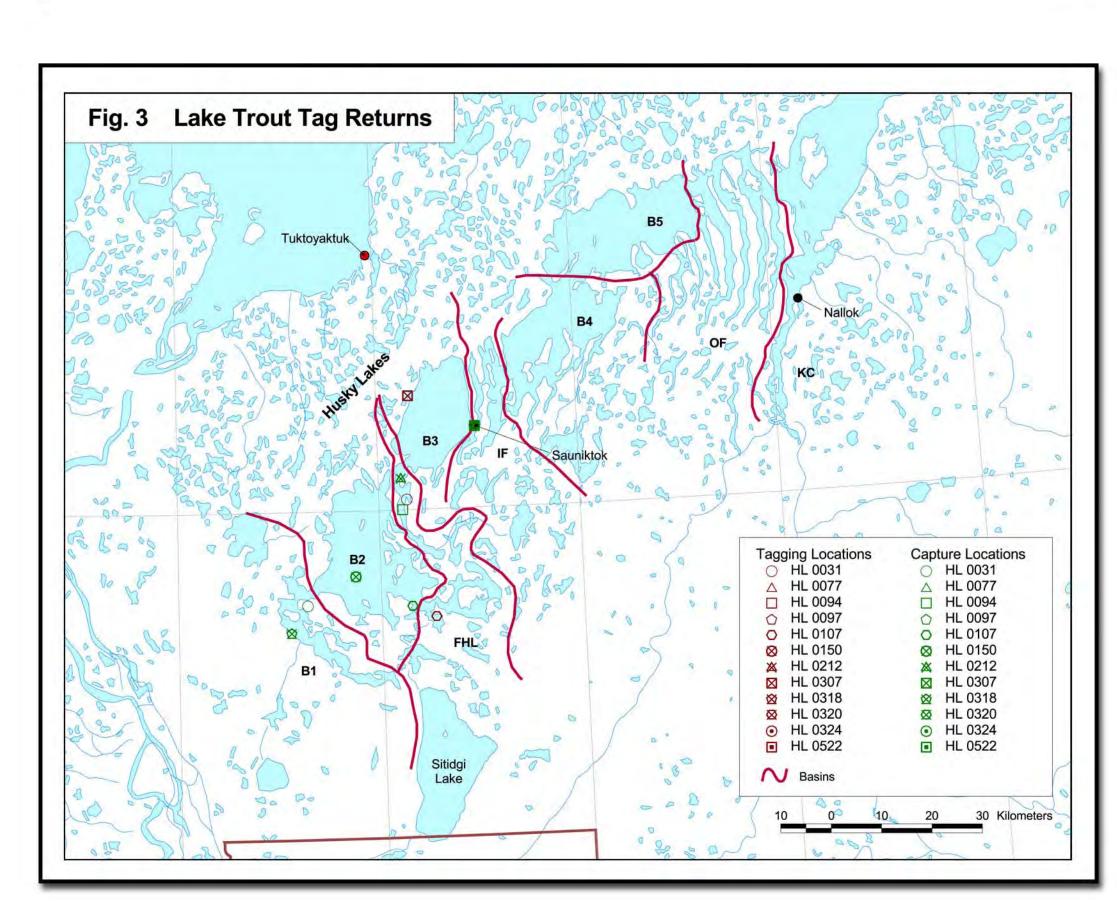


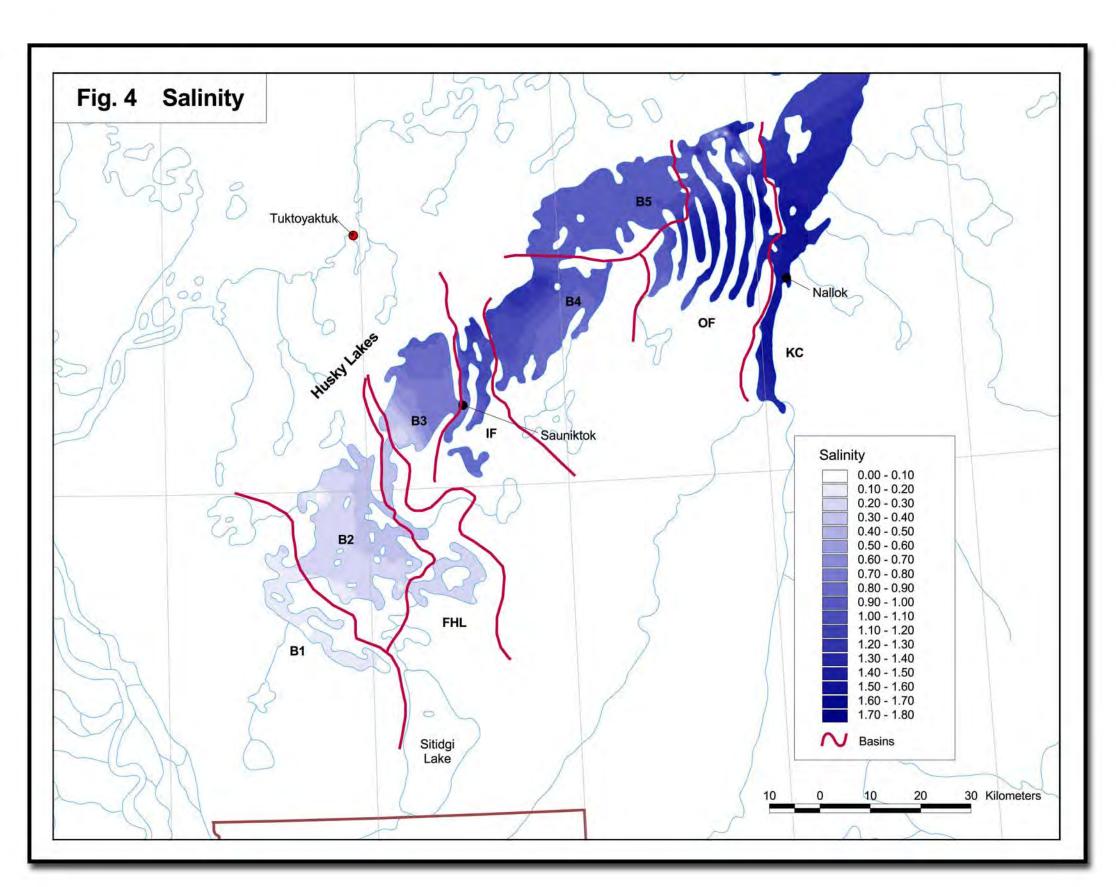
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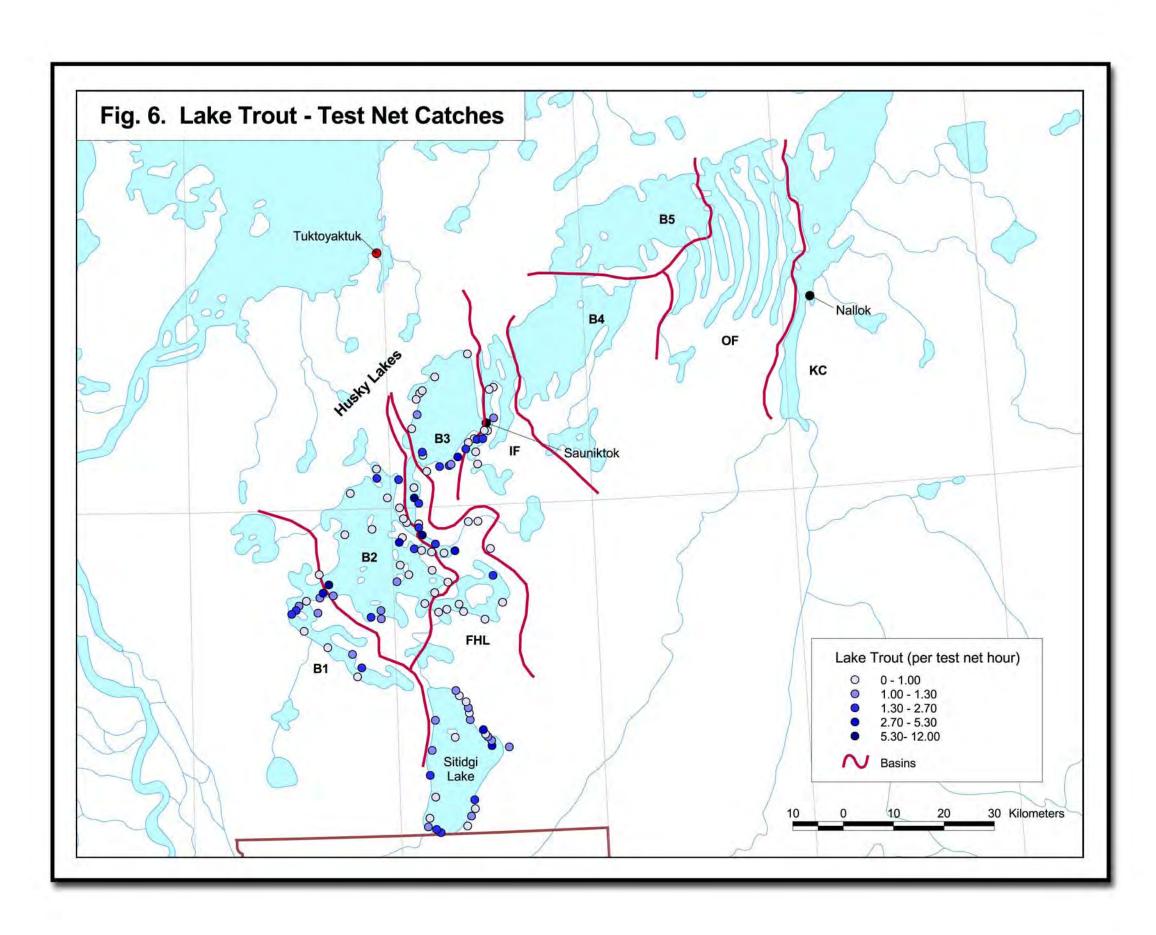
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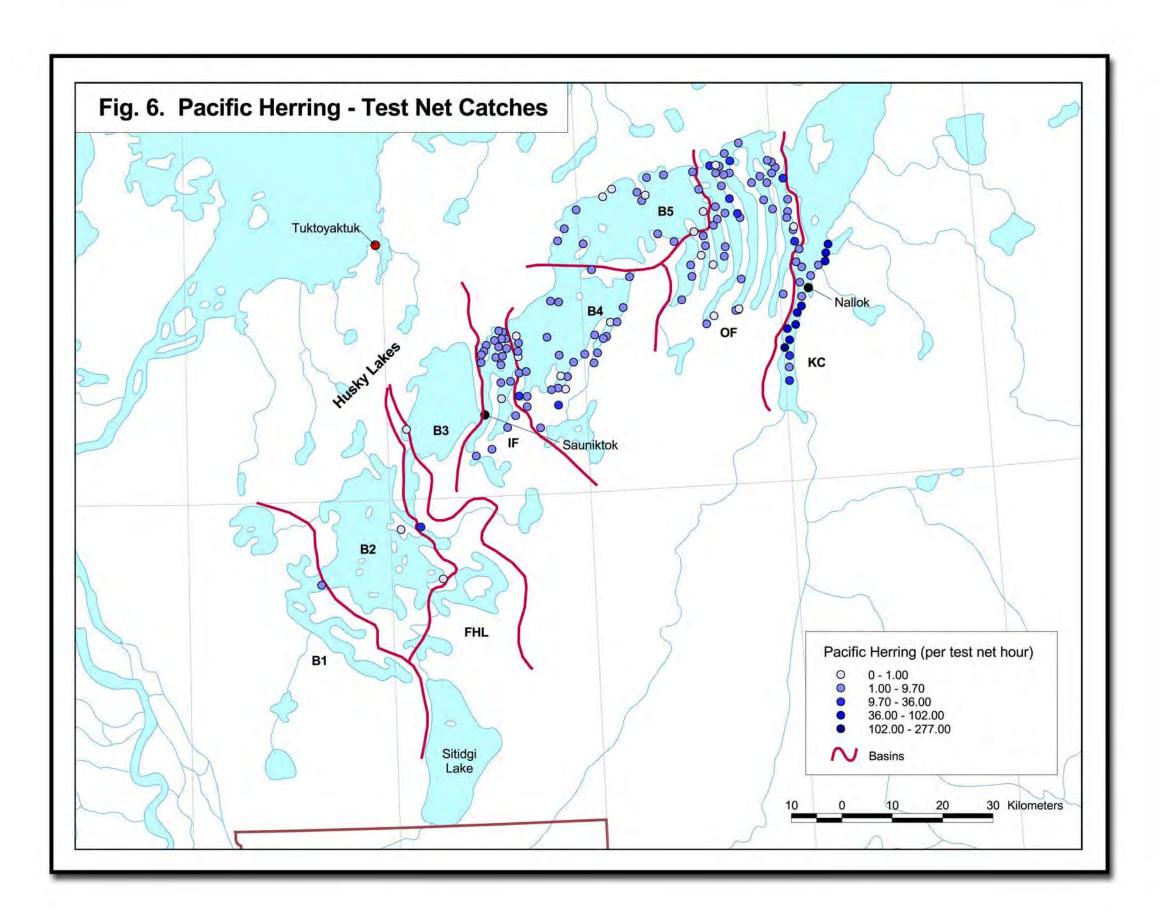












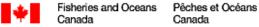
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Thanks to Todd Slack and Alan Udell, both of Yellowknife, and Dustin Whalen, of Geological Survey of Canada in Dartmouth, NS, for preparation of figures and bathymetric maps; Julia Kenyon, Victoria, for entering biological data and summarizing tag returns; Paul Graveline of North/South Consultting for second reading of the otoliths; Curtis Martin of DFO Winnipeg for stomach content analyses; Gary Carder for first reading of the ototliths; Ken Mills, DFO, for aging the fins; Gary Stern and Brian Bilbeck, DFO, for conducting the analysis of hydrocarbons in fish tissues; Mike Foreman, DFO for providing historic bathymetric data; Carol Read of DFO for assistance with many tasks; Archipelago Marine Research for providing historical data sets; Marlene Evans, Doug Halliwell and Kerry Walsh of Environment Canada for water quality, lower trophic and sediment analyess; Roger Pilling, Gerry Wright and George Lennie, WSC, and Frank Pokiak, Tuk HTC, for their roles in the installation of the water gauging station.

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FISH SPECIES DISTRIBUTION AND ASSOCIATED WATER CHEMISTRY ATTRIBUTES IN THE HUSKY LAKE AND SITIDGI LAKE SYSTEM, NT

January 31, 2007

Submitted to

Fisheries and Oceans Canada Yellowknife, NT



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Prepared by

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January 31, 2007

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1 INTRODUCTION

Fish sampling surveys were completed by the Department of Fisheries and Oceans (DFO) in the Husky Lake and Sitidgi Lake system (Figure 1) using non-destructive gill netting techniques in 2001 – 2004 (L. Harwood, DFO, Yellowknife, NT. Pers. Comm., Harwood 2003). The surveys resulted in the handling of several thousand fish from 18 different species in 641 net sets across all basins of the lake system. At the times of gill netting, a water quality Sonde was deployed for measurement of pH, dissolved oxygen (DO), turbidity, specific conductivity, salinity, and water temperature over a water profile either at the netting site or in close proximity to the netting site within the same basin. Additional measurements with the Sonde were made on other infrequent dates when water samples were collected for analysis of a large spectrum of other analytes including nutrients, metals, and other contaminants at a standard sampling station in each main lake basin of Husky Lake. Occasionally, physical descriptions of fish habitat were made at a few fish sampling sites during the fish sampling activities.

Multivariate statistical analysis was applied to the fish catch data that was supplied by DFO to examine groupings of fish samples throughout the lake system according to the catch and species composition measurements. Summary statistics of chemical attributes across the lake basins were also calculated to reveal gradients of water chemistry that might coincide with any change in fish population structure over the longitudinal lake gradient. Results of these analyses are presented in this report to contribute insight into spatial variation in fish community structure and associated chemical gradients in the Husky Lake system.

The results are considered an introduction to an analytical approach for examining spatial variation in fish community structure and associated habitat attributes in Husky Lake. The results are considered preliminary. They will be part of a suite of future analyses to be done by DFO looking at links between habitat, water quality, and fish distribution and abundance in the Husky Lake system.

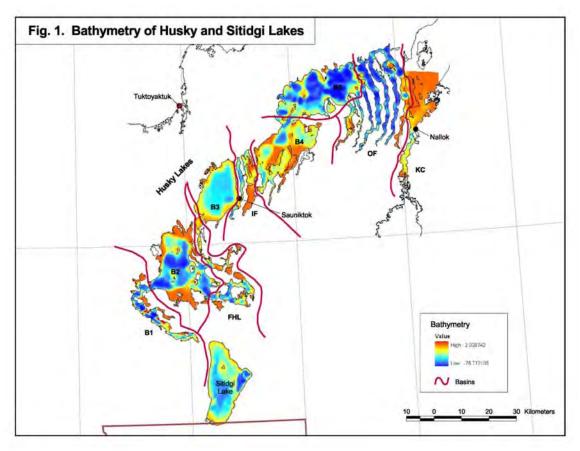


Figure 1. Map of the Husky and Sitidgi Lakes study area showing the multibasin bathymetry. Map provided by DFO (L. Harwood. DFO. Yellowknife, NT, Pers Comm). Alph-numeric codes indicate lake basin labels (e.g. B1, B2, etc.) as defined by DFO.

2 STUDY AREA

The data supplied by DFO included fish catches from all of the Husky Lake basins extending from KC in the north, having a saline influence from the Arctic Ocean, south to B1 (Figure 1). The lineal north to south distance over which the Husky Lake basins extended was approximately 142 km. The study area also included Sitidgi Lake that discharged into Husky Lake in the south at basin B1.

3 METHODS

3.1 Compilation of biological data

Excel files listing the fish catches across all years (2001 through 2004) were received from DFO (L. Harwood, DFO, Yellowknife, NT. Pers. Comm.). They included 1923 observations (e.g. rows of data) of fish catch where an observation was catch in a gill net panel per hour. These data were based on a fishing period of 50-60 minutes

using a 60 m non-destructive gill net having 1.5", 2.5", and 3" mesh panels that was fished at a water depth of 1.8 m or 3.7 m and was anchored to shore. Each panel was 20 m in length. For analysis, all data were converted to catch/net hour by summing the panel catches for each gill net set, resulting in 641 observations.

A unique sample code was derived for each fish catch observation. It consisted of characters for lake name, basin label, year, and site number. Site number was that assigned by DFO for each sampling site in a given year.

Across all observations, a total of 18 fish species were found. They included lake whitefish, arctic cisco, least cisco, lake trout, arctic grayling, northern pike, pacific herring, round whitefish, broad whitefish, inconnu, four horned sculpin, starry flounder, saffron cod, arctic flounder, Greenland cod, rainbow smelt, long nosed sucker, and burbot.

3.2 Compilation of habitat data

Excel files listing habitat attributes at sites of gill netting and other locations throughout the lake system across all years (2001 through 2004) were received from DFO (L. Harwood, DFO, Yellowknife, NT. Pers. Comm.). The files were merged and 1309 unique observations (e.g. rows of data) were found. All observations included concentrations or other record of chemical analytes and occasional comment of shoreline and lake bottom features. Hence, for our purposes, habitat attributes actually meant chemical concentrations of a range of analytes. All observations did not include all variables and thus were incomplete. Most chemical measurements were from deployment of a water quality Sonde (1194 observations) that measured pH, dissolved oxygen (DO), turbidity, specific conductivity, salinity, and water temperature over a water profile. Others included a suite of nutrients, electrochemical measurements, in addition to alkalinity, colour, suspended solids, and turbidity that were analysed by the Taiga Environmental Laboratory (operated by Indian and Northern Affairs Canada) from water samples collected on one episode from each of two basins in 2001 and 2002, and from one basin on 4 dates in 2003. Still other data included concentrations of metals and hydrocarbon compounds and contaminants that were analysed by the Environment Canada laboratory in Burlington from water samples that were collected at the same time as those that were submitted to Taiga.

After consultation with the project monitor, a decision was made to focus attention on the expected north to south salinity gradient across the lake basins and determine if a relationship existed between fish community composition and the salinity gradient. Chemical variables associated with salinity including the direct salinity measurement as well as pH, specific conductivity, and TDS were of particular interest for analysis. Other variables including alkalinity, DO, colour, and total phosphorus were also selected because of their importance in assessing broad scale water quality in

lakes (Perrin and Blyth 1998). Because there was little extra time required to examine a few contaminants, heavy metals including Cu, Cd, Pb, and Zn were also selected.

Concentrations of the chemical analytes that were less than the detection limit of the laboratories were reported by DFO as the lab detection limit divided by two. Since there is no chemical justification for making this change, all values that were less than the detection limit were set at that limit.

All chemical data were sorted to select observations corresponding with the top 3 m of the littoral zone where most of the gill nets were set. To obtain a single chemical observation to correspond with a gill net set, the mean concentration found among measurements in the top 3 m was determined. Sample size for this calculation ranged from 1 to 3 at a given site.

As described for the fish catch data, a unique sample code was derived for each episode of water chemistry measurement. It consisted of characters for lake name, basin label, year, and site number. Site number was that assigned by DFO for each sampling site in a given year. The same sample code in the fish catch file and the chemistry file meant that those two observations were paired (fish catch and water chemistry measurements were done at the same time and location). A total of 184 exact pairs of fish catch and chemistry observations were found.

More pairings between fish catch and chemistry observations were selected over and above the 184 exact pairs by developing a sorting code that linked biological and habitat data that were not always collected at the same time and location but were reasonable approximations. The code provided a means to sort the biological and habitat data and optimize the size of sample used in statistical analyses according to a set tolerance for spatial and temporal separation between the fish catch and the habitat data. This kind of sorting was required to pair individual habitat and biological observations across the whole data set and thereby facilitate any analysis in which habitat attributes were required to be linked to a given observation of fish catch. It was also required to link habitat and biological data wherein the habitat data were collected at times and locations that were reasonably close to the biological data. The coding is explained in Table 1.

Table 1. Explanation of a data sorting code that was applied to each fish catch and chemistry observation.

Sort code number	Sort code description				
0	Biological and chemistry data were from the same site and time				
1	Chemistry data were from a different date within the same year but same location as the fish catch data				
2	Chemistry and fish catch data were from the same date but the chemistry data were from a site as close as could be found to the fish catch location. That nearby site was called a "nearest neighbor" and it was defined as a site having a DFO site code closest to that assigned to the gill netting site.				
3	Chemistry and fish catch data were from a different year but the chemistry data were from the same location as the fish catch data				
4	Chemistry and fish catch data were from different years and the chemistry data were from a site as close as could be found to the fish catch location. That nearby site was called a "nearest neighbor" and it was defined as a site having a DFO site code closest to that assigned to the gill netting site.				
5	Chemistry and biological data were from different dates within the same year and the chemistry data were from a site as close as could be found to the fish catch location. That nearby site was called a "nearest neighbor" and it was defined as a site having a DFO site code closest to that assigned to the gill netting site.				
6	Chemistry and fish catch data were from different lake basins				

For purposes of linking salinity, nutrient concentrations, and metal contaminants to fish community catch rate and composition, only chemical observations coded with a 0, 1, 2, or 5 were selected for analysis. This selection yielded a sample size of 251 observations, which was an increase over the 184 exact pairs of fish catch and chemistry observations (e.g. coded 0).

4 ANALYSIS OF SPATIAL VARIATION IN FISH COMMUNITY DISTRIBUTION

The compilation of all fish catch data amounting to 641 observations was used to describe and delineate any spatially defined groups of fish communities that may be apparent in the Husky Lake system.

The first step was to strip out all observations that had a zero catch because there must be fish present in any given catch to contribute to interpretation of the distribution of fish. That step resulted in a final compilation of 575 observations that were read into Primer v5 multivariate analysis software (Clarke and Warwick 2001, Clarke and

Gorley 2001). Each observation was coded using year and basin as factors that were used for visualizing the distribution of samples in plots.

Similarities between all paired combinations of the 575 fish samples were calculated using the Bray Curtis coefficient (Krebs 1999) in Primer to produce a similarity matrix. Because we were interested in the contribution of all fish species to spatial patterns in community composition, a square root transformation was applied to all observations before the matrix was calculated. The transformation moderately downweighted the importance of the common species and increased the weighting of the rarer species. It also increased the weighting of species occurring in moderate abundance in the net catches. The Bray Curtis coefficient was defined as:

$$S_{jk} = 100 \left\{ 1 - \frac{\sum_{i=1}^{p} |y_{ij} - y_{ik}|}{\sum_{i=1}^{p} (y_{ij} + y_{ik})} \right\}$$

where S_{jk} is the similarity between the *j*th and *k*th samples, y_{ij} is the abundance for the *j*th species in the *j*th sample, y_{ik} is the abundance for the *j*th species in the *k*th sample, and there are i = 1, 2, ..., p species.

An overview of similarities of fish communities between samples was examined using the group average linkage in the hierarchical, agglomerative clustering algorithm performed in PRIMER, from which a dendrogram was plotted. A preliminary non-metric multidimensional scaling (MDS) analysis was also run in Primer from which an ordination was plotted. MDS is a procedure for fitting a set of points in a space such that the distances between points correspond as closely as possible to dissimilarities between objects. Output is displayed on two-dimensional images having no scaling units wherein space between objects on the image provides perspective of dissimilarities. These images are called ordinations. Both of the analyses revealed 3 extreme outliers having no similarity to any other sample. They included sample code SL003012 (gill net set in Sitidgi Lake in 2003 having a DFO sample number 12), SL003010 (gill net set in Sitidgi Lake in 2003 having a DFO sample number 10), and HLB2001072 (gill net set in Husky Lake in basin B2 in 2001 having a DFO sample number 72). These samples were removed from further analysis.

Another MDS was then run to determine if spatially different groups of samples could be distinguished on an ordination plot based on the fish composition and catch rate. Again the source data were square root transformed to downplay the influence of very abundant species and increase the importance of rarer species. Results in Figure 2 did indicate spatially separated sample groups along the basin gradient. B5 samples were clearly separated from SL samples but there was substantial overlap indicating high similarity between B5, OF, and KC samples. B3 samples formed a group having

large overlap with IF samples. B2 samples formed a band between the B3/IF group and the SL samples. B1 samples showed no unique grouping either on its own or with other basins. B4 samples were substantially similar to the OF samples and appeared to span a gradient between the north end of the lake at B5/OF and the middle of the lake at B3. The ordination had a stress level of 0.15, which indicated a useful and acceptable 2-dimensional picture of sample relationships. For comparison, a stress level over 0.2 indicates that the 2-dimensional may not be a good representation of sample relationships.

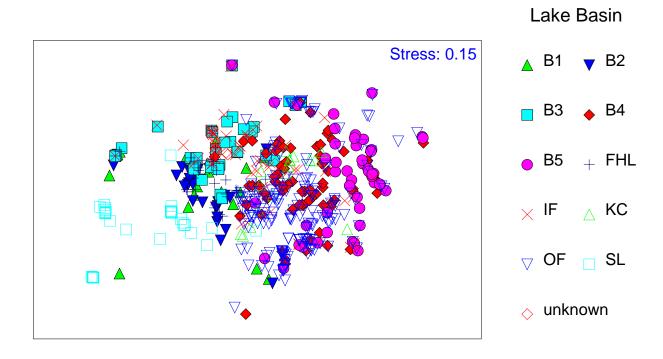


Figure 2. Ordination of all fish catch samples (n=575) from Husky and Sitidgi Lakes. The samples are colour and symbol coded to show dissimilarities of samples collected from the different basins. Samples that were not assigned to a basin in the source data (n=8) were coded as "unknown".

A "basin effect" was tested using analysis of similarities (ANOSIM) in Primer to derive a statistic that indicated the degree of similarity of fish communities within and between lake basins. The resulting R statistic was based on a non-parametric permutation procedure that was applied to the similarity matrix underlying the MDS. This procedure was a multivariate analogue of a standard one-way analysis of variance. The R statistic contrasted the observed differences in fish species composition and catch

rate between basins with fish species composition and catch rate within basins using the equation:

$$R = \frac{\left(\overline{r_B} - \overline{r_W}\right)}{0.5M}$$

where M=n(n-1)/2 and n is the total number of observations, $\overline{r_W}$ is the average of all rank similarities among observations within basins, and $\overline{r_B}$ is the average of all rank similarities arising from all pairs of observations between the different basins. R can range from 0 in which there is no difference in community composition between basins (similarities between and within basins are approximately the same) to 1 in which all observations within basins are more similar to each other than they are to any observations from different basins.

The global R value was 0.35 and it was significant at 0.1%. A R statistic <5% was considered significant for purposes of comparing fish community structure and catch rate between basins. The relatively low R value means that some unique attributes between one or more pairs of basins were present but many similarities between basins were also present. The probability value means that if all samples were randomly assigned to any basin and R was re-calculated and this was done a very large number of times (default is 999 times), the probability of R being greater than 0.35 (the calculated R statistic) was 1 in 1000, which was less than our cut off of 5%. Hence, we rejected the null hypothesis of no difference in fish community composition between any basin pair. Fish community composition was significantly different between one or more basin pairs.

R values for basin pairs were then examined to determine where the differences in composition and catch rate were present. For these comparisons, some rules were applied. For there to be clear differences in fish community structure and catch rate, a basin pair having R≤0.2 was considered to be almost identical, while a pair having R>0.2 and R≤0.4 was considered weakly separable. A basin pair having R>0.4 and R≤0.6 was considered to indicate clear differences despite having some overlap, and R>0.6 was considered to indicate well separated community structure and catch rate. Results are shown in Table 2.

Starting at the north end of the lake, we see that KC and OF were weakly separable (R=0.28), as were B5 and OF (R=0.34), B5 and KC (R=0.33), and B4 and KC (R=0.27). Fish communities between B4 and B5 (R=0.11), between B4 and OF (R=0.14), and between IF and B4 (R=0.21) were almost identical or weakly separable. As we move south, we see clearer differences were present between B3 and B5 (R=0.54), between B3 and OF (R=0.46), and between B3 and KC (R=0.49). B3 and B4 were weakly separable (R=0.37) and B3 and IF were almost identical but given the greater separation of B3 and B5, we conclude that B4 and IF were zones hosting a

transition of fish communities between basins in the north and in B3. Because communities between B4 and B5 were almost identical (R=0.11), we argue that a boundary between B3 and IF can be assigned for purposes of assigning samples to groups to visualize the north-south gradient in fish communities. We know there were similarities in the fish communities between B3 and IF and B4 but there was enough of a separation between B3 and the other northern basins to suggest a transition existed in that B3 to B4 zone.

Working further south we see that B3 was virtually identical to B2 (R=0.13), as it was to FHL (R=0.11), and B1 (R=0.09). The fish community in Sitidgi Lake was relatively unique and well separated from the others (e.g. for SL-B1 R=0.51, for SL-B2 R=0.65, SL-B3 R=0.55).

Our overall conclusion is that 3 general groups of fish communities can be defined over the Huskly Lake - Sitidgi Lake gradient. The communities in IF, B4, B5, OF, and KC showed some gradient of change but were similar enough to be considered a single group for further analysis. Samples from those basins were assigned to sample Group 1. The fish communities in B1, B2, B3, and FHL were virtually the same and could be considered another unique sample group that was assigned as Group 2. The fish community in Sitidgi Lake was unique and was assigned as Group 3 for further analysis. One could argue for further separation of basins in Group 1 samples, particularly recognizing the IF to B4 transition zone, but for the present exploratory purposes, leaving these samples in Group 1 was acceptable.

The ordination shown in Figure 3 summarizes these conclusions. While there was overlap among some of the samples on the ordination, a clear gradient was shown with Group 1 and Group 3 samples being most dissimilar and Group 2 samples in the middle. This ordination more clearly indicated a north to south gradient in fish community structure and catch rate than did the multi-basin ordination in Figure 2.

Table 2. Pairwise R statistics and levels of significance for basin comparisons. Any significance level <5% was considered significant. The far right column (number ≥ observed) compliments the test of significance. If the sample labels were randomly assigned to basins, R values re-calculated, and this calculation was repeated 999 times, the number of those re-calculated R values that are greater than or equal to the R test statistic is the "number ≥ observed". For the R statistic to be significant, the "number ≥ observed" should be zero or incidental.

Pairwise Tests

	R	Significance	Possible	Actual	Number >=
Groups	Statistic	Level %	Permutations	Permutations	Observed
B1, B2	0.039	12.4	Too Many	999	123
B1, B3	0.088	2.1	Too Many	999	20
B1, B4	0.457	0.1	Too Many	999	0
B1, B5	0.51	0.1	Too Many	999	0
B1, FHL	0.127	0.2	Too Many	999	1
B1, IF	0.167	0.6	Too Many	999	5
B1, KC	0.553	0.1	Too Many	999	0
B1, OF	0.498	0.1	Too Many	999	0
B1, SL	0.505	0.1	Too Many	999	0
B2, B3	0.126	0.1	Too Many	999	0
B2, B4	0.48	0.1	Too Many	999	0
B2, B5	0.617	0.1	Too Many	999	0
B2, FHL	0.069	0.3	Too Many	999	2
B2, IF	0.21	0.1	Too Many	999	0
B2, KC	0.718	0.1	Too Many	999	0
B2, OF	0.462	0.1	Too Many	999	0
B2, SL	0.646	0.1	Too Many	999	0
B3, B4	0.372	0.1	Too Many	999	0
B3, B5	0.542	0.1	Too Many	999	0
B3, FHL	0.114	0.1	Too Many	999	0
B3, IF	0.074	1.1	Too Many	999	10
B3, KC	0.492	0.1	Too Many	999	0
B3, OF	0.464	0.1	Too Many	999	0
B3, SL	0.546	0.1	Too Many	999	0
B4, B5	0.114	0.1	Too Many	999	0
B4, FHL	0.407	0.1	Too Many	999	0
B4, IF	0.21	0.1	Too Many	999	0
B4, KC	0.274	0.1	Too Many	999	0
B4, OF	0.143	0.1	Too Many	999	0
B4, SL	0.641	0.1	Too Many	999	0
B5, FHL	0.625	0.1	Too Many	999	0
B5, IF	0.387	0.1	Too Many	999	0
B5, KC	0.331	0.1	Too Many	999	0
B5, OF	0.338	0.1	Too Many	999	0
B5, SL	0.596	0.1	Too Many	999	0
FHL, IF	0.103	0.3	Too Many	999	2
FHL, KC	0.745	0.1	Too Many	999	0
FHL, OF	0.383	0.1	Too Many	999	0
FHL, SL	0.723	0.1	Too Many	999	0
IF, KC	0.262	0.1	Too Many	999	0
IF, OF	0.309	0.1	Too Many	999	0
IF, SL	0.539	0.1	Too Many	999	0
KC, OF	0.277	0.1	Too Many	999	0
KC, SL	0.688	0.1	Too Many	999	0
OF, SL	0.673	0.1	Too Many	999	0

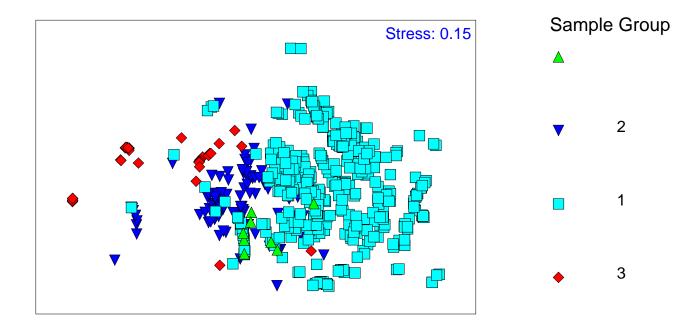


Figure 3. Ordination of all fish catch samples (n=575) from Husky and Sitidgi Lakes, plotted by sample group. Samples that were not assigned to a basin in the source data (n=8) and thus could not be assigned to a sample group were coded as green triangles.

The SIMPER routine in PRIMER was used to determine which fish species or groups of species contributed most to the similarities within sample groups and dissimilarities between the sample groups. This routine is essentially a decomposition of the overall Bray Curtis measure to define the relative contribution of individual species to an estimate of between-group dissimilarity and within-group similarity. The resulting species contributing more than 5% of the within-group similarity and cumulatively contributing over 90% of the within-group similarity and contributing to between-group dissimilarity may be considered discriminators of the fish community gradient in the Husky Lakes. They can be called biological indicators.

There were clear differences in the composition and catch rate of fish species between each of the sample groups (Table 3). Group 1 was characterised by the highest species richness (16 taxa in Group 1 compared to 13 in Group 2 and 6 in Group 3), comprising a combination of saline tolerant, marine, and freshwater taxa. Least cisco, arctic cisco, Pacific herring, starry flounder, and lake whitefish were caught at highest rates in Group 1 compared to the other groups, implying greater abundance

compared to the other species. The species contributing most to within-group similarity and could be considered biological indicators of Group 1 samples included lake whitefish, least cisco, arctic cisco, Pacific herring, and starry flounder. These species cumulatively accounted for 96% of the within-group similarity and were characteristic of the Group 1 community attributes. Those attributes included low catch rate of lake whitefish, and highest catch rate of the species common to estuaries having a wide range of salinities (cisco species and starry flounder) among all three sample groups. Compared to Group 1, the Group 2 fish community was characterised by a large increase in catch rates of the lake whitefish and lake trout, which were the indicators of the Group 2 community. There was also a decline in the catch rate of the species tolerant of salinity (e.g. the ciscos) or those more typical of estuarine conditions (e.g. starry flounder) compared to Group 1 and complete absence of the rarer marine and freshwater species that were found in Group 1. Group 3 samples were characterized by extremely low catch rates and fewest species among all groups. Lake whitefish, lake trout, and northern pike were the group indicators and they were captured at highest rates (albeit at <1 fish every 33 hours of net fishing time).

Table 3. Percent contribution of fish species to within sample group similarities defined using the SIMPER routine in PRIMER. Only fish species contributing most to group similarity and cumulatively comprising >90% of within-group similarity and contributed to betweengroup dissimilarity are listed. Any species found at a catch rate of <0.001 fish/net hour was assigned a zero catch.

Fish species	Mean ca	tch rate (nui hour)	mber/net	/net Percent contribution group similarity				
	Group	Group	Group	Group	Group	Group		
	1	2	3	11	2	3		
Lake whitefish	1.4	6.8	0.03	15	72	17		
Lake trout	0.04	0.9	0.02		21	69		
Least cisco	2.7	0.4	0.003	38				
Arctic cisco	1.6	0.11	0	18				
Pacific herring	3.9	0.07	0	15				
Starry flounder	1.3	0.32	0	10				
Northern pike	0.01	0.62	0.01			13		
Arctic grayling	0	0.34	0					
Round whitefish	0	0.09	0.003					
Broad whitefish	0.19	0.11	0.002					
Inconnu	0.11	0.02	0					
Four horned sculpin	0.16	0.22	0					
Saffron cod	0.23	0.04	0					
Arctic flounder	0.51	0	0					
Greenland cod	0.01	0	0					
Rainbow smelt	0.13	0	0					
Long nosed sucker	0.01	0	0					
Burbot	0.003	0	0					
Total	12.303	10.04	0.068	96	93	99		

5 LINKING CHEMICAL ATTRIBUTES TO FISH COMMUNITY COMPOSITION

Discriminant function analysis (DFA) was initially considered as an analytical approach to reveal the relative importance of the many chemical analytes that were measured over the years of study in Husky Lake. Because most of these data were found to be incomplete (all variables not measured on all dates), the DFA was of limited practical use because it requires complete observations of all variables linked to all biological observations. More importantly, most chemical observations were measured using a water quality Sonde that is good at providing insight into electrochemical characteristics and salinity gradients, which was the basic information needed to interpret the lake water chemistry. To make best use of the Sonde data, any link between a possible salinity gradient and fish catch rate and composition, was a focus for analysis. Since analysis of a large number of chemical variables was not possible or necessary, a DFA was not needed. Alternatively, chemical observations that corresponded to sample codes 0, 1, 2, and 5, as defined in Table 1, were used to provide summary statistics of chemical conditions across the three sample groups that were defined in Section 4. In addition to salinity attributes, variation in phosphorus concentrations and selected metals that can be toxic in marine and freshwaters (Cu, Cd, Pb, Zn) were examined across the sample group gradient. After summary statistics were run, an outlier of total phosphorus (TP) concentration was found for sample code HLOF003019 (DFO sample site 19 in 2003 in basin OF). That concentration was stated as 2.52 mg/L, which was 2 orders of magnitude higher than the TP concentrations in all other samples. The statistics were re-run after this value was deleted.

A strong salinity gradient was clear and other chemical differences between fish sample groups were also apparent (Table 4). Salinity of approximately 1% (about a third of that in the ocean) was characteristic of Group 1 samples, which indicated the presence of a salt wedge intrusion or diffusion of saline water in the northern lake basins. That salinity produced a steep conductivity gradient between the sample groups, with values ranging from more than 18,000 μ S/cm at Group 1 sites to less than 100 μ S/cm at Group 3 sites. It also presented alkaline conditions at Group 1 and 2 sites but in the absence of salinity at Group 3 sites, the water was more acidic, indicating a left shift in the carbonate equilibria in the transition from Group 2 sites to Group 1 sites.

Average dissolved oxygen concentrations were low at Group 1 and 2 sites (5 – 5.5 mg/L), suggesting substantial oxygen demand from sediments in the shallow littoral habitat where the gill nets were set. In contrast, the DO concentrations at Group 3 sites in Sitidgi Lake were very high and probably close to saturation. There were, however, only two measurements from Sitidgi Lake, which may not be representative of the whole lake DO concentrations. Water at Group 1 sites had moderate TP concentrations in a range that indicated mesotrophic conditions (Wetzel 2001). The mean TP concentration at the Group 2 sites was very low and in an oligotrophic range (Wetzel 2001). Given that accumulation of labile organic matter from internal primary production may be limited

under the mesotrophic and oligotrophic conditions, it is not clear why the DO concentrations were low at the Group 1 and 2 sites. Further investigation of trophic state and other limnological attributes including possible introduction of organic matter from shoreline tundra in summer is required to investigate the source of DO demand at those sites.

Among the metals, the mean Cu, Pb, and Zn concentrations were substantially less than guideline values for the protection of aquatic life (CCME 2006), implying little risk of toxicity from those metals. The mean Cd concentration of 0.0001 mg/L that was found at Group 1 and 2 sites was an order of magnitude above the CCME freshwater guideline concentration of 0.000017 mg/L and it was essentially the same as the marine guideline concentration of 0.00012 mg/L. This finding does not mean that Cd toxicity was present at Group 1 and 2 sites but it does flag the metal for further investigation.

Table 4. Mean concentration or measure of chemical analytes by fish sample group.

Lab or instrument	Analyte Mean concentration (units analyte) and sample size (
		Group 1	Group 2	Group 3
Sonde	рН	7.6 (131)	7.8 (79)	6.6 (33)
Sonde	DO (mg/L)	5.5 (126)	5.0 (79)	10.4 (2)
Sonde	Specific Conductivity (µS/cm)	18602 (129)	6110 (79)	95 (33)
Sonde	Salinity (%)	1.08 (131)	0.32 (79)	0.00 (33)
Sonde	Water temperature (°C)	8.8 (131)	11.0 (79)	13.5 (33)
Taiga (INAC)	Total Dissolved P (mg/L)	0.024 (10)	0.006 (1)	Not measured
Taiga (INAC)	Total P (mg/L)	0.024 (9)	0.007 (1)	Not measured
Taiga (INAC)	Alkalinity (mg/L)	72 (12)	52 (3)	Not measured
Taiga (INAC)	Colour	9.2 (12)	5.0 (3)	Not measured
Taiga (INAC)	TDS (mg/L)	14679 (10)	4777 (3)	Not measured
Burlington (EC)	Total Cd (mg/L)	0.000113 (12)	0.0001 (3)	Not measured
Burlington (EC)	Total Cu (mg/L)	0.001785 (12)	0.0008 (3)	Not measured
Burlington (EC)	Total Pb (mg/L)	0.000135 (12)	0.0002 (3)	Not measured
Burlington (EC)	Total Zn (mg/L)	0.011463 (12)	0.0046 (3)	Not measured

6 CONCLUSIONS

Results from Sections 4 and 5 are summarized in Table 5 to show the association of the gradient of fish community structure and catch rate with chemical attributes between and within the sample groups. If we assume that fish catch rate is an index of abundance, Table 3 indicates that over the north to south gradient there was a shift from high to lower fish species diversity and a break in abundance between Husky Lake and Sitidgi Lake. This north to south gradient was associated with the declining

presence of saline tolerant fish species as the presence of the salt wedge intrusion or diffusion of saline water diminished and a shift occurred from apparent mesotrophic conditions in the north to oligotrophic conditions in the south (Table 5).

Table 5. Summary of fish community and chemical gradients found in Husky Lake and Sitidgi Lake.

Group number	Indicator fish species (important in defining within-group similarity and between-group dissimilarity)	Chemical condition
1 (Basins KC, OF, B5, B4, IF)	 Lake whitefish (low catch rate) Least cisco Arctic cisco Pacific herring Starry flounder 	 Very high conductivity and TDS from moderate salinity (30% of seawater) Alkaline pH Low DO concentration in littoral zones Moderate TP concentration implying mesotrophic conditions Potential Cd toxicity
2 (Basins B3, B2, FHL, B1)	Lake whitefish (high catch rate)Lake trout	 High conductivity and TDS Very low salinity Alkaline pH Low DO concentration in littoral zones Low TP concentration implying oligotrophic conditions Potential Cd toxicity
3 (Sitidgi Lake)	 Lake whitefish (very low catch rate) Lake trout (very low catch rate) Northern pike (very low catch rate) 	 Low conductivity and no salinity Acidic pH High DO concentrations in littoral zones

7 LIST OF REFERENCES

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8 APPENDIX B: RAW DATA APPENDICES

Raw data appendices are available on CD or via file transfer from DFO.

Fish assemblage structure and species diversity with relationships to environmental variables in an arctic estuary: the Husky Lakes ecosystem, Canada.

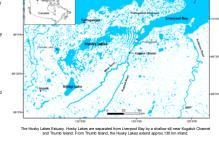
Marie-Julie Roux¹, Lois Harwood¹, Xinhua Zhu¹, Paul Sparling² and Ross F. Tallman¹

Fisheriez and Oceanie Péches et Océanie

PH dominant







The Husky Lakes Ecosystem

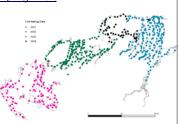


- Mean depth is 13 m with maximum depth exceeding 90 m in B1, B2 and B5
- Catchment Area (for HL only) is 9 543 km²
- shwater inputs to HL (excluding KG) are low (annual freshwater discharge of 1 km² yr ¹(Gushue et al. 1996)) and mainly occur in the spring. Most freshwater is supplied by ice melt (Macdonald et al. 1999). Sitidgi Lake (SL) accounts for most freshwater runoff to HL.
- Tides are semidiumal and of small amplitude. Strong mater mixing in HL occurs as a result of its unique physical configuration (i.e. complex shoreline and bathymetry with 'finger areas' acting to constrain and accelerate flow) (Carmack & Macdonaid 2008).
- The system is extremely oligotrophic and ice-covered on average eight months a year (Grainger & Evans 1982).
- Presence of horizontal salinity, pH and temperature gradients among basins

	Morphometries			Depth (m)		Salinity (ppt)		pH		Temperature (°C)		
	Area	Perimeter	P:A ratio	Catchment	mean ± stdev	max	mean ± stdev	range	mean ± stdev	range	mean ± stdev	range
	(km²)	(km)		(km²)								
B1	107	200	1.88		22.7 ± 21	97.6	1.5 ± 0.4	0.8-2.3	8.0 ± 0.2	7.7-8.2	12.1 ± 2.4	6.8-15.8
B2	512	599	1.17		12 ± 10	98.1	2.8 ± 0.6	0.5-3.9	7.8 ± 0.1	7.6-8.0	10.6 ± 1.7	6.7-15.0
B3	250	164	0.66		6.3 ± 4	73	6.9 ± 1.5	2.7-9.3	7.7 ± 0.4	6.9-8.3	8.0 ± 1.4	5.3-11.1
B4	299	289	0.97		5.7 ± 5	39.9	9.8 ± 1.3	6.7-13.0	7.9 ± 0.3	7.1-8.5	9.4 ± 2.1	6.4-13.5
B5	418	253	0.61		11.8 ± 14	99.7	10.5 ± 1.4	8.5-13.7	8.2 ± 0.6	6.9-9.0	8.7 ± 2.4	4.3-12.4
IF	86	170	1.97		10.5 ± 7	35.7	10.5 ± 1.6	6.5-13.0	7.4 ± 0.2	7.1-8.1	8.3 ± 1.7	6.0-13.6
OF	263	590	2.24		17.7 ± 13	72.8	13.2 ± 2.7	7.3-17.4	7.2 ± 0.4	6.6-8.7	7.8 ± 3.5	1.9-18.3
HL(total)	1933	2265	1.17	9543	13.3 ± 14	98.1	9.3 ± 4	0.5-17.4	7.6 ± 0.5	6.6-9.0	8.9 ± 2.8	1.9-18.3

Sampling Effort

- 585 test nets were set during summers of 2001 to 2004
- In all years, sampling was conducted following ice break-up.
- Experimental gillnets 54.9 m long consisting of three 18.3 m panels of 76 mm, 38 mm and 64 mm monofile stretched-mesh, were used. Net height was either 1.8 m or 3.7 m.
- Nets were set perpendicular to the shoreline at an interval distance of approx. 1 km for \pm 60 minutes. Net depth varied between 0.5 m to 27 m.
- Surface salinity (S), pH, and water temperature (T) measurements were taken at test netting sites (n=190) or interpolated using GIS (linear interpolation). Interpolated values were within 0.01 ± 0.08 (pH), 0.04 ± 0.4 (S), and 0.15 ± 1.7 (T) of measured values, respectively.



Fish Assemblage Structure I WF dominant (%)(p)=82) PH dominant (%IRI=20) B2 **B1** LWF dominant Abundance vs environmental variables Species composition and relative abundance Species composition, percent contribution to total CPUE (%CPUE), frequency occurrence (%F), index of relative importance

Corgona sandmula		Scientific name	Common name	Acronym	%CPUE	%F	IRI	%IRI	Incidence
Corgonac anamonal	dae	Coregonus clupeaformis	Lake Whitefish	LWF	24.15	47.87	1156.38	35.45	dominant
Solvelines namergeobs Leit Toot LT		Coregonus sardinella	Least Cisco	LC	19.28	43.44	837.54	25.68	dominar
Coropous nature Broad Whitefalb BWF Corol		Coregonus autumnalis	Arctic Cisco	AC	10.34	27.73	286.58	8.79	commo
Storman Armania Principul Incomus DCC 0 1 Thymatim arcticus Armania Care Gergliag AG 0 1 Thymatim arcticus Armania Care Gergliag AG 0 1 Thymatim Care Armania Care Gergliag AG 0 1 Thymatim Care Armania		Salvelinus namayeush	Lake Trout	LT	1.98	15.71	31.03	0.95	occasiona
Thymadlus arctics Phase Actic Graphing AG ACT Prosping region of Prosping regions and Phase Actic Graphing AG ACT Prosping Phase Actic Graphing ACT ACT Prosping Phase ACT Prosping Phase ACT Phase ACT Prosping Phase ACT Prosping Phase ACT Prosping Phase ACT Phase ACT Prosping Phase ACT Prosping Phase ACT P		Coregonus nasus	Broad Whitefish	BWF	2.16	9.98	21.55	0.66	occasiona
Principlina (yiluboccion) Road Whitelibal RWF 0.2 Chipeighe Chipeighe Pacific Herring PH 23.3 Plearmentine Plackolohy sollina Serry Flounder SF 3.2 Cladidee Plan romectes glacialis Arctic Flounder AF 2.2 Caliddee Cold Sp* COD COD T 1.0 Las latas Burbot BT 1.0 1.0 Cottidae Mystrocephalm quadric-ornas Fourhon Scalpin 115 1.		Stenodus leucichthys	Inconnu		0.78	4.25	3.32	0.10	ran
Chipedae Choro pullui Pacife Herring PH 23.1 Florencecide Placetohys soldiaus Sury Flounder SF 5. Florencecide Placetohys soldiaus Sury Flounder SF 6. Florencecide Chipedae SF 6. Florencecide Placetohys soldiaus Sury Flounder SF 2.2 Cladidae Chipedae Chipedae SF 6.2 Cladidae Chipedae Chipedae SF 7. Collidae SI 6.2 Las loss Burbot BT 0.0 Cottidae Mynuscephalus quadricursus Fourhom Scalpin FHS 1.		Thymallus arcticus	Arctic Grayling	AG	0.71	3.33	2.36	0.07	ran
Platestonecische Platescholys szelluns Stury Flounder SF 8: 8: Plearuncecische Platescholys szelluns Stury Flounder SF 8: 8: 2: Candidate Cad Sp.* Col Sp.* Sp.* Col		Prosopium cylindraceum	Round Whitefish	RWF	0.18	1.48	0.27	0.01	rar
Plearonectes glacialis Arcis Flounder AF 2.1	e e	Clupea pallasii	Pacific Herring	PH	23.80	26.80	637.88	19.55	dominan
Gaddale Cod Sp.* Cod Sp.* COD 1.1 Lotal fota Burbot BT 0.1 Cottidae Myoxocophafus quadricornis Fourhorn Sculpin FHS 1.2	ectidae	Platichthys stellatus	Starry Flounder	SF	8.51	25.69	218.76	6.71	commo
Lota lota Burbot BT 0.1 Cottidae Myoxocephalus quadricornis Fourhorn Sculpin FHS 1.4		Pleuronectes glacialis	Arctic Flounder	AF	2.98	9.06	26.99	0.83	occasiona
Cottidae Myoxocsphalus quadricornis Fourhorn Sculpin FHS 1.		Cod Sp.*	Cod Sp*	COD	1.64	10.72	17.53	0.54	occasiona
ayout quantonia toutou stupu		Lota lota	Burbot	BT	0.02	0.18	0.00	0.00	rar
		Myoxocephalus quadricornis	Fourhorn Sculpin	FHS	1.43	8.69	12.42	0.38	occasiona
Esocidae Exos lucius Northern Pike NP 1.4	2	Exos lucius	Northern Pike	NP	1.40	6.28	8.82	0.27	occasiona
Osmeridae Osmerus mordax Rainbow Smelt RBS 0.0	lac	Osmerus mordax	Rainbow Smelt	RBS	0.62	0.92	0.57	0.02	rar
Catostomidae Catostomus catostomus Longnose Sucker LNS 0.0	nidae	Catostomus catostomus	Longnose Sucker	LNS	0.04	0.37	0.01	0.00	ran
*Includes Arcsogadus glacialis (Arctic Cod), Eleginus gracilis (Salfron Cod) and Gadus opac (Greenland Cod).	Arcsogadus	glacialis (Arctic Cod), Elegèrus grac	sitz (Saffron Cod) and G	iadus ogac (Grees	sland Cod).				

- · 6 107 fish from 8 families and >17 species were caught.
- Salmonidae was the most diverse and abundant family, with 8 species accounting for 60% of total CPUE and 72% of IRI.
- Four Coregonids (LWF, LC, AC and BWF) accounted for 56% of total CPUE.
- explained 86% of total CPUE and 96% of IRI.
- Species richness was similar among basins. Diversity indices ranged from 0.48 and 0.80.
- · Salinity predominantly determines fish assemblage structure in HL, followed by pH and

Key findings and Implications

entital variables in HL. The eigenvalues of axis 1 (horizontal) and axis 2 (vertical) are 0.42 and respectively. The plot displays 12% of the inertia and 84% of the variance in the weighted or of energies shundarous with personal to accommend to eighber (arrange). Across legoth and

Fish assemblage structure was strongly influenced by horizontal salinity gradients, with progressive changes in species dominance from freshwater to marine taxa (i.e. from Lake White Fish to Ciscos and Pacific Herring) from B to OF, and the co-occurrence of species with contrasting salinity tolerance (such as Lake Trout and Starry Flounder) at Intermediate salinity values in B3, IF and B4.

Results suggest that freshwater budget is likely key to the abundance and spatial distribution of fish in the HL system. Any activity affecting freshwater inputs to HL, especially to inland-most basins, will have important consequences on fish assemblage structure.

Information on fish species distribution and community structure will be useful to elaborate conservation and management plans and for evaluating future impacts of impeding anthropogenic

Acknowledgments

PH dominant (SUPL-21)

SF common (%IRI=9

KĠ

Diversity

 $H = -(\sum_{i} P_{i}(\ln P_{i}))$ = diversity equally is

Ecological Assessment of Husky Lakes: Highlights Report

Marie-Julie Roux, Lois Harwood and Paul Sparling

The ecological assessment of Husky Lakes and Sitidgi Lake was conducted over a four year period during summers of 2001-2004. The assessment was paralleled by a five-year community-based monitoring survey of the spring subsistence fishery for Lake Trout (2000-2004).

The Husky Lakes form an estuarian system draining into Liverpool Bay in the Beaufort Sea (Figure 1). The lakes are separated from Liverpool Bay by a shallow sill near Thumb Island and consist in a series of interconnect basins linked by narrow channels or 'fingers'. For this study, we distinguished five main basins in Husky Lakes (B1 to B5) and two finger areas (inner fingers (IF) and outer fingers (OF)) (Figure 2). Kugaluk Channel (KG), the narrow inlet located at the southwest end of Liverpool Bay, was also considered for ecological assessment (Figure 2). Sitidgi Lake is a large freshwater body that drains into the inland-most basins of Husky Lakes (B1 and B2) (Figures 1 & 2).

Both the Husky Lakes and Sitidgi Lake hold historical and present-day economic and cultural importance to Inuvialuit from Tuktoyaktuk and Inuvik. The region is currently subject to increasing opportunities for anthropogenic development (i.e. highway construction and natural gas exploration/production) as well as to short and long-term impacts of ongoing climate change.

This study documents baseline ecological information on Husky Lakes and Sitidgi Lake including physical ecosystem characteristics, water composition/properties, fish abundance, diversity and spatial distribution during the open water season, and biological characteristics of Lake Trout harvest. This information confirms the unique character of the Husky Lakes ecosystem and will be useful for guiding future monitoring effort and evaluation of the effects of human activity and global change in the Husky Lakes-Sitidgi Lake Area.

Highlights - Physical ecosystem structure

- From Thumb Island, the Husky Lakes extend approximately 130 km inland and cover an area of 1933 km² (Figure 1).
- The Husky Lakes shoreline is extensive (total perimeter > 2000 km).
- Drainage area for Husky Lakes only (not including Kugaluk Channel) is 9 543
 km² (see Figure 2 for catchment boundary).
- The Husky Lakes have a complex bathymetry. Mean depth was 13 m throughout the estuary but varied greatly among basins, from 6 m in B3 and B4 to 23 m in B1. Maximum depth was 98 m in B1 and B2 and exceeded 70 m in all basins but B4 and IF (max depth ≤ 40 m) (Figure 3).
- Kugaluk Channel had a mean depth of 6 m and maximum depth of 24 m.
- Sitidgi Lake covers an area of 291 km² and is characterized by a small perimeter to area ratio (0.38).
- Sitidgi Lake is relatively shallow with mean and maximum depths of 7 m and 37 m, respectively. Deeper areas (> 20 m) are mainly located in the eastern arm of the lake (Figure 4).

Highlights – Water composition and properties (Husky Lakes)

- Vertical gradients in water composition (i.e. changes in concentrations with increasing depth) were generally small. Horizontal (spatial) gradients were more important.
- The Husky Lakes estuary is highly oligotrophic with total phosphorous concentrations in surface water ranging from 0.01 mg L⁻¹ (in B2, B4 and IF) to 0.07 mg L⁻¹ (in B5).

- Spatial variation in essential nutrient (phosphorous and nitrogen) concentrations indicated potential nitrogen limitation for primary productivity near the mouth of the estuary and phosphorous limitation in inland-most basins.
- Water samples from the inland-most basins (B1 and B2) were characterized by lower alkalinity, conductivity, turbidity, pH, total dissolved solids (TDS) and trace nutrient (Ca, Mg, Na, K, Cl, SO₄) concentrations relative to other parts of the system.
- Kugaluk Channel had higher water color, turbidity, total suspended solids
 (TSS), particulate organic carbon (POC) and nitrogen (PON), dissolved organic
 carbon (DOC) and total phosphorous concentrations compared to other parts of
 the estuary, reflecting the importance of riverine inputs in the channel and its
 potential contribution to primary productivity near the mouth of the
 estuary.
- Organic contaminant concentrations determined for surface water samples from Husky Lakes (n=2) were all below the detection limit.
- Salinity was the most contrasting water property in the estuary ranging 0.4-17.4 ppt at the surface (Figure 5).
- Average salinity values in surface water showed a progressive increase from 1.3 ppt in B1 to 12.9 ppt in OF. The inland-most basins (B1 and B2) and parts of KG were characterized by oligohaline water (salinities < 5.0 ppt) while other parts of the estuary were mesohaline (salinities between 5-18 ppt) (Figure 5).
- Surface water temperature averaged 9.6°C in Husky Lakes with a higher mean temperature in B1 (13.3°C) relative to other parts of the system (exception of B2) (Figure 6).

- Surface water temperature in Kugaluk Channel ranged 8-16°C with a mean of 13°C.
- Vertical temperature and salinity profiles underlined the prevalence of mixing conditions throughout the estuary (Figure 7).
- Intense mixing (as indicated by relatively constant temperature and salinity measurements with increasing depth) was observed in IF and OF and to a lesser extent in KG and at station 13 in B5 (Figure 7).
- Temperature stratification of the water column was observed in most basins with the occurrence of a mixed layer in B1 and B2 and at station 11 in B4. Mixed layer thickness ranged 3-7 m depending on station (Figure 7 (A,B and D)).
- Salinity stratification of the water column was only visible at one site (station 6 in B2 (Figure 7 (B)).
- A cooler (0-1°C) bottom layer was observed in OF, B5 (station 13), B2 (stations 3, 5-6) and B1.
- A lower salinity layer near the bottom was observed in OF (station 18), B5 (station 13), B4 (stations 9-10), B2 (station 6) and B1 (Figure 7).

Highlights – Fish abundance and catch composition.

- A total of 564 test nets were set in Husky Lakes, 21 nets were set in Kugaluk Channel and 55 nets were set in Sitidgi Lake during the study period.
- Fish abundance as CPUE (Catch Per Unit Effort number of fish caught per 100 m² experimental net per hour) was highest in Kugaluk Channel with an average of 62 fish per net hour compared to 7 fish per net hour in all of Husky Lakes and 2 fish per net hour in Sitidgi Lake.

- Within Husky Lakes, fish abundance was higher in OF (9 fish per net hour) relative to B3, B5 and IF (4-5 fish per net hour) and higher in B2 (8 fish per net hour) relative to IF (4 fish per net hour).
- A total of 6 108 fish from 8 families and more than 17 species were caught in Husky Lakes and Kugaluk Channel. Catch per species included Arctic Cisco (Coregonus autumnalis (Pallas)) (n=647), Least Cisco (Coregonus sardinella (Valenciennes)) (n=1071), Lake Whitefish (Coregonus clupeaformis (Mitchill)) (n=1476), Round Whitefish (Prosopium cylindraceum (Pallas)) (n=13), Broad Whitefish (Coregonus nasus (Pallas)) (n=109), Inconnu (Stenodus leucichthys (Güldenstädt)) (n=44), Arctic Grayling (Thymallus arcticus (Pallas)) (n=48), Lake Trout (Salvelinus namaycush (Walbaum)) (n=141), Longnose Sucker (Catostomus catostomus (Foster)) (n=2), Northern Pike (Esox lucius (Linnaeus)) (n=97), Burbot (Lota lota (Linnaeus)) (n=1), Fourhorn Sculpin (Myoxocephalus quadricornis (Linnaeus)) (n=87), Rainbow Smelt (Osmerus mordax (Mitchill)) (n=60), Pacific Herring (Clupea pallasi (Valenciennes)) (n=1510), Arctic Flounder (Liopsetta glacialis (Pallas)) (n=163), Starry Flounder (Platichthys stellatus (Pallas)) (n=536) and Cod (Gadidae sp.) (n=103).
- A total of 115 fish from 8 species were caught in Sitidgi Lake. Catch by species included Arctic Cisco (*C. autumnalis*) (n=1), Least Cisco (*C. sardinella*) (n=5), Lake Whitefish (*C. clupeaformis*) (n=41), Round Whitefish (*P. cylindraceum*) (n=6), Broad Whitefish (*C. nasus*) (n=4), Lake Trout (*S. namaycush*) (n=37), Northern Pike (*E. lucius*) (n=20) and Burbot (*L. lota*) (n=1).
- Catch composition in Kugaluk Channel was characterized by a strong dominance of Pacific Herring with an average CPUE of 35 Herring per net hour representing 56% of total CPUE from all species (CPUE_T) in this part of the system. Second in importance were Starry Flounder and Arctic Flounder, each explaining 17% and 8% of CPUE_T.
- In Husky Lakes, the catch was dominated by Lake Whitefish and Least
 Cisco which accounted for 30% and 25% of CPUE_T, respectively. Second in

importance were Arctic Cisco (14% of CPUE_T) and Pacific Herring (13% of CPUE_T).

In Sitidgi Lake, the catch was dominated by Lake Whitefish and Lake Trout
with average CPUEs of 0.78 Lake Whitefish and 0.65 Lake Trout per net
hour explaining 38% and 31% of CPUE_T, respectively. Second in
importance was Northern Pike which accounted for 16% of CPUE_T in the
lake.

Highlights – Lake Trout abundance and spatial distribution*

- Lake Trout was caught in Sitidgi Lake and in B1, B2, B3 and IF in Husky Lakes (Figure 8).
- Lake Trout abundance was relatively low in individual test nets with a maximum of 4 Lake Trout per net hour recorded in Husky Lakes.
- Average Lake Trout abundance was lower in the inner fingers (IF) area of Husky Lakes (0.17 Trout per net hour) relative to Sitdgi Lake (0.65 Trout per net hour) and B2 (0.59 Trout per net hour) (Figure 9).
- Spatial distribution and relative abundance information indicated that Lake
 Trout mainly occurred at salinities ranging from 0-5 ppt (in Sitidgi Lake, B1
 and B2) but remained present (though in lower abundance) at intermediate
 salinity levels (7-13 ppt) in IF.

The results suggest that any activity affecting freshwater budget in inland-most basins of Husky Lakes (namely B1 and B2) will have consequences for Lake Trout distribution and abundance in the system.

^{*}The spatial distribution and relative abundance of individual fish species caught in Husky Lakes and Sitidgi Lake was similarly evaluated and discussed in the full report.

Highlights – Fish assemblage structure, species occurrence and diversity.

- Salmonidae was the most diverse and abundant family in Husky Lakes with 8 species accounting for 82% of IRI (Index of Relative Importance) and 60% of net CPUE (CPUE from all species not including nets with zero catch).
- Together, four coregonids (Lake Whitefish, Least and Arctic Cisco and Broad Whitefish) accounted for 56% of net CPUE.
- Occurrence (as based on %IRI) identified Lake Whitefish, Least Cisco and Pacific Herring as the dominant species in Husky Lakes and Kugaluk Channel.
 Common species were Arctic Cisco and Starry Flounder. Other species (n = 12) had only occasional or rare occurrences.
- There was a spatial transition in species dominance from Lake Whitefish
 (in B1, B2 and B3) to co-dominance of Lake Whitefish and Pacific Herring
 (in IF) and Lake Whitefish, Pacific Herring, Ciscos (both Least and Arctic)
 and Starry Flounder (in B4). Ciscos and Pacific Herring were co-dominant
 in B5. Least Cisco was dominant in OF. Pacific Herring was the dominant
 species in KG.
- Richness (as the average number of different fish species in the catch) was similar among basins, ranging from 10 to 13.
- Diversity indices ranged between 0.48-0.80 (Simpson's (D)) and 1.13-1.80 (Shannon-Weaver's (H')). A lower and higher diversity of fish characterized B2 and B4, respectively.
- Multivariate analyses demonstrated that the relative abundance of fish species in Husky Lakes was primarily determined by salinity (Figure 10).
 These results indicate that freshwater budget is key to fish assemblage structure and species occurrence in the estuary.

Highlights – Spring Fishery for Lake Trout

- A total of 921 Lake Trout harvested in the spring subsistence fishery were sampled for biological characteristics during the five-year monitoring programme.
- Sampled Lake Trout were harvested in Sitidgi Lake (SL) and in B1, B2, B3 and IF in Husky Lakes. Monitoring efforts targeted harvests from B2 and B3 in all years.
 B1 was monitored in 2001-2004 and SL was monitored in 2001 and 2004 only.
- Harvested Lake Trout on average measured 664 mm fork length, weighted
 3.7 kg and were 21 years of age.
- Minimum and maximum size at harvest was 223-1016 mm (fork length) and 0.2-11.5 kg, respectively.
- Larger and heavier Lake Trout were harvested from B3 relative to those harvested in B2 and/or B1 depending on year.
- Minimum age at capture was 8. Maximum age at capture was 55.
- Modal age was variable and a broad range of age classes (spanning 29 to 46 years) characterized annual harvest samples (Figure 11).
- The occurrence of older Lake Trout in the subsistence harvest was important. Lake Trout ≥ 30 years of age accounted for 5 to 15% of the catch on an annual basis and represented 10% of the entire harvest over the study period (Figure 11).
- Examination of stomach contents indicated that the diet of Lake Trout from Husky Lakes during spring and summer is dominated by Pacific Herring.
- Mercury (Hg) levels determined for 10 Lake Trout specimens harvested in the spring fishery averaged 0.18 ppm (range of 0.11-0.22 ppm), which is below the Canadian guideline limit for safe fish consumption (0.5 ppm).

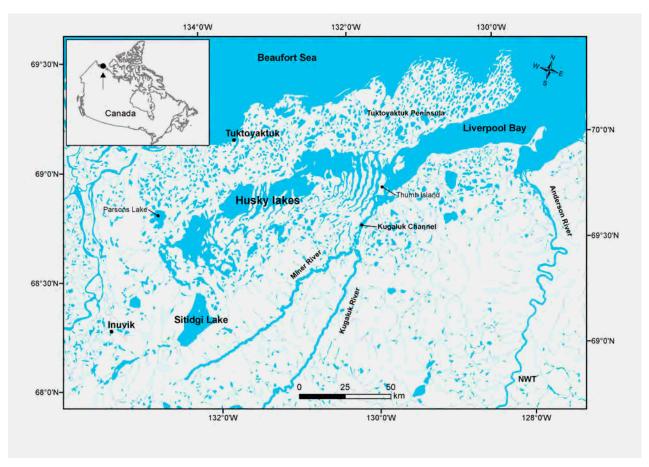


Figure 1. The Husky Lakes, Liverpool Bay and Sitidgi Lake Area.

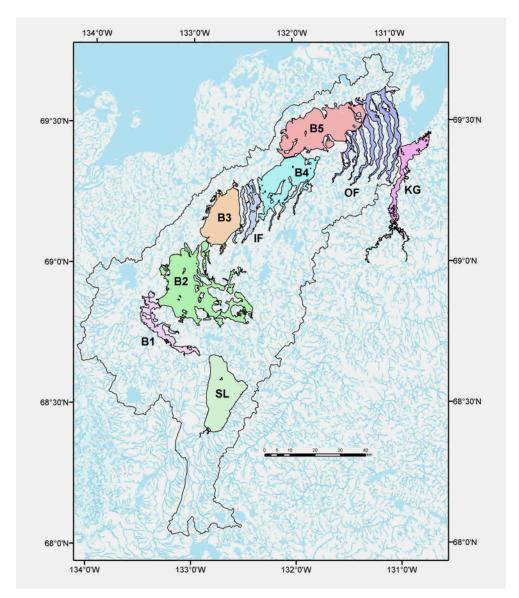


Figure 2. Basins subdivisions for Husky Lakes (B1-B5, Inner Fingers (IF), Outer Fingers (OF) and Kugaluk Channel (KG) in Liverpool Bay). SL = Sitidgi Lake. The contour line indicates catchment area boundary for Husky Lakes (not including KG).

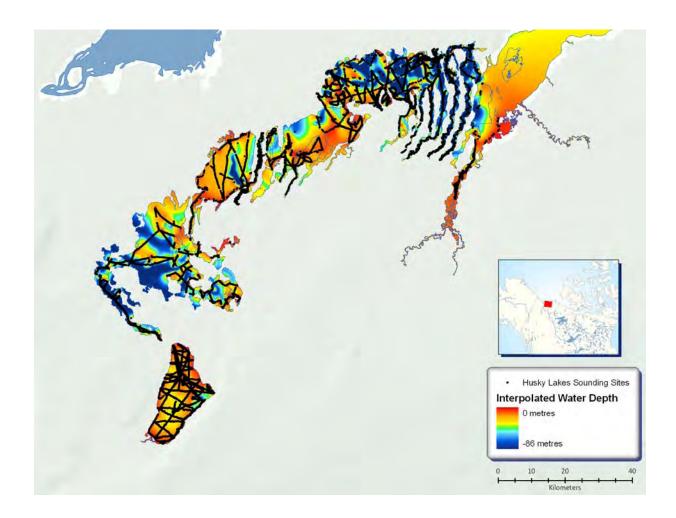


Figure 3. Bathymetric map of Husky Lakes and Sitidgi Lake showing emplacements of depth soundings. The bathymetric survey of Husky Lakes and Kugaluk Channel consisted in a total of 17 016 depth soundings. Spatial coverage was equivalent to 9 depth measurements per km² throughout the system but ranged between 2-20 measurements per km² among basins.

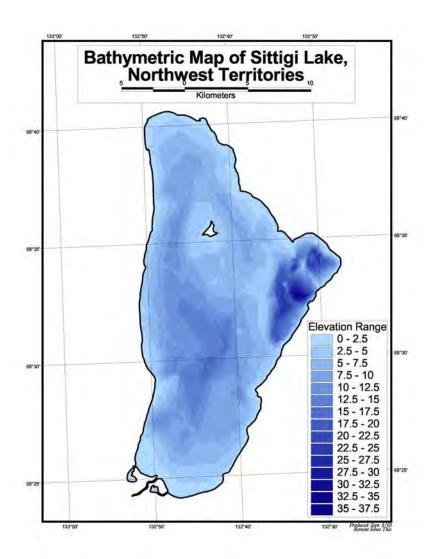


Figure 4. Bathymetric map of Sitidgi Lake.

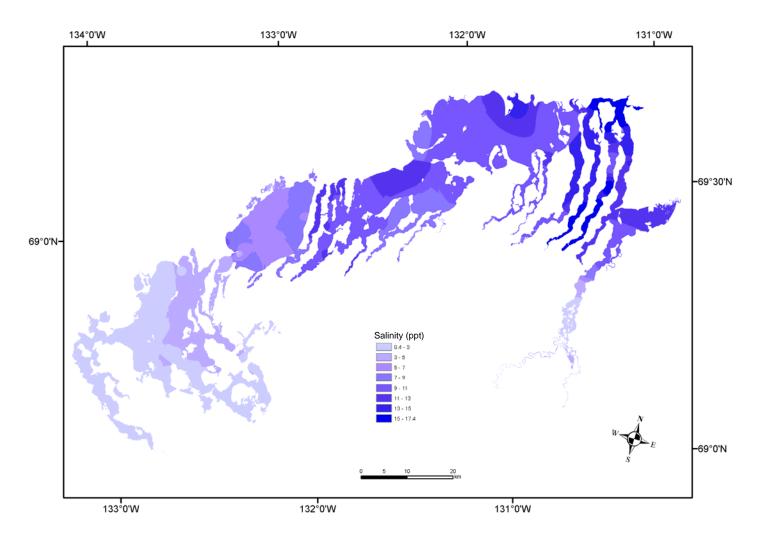


Figure 5. Interpolated surface water salinity (in parts per thousand (ppt)) for Husky Lakes and Kugaluk Channel in Liverpool Bay. Interpolation was conducted based on 196 *in-situ* measurements effectuated throughout the system.

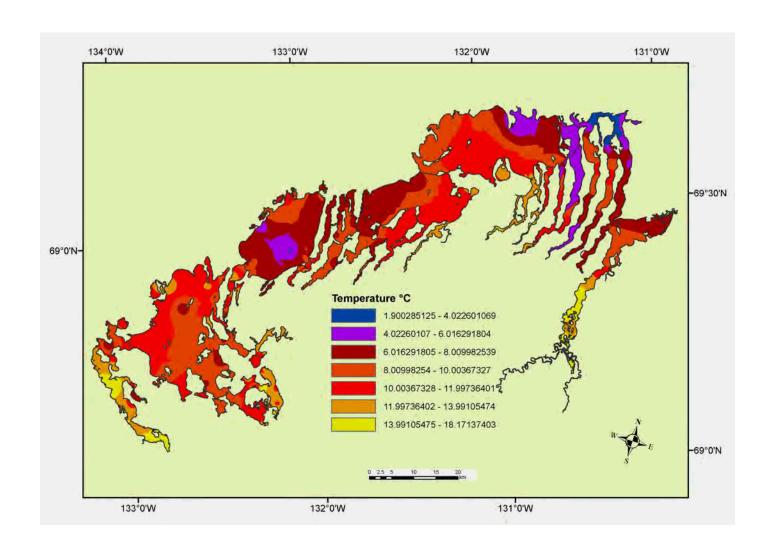


Figure 6. Interpolated surface water temperature in Husky Lakes and Kugaluk Channel during the open water season. Interpolation was conducted based on 196 *in-situ* measurements effectuated throughout the system in late July-early August of each year.

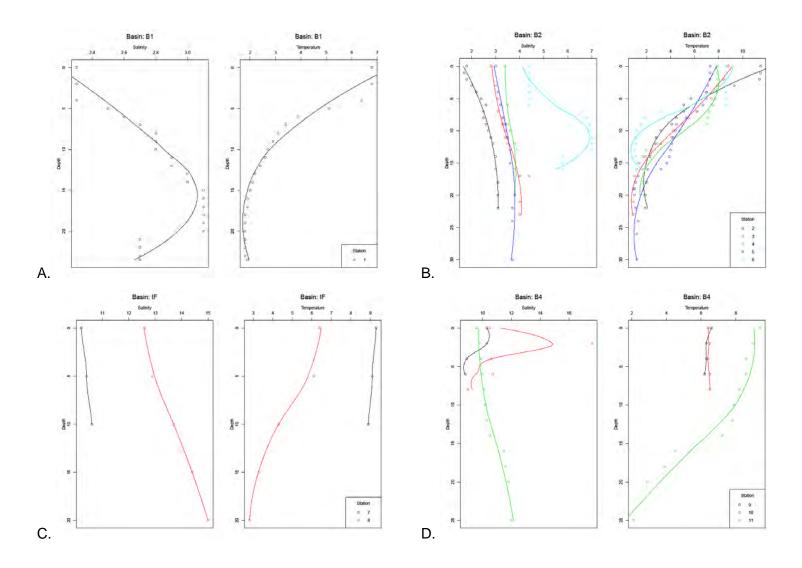


Figure 7. Temperature (°C) and salinity (ppt) profiles with depth by basin (A-G) and sampling stations (1-20).

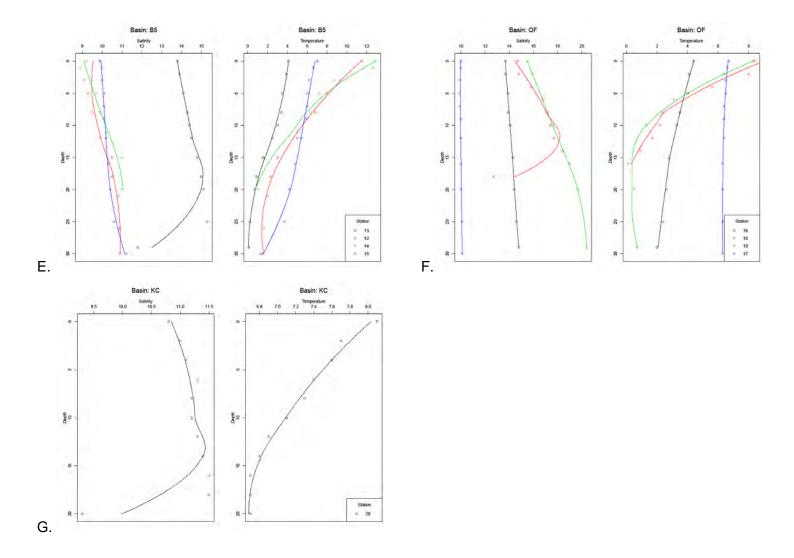


Figure7 (continued).

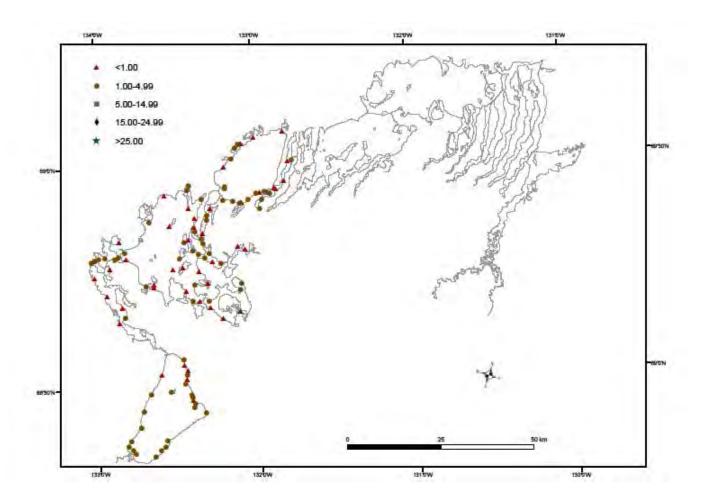


Figure 8. Lake Trout distribution and relative abundance as CPUE (no. of fish caught per 100 m² experimental net per hour (see legend)) in Husky Lakes and Sitidgi Lake.

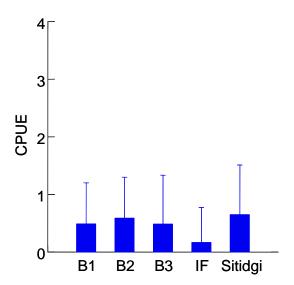


Figure 9. Average Lake Trout abundance as CPUE (no. of Trout per 100 m 2 net per hour) (mean \pm 1 SD) by location.

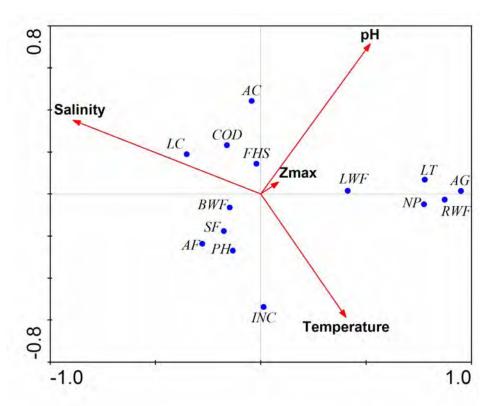


Figure 10. Canonical Correspondence Analysis (CCA) bi-plot for fish species relative abundance and environmental variables (arrows) in Husky Lakes and Kugaluk Channel. The eigenvalues of axis 1 (horizontal) and axis 2 (vertical) are 0.42 and 0.22, respectively. Arrows length and direction indicate the rate and direction of maximum change in the environmental variables. AC=Arctic Cisco; AF=Arctic Flounder; AG=Arctic Grayling; BWF=Broad Whitefish; COD=Cod sp.; FHS=Four Horn Sculpin; INC=Inconnu; LC=Least Cisco; LT=Lake Trout; LWF=Lake Whitefish; PH=Pacific Herring; NP=Northern Pike; RWF=Round Whitefish; SF=Starry Flounder.

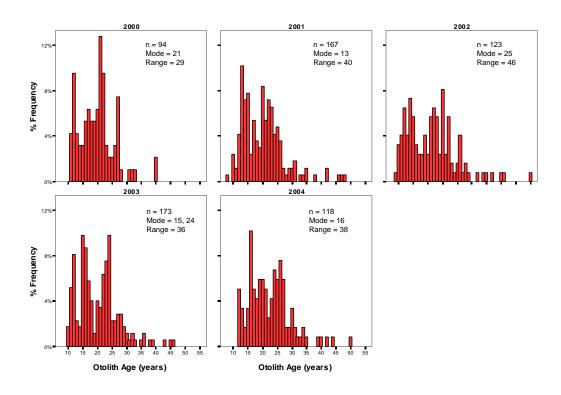


Figure 11. Annual age frequency distributions for Lake Trout harvested in the spring subsistence fishery in Husky Lakes and Sitidgi Lake, 2000-2004.