Fisheries and Oceans Canada | Pêches et Océans Canada

Fish Habitat Management
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Gestion de l'Habitat du Poisson
Suite 301 5204, 50e Avenue
Yellowknife (Territoires du Nord-Ouest)
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June 8, 2012

Via e-mail to:
nspencer@reviewboard.ca

Mackenzie Valley Environmental Impact Review Board
#200 Scotia Center
5102-50th Ave
Yellowknife, NT
X1A 2N7

RE: DFO Information Request for the Tyhee NWT Corp. Yellowknife Gold project (EA0809-003)

Fisheries and Oceans Canada (DFO) is pleased to provide the Mackenzie Valley Environmental Impact Review Board (MVEIRB) with information requests based on our review of Tyhee NWT Corp.'s Developer's Assessment Report for the Yellowknife Gold project. DFO's information requests can be found in the attached document.

On May 31st 2012, Tyhee submitted new information in response to the MVEIRB additional information requests. The topics included:

- IR 1-1-1 Estimation of Tailings Containment Area Concentrations
- IR 1-1-2 Cyanide Attenuation with attached references
- IR 1-1-3 Effluent Treatment Options
- IR 1-1-4 Water Quality Monitoring and Adaptive Management
- IR 1-1-5 Water Quality Issues Related to Existing Impacts from Discovery Mine (Cumulative Effects) with attached figure

DFO did not have sufficient time to review and consider this new information in the development of this information request submission.

If you have any questions or comments, please contact Sarah Olivier at (867) 669-4919 or e-mail (sarah.olivier@dfo-mpo.gc.ca).

Sincerely,

Larry Dow
A/Area Director
Fisheries and Oceans Canada

cc Kelly Burke, Fisheries and Oceans Canada
Bev Ross, Fisheries and Oceans Canada
Lorraine Sawdon, Fisheries and Oceans Canada
Corrinne Gibson, Fisheries and Oceans Canada

Tyhee NWT Corp. Yellowknife Gold Project
Fisheries and Oceans Canada Information Requests

IR #: DFO_1
Subject: Tailings Alternative Assessment
Section: DAR, Appendix L – Tailings Alternatives Assessment
Preamble/Rationale:
Tyhee is proposing to deposit mine tailings into Winter Lake which is a fish frequented waterbody. As required under the Metal Mining Effluent Regulations (MMER), a Tailings Alternative Assessment must be conducted that objectively and rigorously assesses all feasible options for tailings disposal and demonstrates through the Environmental Assessment that this option is the most appropriate option from an environmental, technical and socio-economical perspective.

The current Tailings Alternatives Assessment (TAA) was conducted prior to the completion of a feasibility study. Sub-Indicators considered for the economic assessment included the evaluation of relative costs based on volume of dam fill, length of tailings distribution pipeline, length of water reclaim pipeline, tailings cover at closure and process requirements for dewatering. It is clearly stated that risks, operational and sustaining costs, water treatment, monitoring, dam raises, gold production schedule, fish habitat compensation and monitoring were not included in the assessment.

Tyhee has indicated that the use of the Northern Portion of Winter Lake is temporary. Considering that the estimated refill period for the northern portion is 50-500 years, and Tyhee is proposing that the southern portion of Winter Lake permanently contain mine tailings, DFO disagrees with this conclusion.

Request:

1. The tables included in Appendix L are blurry, please provide legible copies.

2. The TAA should be updated to include the following:
    a. The estimated cost of habitat compensation and monitoring required under the *Fisheries Act* and *Metal Mining Effluent Regulations* Schedule II;
    b. Inclusion of a water treatment plant;
    c. Cost of monitoring during construction, operations and closure.

3. Some of the criteria used in the TAA favour the selection of lakes as a tailings containment area, such as on-land footprint area, potential for generating dust during operations and potential for acid rock drainage (ARD). If these criteria are used, a full life-cycle analysis (including post closure) must to be considered. For example, there is a potential for dust generation at closure from the TCA. Furthermore on-land footprint may not be an appropriate selection criterion, especially if in-water footprint area is not included.

Please provide an updated TAA with full-life cycle analysis of each criterion, including consideration of in-water footprint.

IR # : DFO_2
Subject: Tailings Containment Area (TCA)
Section: DAR 4.12.3; 4.12.4; 4.13.1; Tables 6.2-2; 6.2.1.1; 6.3.3.2; 6.8.1.4; 8.4; 11.0 and March 28, 2012 Tyhee NWT Corporation's letter to MVEIRB
Preamble/Rationale:
Tyhee is proposing to construct a Tailing Containment Facility within Winter Lake, where there is known seasonal rearing and foraging habitat for Northern Pike. Winter Lake flows into Narrow Lake, which also contains habitat for several fish species, via a small stream in the northwest basin of Winter Lake. Limited information has been provided about the construction, operations, maintenance, closure and monitoring of the TCA. Discharge from TCA is stated to mimic the natural hydrograph, from July to September.

In a letter on March 28th, 2012 to the MVEIRB, Tyhee listed project changes that would enhance the economics and lesson the environmental effects of the Yellowknife Gold Project (YGP). The operational changes proposed include the removal of Nicholas Lake deposit from the proposed mine plan; the redesign of the TCA to better manage the tailings; the relocation of the waste rock piles from Round Lake (removing it from the watershed) to an area between Winter Lake and Narrow Lake.

Request:

1. Provide details on potential seepage pathway from the TCA to the receiving environment (including potential groundwater interactions).

2. Figure 1 – Revised Site Infrastructure does not show sumps or other types of seepage collection from the TCA. Based on the preliminary designs for the TCA and potential discharge pathways, please indicate in a figure the locations of sumps, and indicate how Tyhee will ensure that seepage is properly contained and does not enter the receiving environment.

3. A Small lake to the South West of Winter Lake will be separated from Winter Lake by the South West Saddle dam constructed for the development of the TCA. Figure 1 – Revised Site Infrastructure, provided on March 28, 2012, indicates that the Waste Rock Pile will be located near Narrow Lake and infill that waterbody.
    a. DFO requires the bathymetry, surface area, depth, connectivity of this waterbody with a discussion of whether the lake can support fish and fish habitat;

    If the lake can potentially support fish, please provide the following:
    b. Description of activities in and around the lake (including the riparian areas);
    c. Assessment of fish use and fish habitat;
    d. Effects of proposed activities during construction, operations and closure.

4. Quantify how Round Lake and Winter Lake contribute to the water levels in Narrow Lake, as well as its available habitat and downstream discharge. Describe the predicted effects to fish and fish habitat as a result of permanently destroying two lakes upstream of Narrow Lake.

5. Based on the recent changes made to the mine plan, please provide a conceptual aquatic effects monitoring plan and a closure and reclamation plan.

6. To assess impacts that may occur during the construction of the TCA, please provide the following information:
   a. Quantify the Harmful Alteration, Disruption and Destruction (HADD) of fish habitat to waterbodies including Winter Lake, Winter Lake Outlet, the stream to Narrow Lake, Narrow Lake, and if appropriate the small lake to the southwest of Winter Lake as a result of the proposed TCA or any other components of the project that could impact fish and fish habitat. This information is required by DFO.
   b. Describe how the northern portion of Winter Lake will be isolated during the construction of the west dam and what mitigation measures will be implemented to reduce impacts to fish and fish habitat. Please also include plans for fish salvage to be undertaken prior to construction in both the northern and southern portions of Winter Lake. Please see Appendix II for DFO's Fish-out Protocol.

7. During operation of the TCA, please provide the following:
   a. DFO understands that the West Dam will initially be permeable and that over time, due to clogging of the rock dam with tailings (pg 540 of DAR), it is predicted to become impermeable. Please describe the mitigation measures Tyhee will implement to ensure that escaped tailings and water of poor quality through the rock dam will not impact Winter Lake Outlet, the connecting stream and Narrow Lake?
   b. Provide predicted changes in dissolve oxygen and nutrient levels in Narrow Lake. What is the likelihood that these changes could impacts the aquatic communities in Narrow Lake (and downstream) or cause winter fish kills? How could water treatment assist in mitigating these types of impacts?
   c. It is stated that "discharges from the TCA to the Narrow Lake Inlet stream will be regulated to simulate, within practical limits, background flow volumes and the seasonal cycle." DFO understands that with the exception of May and June, discharge from TCA (if regulatory requirements are met) will mimic the natural hydrograph. The hydrograph data for May, June, and September are currently incomplete for the mean monthly discharge ranges from Winter Lake and Narrow Lakes. Please provide the following:
      i. Data for the incomplete months (May, June and September) and considered as part of the discharge plan and capacity calculations for the TCA.
      ii. Identify the extent to which flows within the Winter Lake Outlet and Narrow Lake Inlet will be altered, and the loss of habitat associated with the change in flows.
      iii. What measures will be implemented to minimize downstream effects (e.g. increased sedimentation and erosion, loss of habitat) in the stream between Narrow Lake and Winter Lake, and Narrow Lake?
      iv. Provide a graph that includes the estimated discharge release from the TCA and all baseline discharge (Fig 2.8-4) for the stream between Narrow

Lake and Winter Lake. What measures will be taken to reduce or eliminate the need to discharge at rates above the natural hydrograph?

v. Define the term “within practical limits”. Should it be determined that it is not practical to simulate the natural flow regime, due to limitations of the TCA design, what is the proposed discharge regime? Describe the predicted impacts to fish and fish habitat of the worse case scenario and provide appropriate mitigation measures.

vi. Should discharge from the TCA not meet the water quality discharge requirements, Tyhee proposes to stop all downstream discharge until such time that the discharge will meet water quality requirements. Should discharge be halted and flows reduced or eliminated, provide anticipated impacts to fish and fish habitat within the stream between Narrow Lake and Winter Lake as well as contingencies to mitigate these potential impacts to fish and fish habitat.

vii. Please provide a conceptual monitoring plan for identifying potential mine-related effects of changes in flow to fish and fish habitat in the receiving environment.

viii. Provide an assessment of potential impacts associated with the discharge regime to fish and fish habitat within the Narrow Lake Inlet stream and downstream watershed. The assessment must consider all fish species at all life stages within the receiving environment including worse case scenarios based on the highest and lowest predicted flows as well as potential erosion of the bed and banks.

8. Periodic releases through a diffuser are required to manage the water levels within the TCA. Please provide:
   a. Location of the diffuser;
   b. Conceptual design of diffuser including dimensions;
   c. Velocities expected to be released from the diffuser;
   d. Mitigation measures to prevent sediment and erosion of the stream between Narrow Lake and Winter Lake.

9. At closure, provide plans with respect to the northern basin of Winter Lake (Ormsby Pit), including:
   a. Final depth of Ormsby pit.
   b. Prediction of the stability of pit walls after closure.
   c. On page 445 of the DAR, Tyhee states that it will take between 50 and 500 years for groundwater to refill Ormsby pit to pre-mine elevations.
      i. Has surface water runoff also be considered in the refill time?
      ii. What criteria will be used to ensure that the basin is suitable for reconnection to the downstream environment? Are meromictic conditions expected?
      iii. Tyhee has proposed to monitor for only 2 to 5 years after closure, despite the estimated 50 to 500 years for Ormsby Pit to refill. Please provide post-closure monitoring plans, with appropriate timeframes, that can demonstrate the success of final reclamation prior to reconnection with the downstream watershed, assuming water quality meets discharge criteria.

iv. Please provide alternative methods/actions to expedite the filling of Ormsby Pit.
v. What are the predicted fish habitat conditions within the Pit (southern portion of Winter Lake) and downstream environment at closure and proposed reconnection?

IR #: DFO_3
Subject: Effects Assessment
Section: 6.1**,** Table 6.1-2, Table 6.3-2, Table 6.3-3, Table 6.3-4
Preamble/Rationale:
In order to properly assess the extent and significance of impacts of a project on the biophysical environment, the EIS must consider positive and negative changes and the interactions of each project activity, or a combination of activities, on a appropriately selected Valued Ecosystem Components (VECs).

Request:

1. In Tyhee's letter to the MVEIRB on March 28th, various changes were made to the mine design that could influence the Effects Analysis. DFO requests that the Effects Analysis be updated to incorporate these changes.

2. The definitions provided in Table 6-1.1 appear to be inappropriate and incomplete. For example, a low magnitude effect for Reversibility was defined as an "effect [that] can be reversed within 100 years" while a Moderate magnitude was defined as an "effect [that] cannot be reversed". A High magnitude effect for Reversibility was not provided. DFO requests that Tyhee revisit the criteria for the Effects Assessment and ensure the definitions are appropriate for the scale of the impact. Consideration should be given to biological time frames such as the reproductive cycles of aquatic species include forage species (invertebrates, forage fish).

3. In Table 6.1-1, under the Consequence column, mine management actions are provided. Monitoring activities are required during all stages of a project to determine if predictions made in the Environmental Assessment are accurate, if mine-related effects are occurring, if follow up and adaptive management actions are required, and to ensure compliance with regulatory instruments. DFO requests that table 6-1.1 be revised accordingly.

4. Table 6.1-2 indicates which VECs were considered in the Effects Analysis. Aquatic ecosystem VECs were neither provided nor assessed within the Effects Assessment. Please provide:
    a. Appropriate VECs for the aquatic ecosystem (plankton, benthic invertebrates, small bodied fish (e.g. Slimy sculpin) a large bodied fish, (e.g. Northern Pike), and fish habitat).
    b. Rationale for why and how they were selected.

Aquatic VECs must be included in an Effects Analysis in order to determine whether the project will have significant adverse environmental effects to the

aquatic environment, including on fish and fish habitat. Please include VECs of ecological and fisheries importance in addition to those selected based on COSEWIC classification.

5. Table 6.3-2 provides potential project-aquatic environment interactions. It is stated that "Species at Risk is not indicated as an environmental component since no aquatic species at risk have been identified within the effect footprint of the Tyhee Project" (pg 451).

   Even though Species at Risk are not present within the local study area, an assessment of effects to fish and fish habitat within and downstream of the project area is required. Appropriate VECs must be selected.

6. Table 6.3-3 provides the Project Activities, Effects, Mitigation Measures and Residual Effects on the Aquatic Environment.
   a. The table does not consider the effects from accidents and malfunctions associated with potential overflow or failure of the TCA or dam failure to fish and fish habitat, and spills are considered unlikely to occur within the vicinity of natural watercourses. Provide the effects assessment of these accidents and malfunctions and potential effects to fish and fish habitat. Mitigation measures and the residual effects must be considered.
   b. Mitigation measures are required to ensure that any impacts or losses of fish habitat are minimized to the greatest extent possible. Please provide planned mitigation measures to minimize impacts and losses to fish habitat.
   c. Under Blasting Effects, Tyhee has committed to "strict adherence to DFO Blasting Guidelines". DFO cautions that recent research results have shown that a more precautionary approach may be warranted, particularly in the north, to protect fish from the effects of blasting. DFO recommend that an instantaneous pressure change guideline of less than or equal to 50 KPA in the waterbody/watercourse be followed. Other mitigation should also be employed including using a series of smaller blasts, timing, and fish exclusion measures if necessary. Two useful references are:
      i. **Offshore Oil and Gas Environmental Effects Monitoring: Approaches and Technologies**. Edited by Armsworthy, Shelley, Peter J. Cranford, Kenneth Lee. Cott, P., B. Hanna. 2005.
      ii. **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.
   d. Under the Surface Water Quantity in Table 6.3-3, elevated discharge rates from the TCA to the Narrow Lake Inlet are planned annually in May and June. However, effects to spring spawning fish that may use this habitat have not been considered, nor have impacts from increased sediment and erosion been evaluated. Provision of this assessment is required.
   e. Tyhee has not considered impacts to fish and fish habitat as a result of discharge quantity and quality from the TCA at spring freshet. Increased flow could result in increased erosion of channel and lake beds and banks, and increased sedimentation, impacting habitat use (e.g. spawning, rearing and foraging) and

affecting the survival of eggs, larval fish and juveniles. It is requested that this assessment be provided.

7. Table 6.3-4 provides the residual effects analysis.
    a. The consequence column appears to only include magnitude and duration. How are other criteria (geographic extent, duration, frequency, reversibility and likelihood) considered in the determination of consequence? Fish health and fish recruitment must be considered for all consequences criteria.
    b. The magnitudes provided for rows 2-4 in the Table are contradictory to the definitions of magnitude provided in Table 6.1-1. The effects associated with the elimination of natural downstream flows from Winter Lake to Narrow Lake (second row), the loss of habitat in Winter lake (row 3), and the loss and modification of flows from Winter Lake Outlet (row 4) have been determined to be “low” in magnitude. The permanent or long term alteration of flows and loss of habitat in these areas are not “within the range of baseline conditions or natural variation” and should not be low in magnitude. Tables 6.3-4 and table 6.1-1 do not appear to be applying the same definitions of criteria.
        i. Please provide revised tables that address this inconsistency.
        ii. Revised tables should also include the criteria and definitions as requested in DFO IR # DFO_3-2 above.

IR # DFO_4
Subject: Fish Habitat
Section: 6.2; 6.3.1.1
Preamble/Rationale:
The proposed development has the potential to impact fish and fish habitat. Effects to fish and fish habitat were not assessed in detail, and were largely excluded from the Effects Assessment provided in section 6.0. DFO requires the following additional information:

Request:
1. It is predicted that bottom temperatures in Narrow Lake will increase over the life of the mine. Water temperature affects both spatial habitat availability and dissolved oxygen content.
    a. Provide potential effects of the predicted temperature increase to fish species. This should incorporate the duration, magnitude, frequency, reversibility, etc. of the predicted increase in temperature to fish populations, recruitment, over-wintering, thermal refugia,
    b. Model the fluctuations in dissolved oxygen (mg/L) anticipated, as a result of changing temperatures in Narrow Lake. Compare these to baseline data obtained.
    c. Provide modelled temperatures and dissolved oxygen concentrations for Narrow Lake, from pre-mine conditions to post-closure of the development.
    d. Please identify measures that would mitigate any adverse effects from increases in water temperature due to the project and monitoring to determine the success of any necessary mitigation.

2. Provide a detailed analysis of the fish habitat (spawning, nursery, rearing, foraging, over-wintering, migratory) conditions predicted in Narrow Lake throughout construction, operations, closure and post closure, including the 50-500 years that it is estimated for Ormsby pit to re-fill.
    a. Provide estimates of the amount of time it will take for the habitat conditions in Narrow Lake to return to baseline conditions, and any anticipated impacts from Ormsby pit re-filling and reconnecting flow to the downstream environment. The assessment should include changes to benthic and fish communities and fish and fish habitat.
    b. Provide the same analysis with the implementation and use of a water treatment plant.

IR # DFO_5
Subject: Fish Habitat Compensation (No Net Loss Plan)
Section: 6.3.3.2
Preamble/Rationale:
The proposed development includes eliminating Winter Lake from the aquatic ecosystem. A portion of the Winter Lake Outlet/Narrow Lake Inlet will be lost, and Narrow Lake may have reduced fish habitat as a result of the proposed development. If this project receives a positive Environmental Assessment decision, Winter Lake will require scheduling under MMER, and require a compensation plan that is acceptable to the Minister of Fisheries and Oceans. For Winter Lake Outlet/Narrow Lake Inlet and Narrow Lake a separate compensation plan would also be required.

Request:
1. Please quantify any HADDs within the stream connecting Winter Lake and Narrow Lake Inlet as well as in Narrow Lake.

2. DFO requires that the fish habitat losses that would result from the destruction of Winter Lake for use for tailings management be quantified. As required under section 27(3) of the Metal Mining Effluent Regulations, a Compensation Plan shall contain:
    c. A description of the location of the tailings impoundment area and the fish habitat affected by the deposit;
    d. A quantitative impact assessment of the deposit on the fish habitat
    e. A description of the measures to be taken to offset the loss of fish habitat caused by the deposit;
    f. A description of the measures to be taken during the planning and implementation of the compensation plan to mitigate any potential adverse effect on the fish habitat that could result from the plan's implementation;
    g. A description of measures to be taken to monitor the plan's implementation
    h. A description of the measures to be taken to verify the extent to which the plan's purposed has been achieved;
    i. A description of the time schedule for the plan's implementation, which time schedule shall provide for achievement of the plan's purpose within a reasonable time; and
    j. An estimate of cost of implementing each element of the plans.

3. As part of the compensation plan(s), the following also must be provided:
    a. Detailed methodology on how the habitat loss is quantified, and how habitat gains from the proposed habitat compensation option(s) are achieved.
    b. Conceptual habitat compensation options, with detailed explanations as to how the productive capacity for fish is increased.

IR # DFO_6
Subject: Cumulative Effects
Section: 10.4.1.2: Surface Water Quality and Aquatic Resources
Preamble/Rationale:
Tyhee has conducted their cumulative effects assessment for the residual effects identified in section 6.0. As DFO mentioned above, the Effects Analysis, including residual effects analysis, does not consider potential effects to the aquatic biota.

Request:
1. Based on the updated Effects Assessment, provide an updated cumulative effects assessment that includes impacts to fish and fish habitat.

IR # DFO_7
Subject: Fisheries and Aquatic Ecosystem Baseline Studies
Section: Tables 2.11-3A to 2.11-3E
Preamble/Rationale:
Appendix D of the DAR provided the results from Tyhee's Fisheries and Aquatic Resource Studies conducted in 2004 and 2005. Baseline data is the benchmark used for assessing potential effects of the project on the environment and to measure the success of mitigation measures likely through monitoring programs such as an Aquatic Effects Monitoring Programs. Tyhee will be required to do monitoring to verify impact predictions and, if required, adaptively manage any additional impacts.

Request:
1. Please identify any additional baseline studies for the aquatic ecosystem that have been undertaken since the 2004 and 2005 studies.

2. Tyhee has provided Habitat Suitability Ratings for five lakes: Round, Winter, Narrow, Nicholas and Brien. These suitability ratings are provided in Tables 2.11-3A to 2.11-3E.
    a. Please provide rationale for why the five species (Northern Pike, Lake Trout, Lake Whitefish, Arctic Grayling and Cisco) were used to determine the habitat suitability ratings for the five lakes. Indicate how small-bodied fish were considered in the habitat suitability rating assessments.
    b. The rating system used did not include nursery, rearing, foraging or migratory habitat for the five species tested against. Please update the habitat suitability ratings for each lake, incorporating assessments of these habitats.
    c. It is indicated on tables 2.11-3A to 3E that Winter Lake and Narrow Lake do not have an outlet or inlet, and these lakes each received a lower rating because of the lack of inlets/outlets. However, assessments of the stream between Winter and Narrow Lakes have been provided, including installation of fish traps within the stream (Appendix D, 2005 Fisheries and Aquatic Resources Report). Please

update the habitat suitability assessments of each lake, incorporating inlets and outlets for each.

d. When the habitat was rated for each of the five species listed above, it was assumed that the habitat suitability ratings were species specific. However, factors used to rate habitat (e.g. over-wintering habitat) were not species specific. The Habitat Suitability ratings assumed over-wintering habitat to be greater than 10 m in depth. However Cott et al. 2008 (Appendix III) demonstrated that Northern Pike were successfully over-wintering in an isolated lake (no inlets or outlets) that was 6m deep. It has been demonstrated that different species have different tolerances to low dissolved oxygen concentrations. While the Habitat Suitability Ratings considered adequate dissolved oxygen levels to be between 5.5-9.5 mg/L, Cott et al. 2008[*] demonstrated that Northern Pike were over-wintering in an isolated lake with a dissolved oxygen concentration of 4mg/L. Species specific tolerances do not appear to have been applied to the habitat suitability ratings. DFO requests that the species specific factors used to determine suitability of over-wintering habitat for the species be assessed, and the habitat suitability ratings be updated accordingly.

e. The Habitat Suitability Ratings gave one point for low winter oxygen levels and two points for high winter oxygen levels. However under the notes, only adequate oxygen levels were provided.
    i. Please provide the values for low and high oxygen levels used to assign points within the Habitat Suitability Rating.
    ii. Please provide the time of year that the values were obtained, the depth profile and number of samples sites for each lake.

f. Table 2.11-2 (pg 165 of the DAR) is not clear. Please clarify which species are found in the Yellowknife Gold Project Study Area, according to literature studies, and based on field investigations. Please identify where in the Study Area these species were found. It should be noted that the scientific name for Walleye is *Sander vitreus*.

g. The Fisheries and Aquatic Resources Report, in Appendix D, dated February 2005, identifies that benthic invertebrates were collected using a 583 µm mesh sieve. Please provide rationale for why this size of sieve was used, and describe the biases using the larger sized mesh may have introduced. Some guidelines, such as the Benthic Invertebrate Sampling Guidelines developed by the BC Ministry of the Environment, identify that 250 µm is appropriate.

h. Stomach content data can be used to determine the presence of small bodied fish and invertebrates. As indicated in Appendix D, the stomach contents of the northern pike consisted of invertebrates. Please provide all available stomach content data.

i. In Figure 7 of the 2005 Spring and Summer Fisheries and Aquatic Resources Report indicate the sampling locations within Winter Lake. The snorkel survey transects appear to be done in conjunction with exposed areas of the shoreline.

[*] Cott, P.A., P.K. Sibley, A.M. Gordon, R.A. Bodaly, K.H. Mills, W.M. Somers, and G.A. Fillatre. 2008. Effects of Water Withdrawal From ice-covered Lakes on Oxygen, Temperature, and Fish. Journal of American Water Resources Association. 44(2): 328-342.

Sheltered and vegetated bays and offshore areas do not appear to have been included in the snorkel survey. Please provide rationale for the sampling sites. The lake assessments provided in Appendix D included the use of minnow traps (2004), experimental monofillament Gill nets (2004), electrofishing of select shoreline of Winter Lake (2005) and snorkel surveys (12 transects, 50m long) in Winter Lake (2005). In DFO's northern experience, the use of minnow traps has often yielded surprisingly low catches, and rarely are all small bodied fish within the waterbody represented in the catches, in northern lakes. We request Tyhee conduct a standardized fish community assessment* in Winter Lake, Narrow Lake and an appropriate reference lake. Conducting these surveys should provide more information about the fish species, populations and communities that may be impacted by the proposed project, will collect adequate baseline data about fish population and community attributes that will inform the Environmental Assessment, and provide adequate baseline data for inclusion and comparison in future AEMPs should the project proceed to the regulatory phase.

*DFO recommends that one of the following protocols be implemented in the upcoming field season: NORDIC Indexed Netting - please see :
Sandstrom, S., M. Rawson, and N. Lester. 2011. Manual of Instructions for Broad-scale Fish Community Monitooring: using North American (NA1) and Ontario Small Mesh (ON2) Gillnets. Ontario Ministry of Natural Resources. Peterborough, Ontario. Version 2011.1 35 p.+ appendices. OR Broad-scale Fish Community Monitoring Program - please see: Morgan, G.E., and E. Snucins. 2005. Manual of Instructions NORDIC Index Netting. Ontario Ministry of Natural Resources. Peterborough, Ontario. 32 p. + appendices.

IR # DFO_8
Subject: Reference Lakes
Section: March 28, 2012 Tyhee NWT Corporation’s letter to MVEIRB
Preamble/Rationale:
In the March 28th submission, Brien Lake was identified as the reference lake for the mine. The use of this lake as a reference lake is limited as it is in the immediate footprint of the mine site and could be affected by mining operations. No other reference lakes have been identified, however other lakes have been assessed. AANDC’s “Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in the Northwest Territories” discuss considerations for choosing appropriate reference sites.

Request:

1. Given the potential for Brien to be impacted by mining operations, provide an assessment and ranking of the appropriateness of Brien Lake and the other lakes which have been assessed as potential reference lakes. Please identify additional lakes for reference purposes.

Appendix I – DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut.

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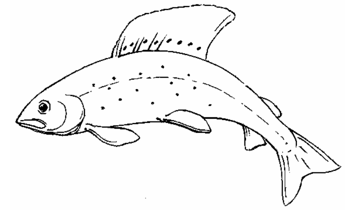


DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut

Rationale

In the Northwest Territories and Nunavut, winter activities such as access road construction, exploratory drilling and camp operations often require large amounts of water. Excessive amounts of water withdrawn from ice-covered waterbodies can impact fish through oxygen depletion, loss of over-wintering habitat and/or reductions in littoral habitat. The potential for such negative impacts to over-wintering fish and fish habitat has made winter water withdrawal a critical issue for Fisheries and Oceans Canada (DFO) in the Northwest Territories and Nunavut. To mitigate impacts to fish from water withdrawal from ice-covered waterbodies, and to provide standardized guidance to water users, including volume limits for certain water source types, DFO has developed this protocol in conjunction with industry and other regulators.

For the purposes of this protocol, a **waterbody** is defined as any water-filled basin that is potential fish habitat. A waterbody is defined by the ordinary high water mark of the basin, and excludes connecting watercourses.

This protocol will **not** apply to the following:

- Any waterbody that is exempted by DFO (e.g. Great Bear Lake, Great Slave Lake, Gordon Lake, and others as and when determined by DFO), and;
- Any waterbody from which less than 100m^3 is to be withdrawn over the course of one ice-covered period.

In order to establish a winter water withdrawal limit for a given waterbody, the following criteria must be adhered to:

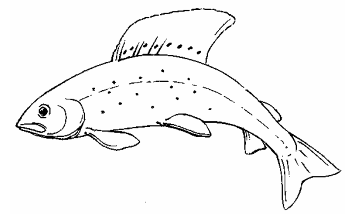
1. In one ice-covered season, total water withdrawal from a single waterbody is not to exceed 10% of the available water volume calculated using the appropriate maximum expected ice thickness provided in Table 1.
2. In cases where there are multiple users withdrawing water from a single waterbody, the total combined withdrawal volume is not to exceed 10% of the available water volume calculated using the appropriate maximum expected ice thickness provided in Table 1. Therefore, consistent and coordinated water source identification is essential.
3. Only waterbodies with maximum depths that are ≥1.5m than their corresponding maximum expected ice thickness should be considered for water withdrawal (Table 1). Waterbodies with less than 1.5m of free water beneath the maximum ice are considered to be particularly vulnerable to the effects of water withdrawal.
4. Any waterbody with a maximum expected ice thickness that is greater than, or equal to, its maximum depth (as determined from a bathymetric survey) is exempt from the 10% maximum withdrawal limit (Table 1).

To further mitigate the impacts of water withdrawal, water is to be removed from deep areas of waterbodies (>2m below the ice surface) wherever feasible, to avoid the removal of oxygenated surface waters that are critical to over-wintering fish. The littoral zone should be avoided as a water withdrawal location. Water intakes should also be properly screened with fine mesh of 2.54 mm (1/10") and have moderate intake velocities to prevent the entrainment of fish. Please refer to the *Freshwater Intake End-of-Pipe Fish Screen Guideline* (DFO, 1995) which is available upon request, or at the following internet address: www.dfo-mpo.gc.ca/Library/223669.pdf.

In order to determine the maximum water withdrawal volume from an ice-covered waterbody, and thereby conform to this protocol, the following information must be provided to DFO for review and concurrence prior to program commencement.

Water Source Identification

1. Proposed water sources, access routes, and crossing locations clearly identified on a map, with geographical coordinates (latitude/longitude and/or UTMs) included.
2. Any watercourse connectivity (permanently flowing and/or seasonal) between the proposed water source and any other waterbody or watercourse.



DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut

3. Aerial photos or satellite imagery of the water sources.
4. Estimated total water withdrawal requirement for work or activity and estimated total water withdrawal per water source (in m^3).

Bathymetric Survey Results

1. For all waterbodies: One longitudinal transect, connecting the two farthest shorelines, is to be conducted regardless of waterbody size. Note: a longitudinal transect may be straight or curved in order to accommodate the shape of a lake (see Figure 1).
2. For waterbodies equal to or less than 1 km in length: a minimum of one longitudinal transect and two perpendicular transects are to be conducted. Perpendicular transects should be evenly spaced on the longest longitudinal transect, dividing the lake into thirds (Figure 1).
3. For lakes greater than 1 km in length: a minimum of one longitudinal transect is to be conducted. Perpendicular transects (minimum of 2) should be evenly spaced on the longest longitudinal transect at maximum intervals of 500 m.
4. Additional transects should be run as required to include irregularities in waterbody shape such as fingers or bays (Figure 1).
5. All longitudinal and perpendicular transects are to be conducted using an accurate, continuous depth sounding methodology, such as open water echo sounding or ground penetrating radar (GPR), that provides a continuous depth recording from one shore to the farthest opposing shore (Figure 1). Any alternative technology should be reviewed by DFO prior to implementing for bathymetric surveys.

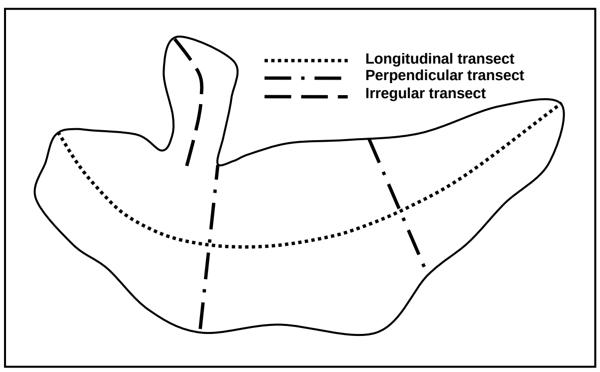
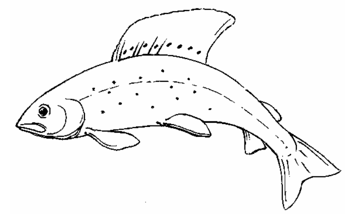


Figure 1. Minimum transect layout for a lake that is less than 1 km in length, with an irregularity.

Volume Calculations

1. Document the methods used to calculate surface area. If aerial photos or satellite imagery were used, provide the date (day/month/year) taken, as surface area may change depending on the time of year. If maps were used, provide the year that they were surveyed.
2. Detail the methods used to determine the total volume of free water, incorporating the relevant bathymetric information.
3. Calculate the available water volume under the ice using the appropriate maximum expected ice thickness, i.e. *Total Volume* $_{lake}$ – *Ice Volume* $_{max\ thickness}$ = *Available Water Volume* (see Table 1 for maximum ice thickness).
4. For programs where ice-chipping is used, the total ice volume to be removed from the waterbody should be converted to total liquid volume and incorporated into the estimate of total water withdrawal requirement per water source.



DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut

Table 1. Maximum expected ice thickness, and corresponding water depth requirements, for different regions in the Northwest Territories.

Area	Maximum Expected Ice Thickness (m)	Minimum Waterbody depth Required for 10% Water Withdrawal (m)
Above the Tree Line	2.0	≥3.5
Below the Tree Line - North of Fort Simpson	1.5	≥3.0
Deh Cho –South of Fort Simpson	1.0	≥2.5

A brief project summary report documenting and confirming total water volume used per water source and corresponding dates should be submitted to DFO within 60 days of project completion. Information should be provided in the following format (this information would also be useful as part of the project description):

Lake ID	number and/or name
Coordinates	latitude and longitude and/or UTM coordinates
Surface area	in ha
Total Lake Volume	in m^3
Under Ice Volume	in m^3 (based on max ice thickness for region)
Max expected ice thickness value used	in m
Calculated 10% Withdrawal volume	in m^3
Total required water volume extracted	in m^3
Aerial photographs of waterbody	PDF format
Bathymetric Map(s) of waterbody	PDF format

Any requests deviating from the above must be submitted to DFO and will be addressed on a site-specific basis.

Beaver and Muskrat

Many species of animals are highly sensitive to water fluctuations. In areas where beaver and muskrat may occur, the appropriate agencies or organizations should be consulted to determine if harmful effects will result from your activities, and whether these effects can be successfully mitigated through modifications to your plans including best management practices.

Please note that adherence to this protocol does not release the proponent of the responsibility for obtaining any permits, licenses or authorizations that may be required.

For more information contact DFO at (867) 669-4915.

Appendix II – General Fish-out Protocol for Lakes and Impoundments in the Northwest Territories and Nunavut

General Fish-out Protocol for Lakes and Impoundments in the Northwest Territories and Nunavut

J.D. Tyson, W.M. Tonn, S. Boss, and B.W. Hanna

Central and Arctic Region
Fisheries and Oceans Canada
Yellowknife, NT X1A 1E2

2011

Canadian Technical Report of Fisheries and Aquatic Sciences 2935

Fisheries and Oceans Canada   Pêches et Océans Canada

Canada

Canadian Technical Report of
Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report 925.

Technical reports are produced regionally but are numbered nationally. Request for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport technique canadien des
Sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques , de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés a titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur don't le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report of

Fisheries and Aquatic Sciences 2935

2011

General Fish-out Protocol for Lakes and Impoundments in the Northwest Territories and Nunavut

by

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ABSTRACT

Tyson, J.D., W.M. Tonn, S. Boss, and B.W. Hanna. 2011. General fish-out protocol for lakes and impoundments in the Northwest Territories and Nunavut. Can. Tech. Rep. Fish. Aquat. Sci. 2935: v + 34 p.

Some development activities in northern Canada will result in unavoidable whole or partial lake destruction. If such a development is approved by Fisheries and Oceans Canada (DFO), the requirement for a fish-out program is included as a component of the *Fisheries Act* s.35(2) authorization. The guiding principle of the fish-out program is to ensure that both the ecological data and fish specimens that are collected can be used to their fullest extent. This can be achieved by recovering and distributing fish to local communities and by properly collecting, recording, and archiving the data from the fish-out program. Whole lake studies, including fish-out programs, can provide exceptional data on fish populations and fish – environmental relationships in the North. This information is useful for assessing patterns and relationships between fish community composition and the habitat characteristics of barrenland lakes. A database has been created that includes information collected on fish species composition and biological, limnological, and habitat characteristics from the lakes that have been fished out in the Northwest Territories. The purpose of this document is to provide a consistent and standardized protocol for proponents to follow when developing a fish-out program.

RÉSUMÉ

Tyson, J.D., W.M. Tonn, S. Boss, and B.W. Hanna. 2011. General fish-out protocol for lakes and impoundments in the Northwest Territories and Nunavut. Can. Tech. Rep. Fish. Aquat. Sci. 2935: v + 34 p.

Certaines activités de développement menées dans le nord du Canada conduiront à la destruction inévitable, complète ou partielle, de lacs. Si des activités de développement de ce type sont approuvées par le ministère des Pêches et des Océans, (MPO), l'exigence d'un programme de pêche-sur-place est reprise en tant qu'élément de l'autorisation en vertu de l'article 35 (2) de la *Loi sur les pêches.* Le principe Pour ce faire, il faut récupérer le poisson et le distribuer aux collectivités locales et collecter, consigner et archiver, comme il se doit, les données tirées du programme de pêche-sur-place. Les études portant sur l'ensemble des lacs, y compris les programmes de pêche-sur-place, peuvent fournir des renseignements de nature exceptionnelle sur les populations de poissons et sur les liens qui prévalent entre l'environnement et les poissons, dans le Nord. Ces données sont utiles pour faire l'évaluation des modèles et des relations entre la composition des communautés de poissons et les caractéristiques sur l'habitat des lacs situés en terres stériles. Une base de données a été mise sur pied; elle comporte les renseignements collectés sur la composition des espèces de poissons et sur les caractéristiques biologiques, limnologiques et sur l'habitat des lacs qui ont fait l'objet de la pêche dans les Territoires du Nord-Ouest. Ce document vise à fournir aux promoteurs de projets un protocole uniforme et normalisé à suivre lors de l'élaboration d'un programme de pêche-sur-place.

INTRODUCTION

BACKGROUND

The need for a fish-out protocol for the Northwest Territories and Nunavut originated in the permitting and construction of diamond mines in the mid-1990s. Kimberlite pipes, one form of the ore-bearing geological structures containing diamonds, are often found to occur under lakes. In order to access these pipes for mining, the overlying lakes need to be dewatered in whole or in part. BHP Billiton's (BHPB) EKATI Diamond Mine, located on the barrens, 300 km northeast of Yellowknife, NT, was the first diamond mine to be permitted in Canada. As a condition of the *Fisheries Act* s.35(2) authorization issued by Fisheries and Oceans Canada (DFO), BHPB was required to recover the fishes from the authorized lakes.

DFO recognized during the development of the authorization that the dewatering of entire lakes at EKATI provided a unique opportunity to acquire a detailed data set on the fish communities and environmental characteristics of several small tundra lakes. A research plan was initiated by DFO Science to conduct the field studies, however, the field tasks were eventually turned over to BHPB. As a result, the following conditions were included in the authorization:

1. Water chemistry and chlorophyll levels would be monitored during the open water season;
2. Benthic invertebrate population densities would be determined;
3. Standardized sampling of fish populations would provide catch-per-unit-effort data;
4. Fish population size estimates would be determined using mark-recapture methods;
5. Fish population size estimates would be determined using hydroacoustic methods;
6. Fish would be batch-marked, by size-class and species, to determine proportional recovery by species and size-class after drainage;
7. A complete census of fish populations, including lengths and weights, would be taken and ageing structures from a subsample of each species would be collected and analyzed; and
8. Data summary reports would be provided to DFO within one year of the field work.

BHPB engaged local communities to staff the fishing crews and prepare the harvested fishes for traditional community uses.

As additional mines completed permitting, fish-out conditions were included in the *Fisheries Act* s.35(2) authorizations. However, the diversity of development activities resulted in an increasing variety of waterbodies to be fished-out. Because there was no established protocol, there were inconsistencies in the way the fish-out programs were conducted which, in turn, affected the confidence in the resulting data and comparability among lakes (Dillon 2002; Thistle and Tonn 2007).

PROTOCOL DEVELOPMENT

The initial fish-out programs provided a number of lessons learned about the practicality of a complete census of fish populations. As well, a need was identified for a common framework and set of objectives to ensure that data acquired through fish-out programs would be collected in a consistent manner. Subsequently, projects were conducted to examine data collected during fish community baseline studies at the various development sites (Dillon 2002) and to establish a database for fish-out data (Tonn 2006). Collected data was also examined to determine whether patterns could be observed among fish communities in barrenland lakes using the baseline and fish-out datasets (Thistle and Tonn 2007).

Lessons Learned

Once the fish-out programs were put into practice, it became evident that a complete census of the fish communities was rarely practical. Even with multiple gear types and an almost complete saturation of the lakes with fishing gear, low rates of fish captures continued for an extended period. Simultaneous lake dewatering concentrated the remaining fishes into ever decreasing basins however, there were no safe methods to recover all the remaining fishes (Tyson 1998a, 1998b; Tyson 1998c; Tyson 1998d; Tyson and McCarthy 1997). The exposed lake bed did not provide a suitable wading substrate for seining or backpack electrofishing. Adding to this, as water levels declined in dewatered lakes (e.g. Panda, Koala, and Airstrip lakes at EKATI), wave action re-suspended sediments resulting in high turbidity. The complete census objective was therefore modified to an intensive cumulative catch per unit effort population estimate. Other lessons are included in the Field Methodology section.

Data Consistency

Given the need for research to further the understanding of fish-habitat relationships in barrenland lakes and that there is a potential for fish-out programs to provide reference data that could be used in such research, it was recognized that a necessary step would be to compile and organize these data into a reference database. These data could contribute to research that would help provide more precise tools for habitat biologists to use in future habitat management decisions. Despite the recognized value of a reference database developed from the fish-out and related projects, major problems were encountered initially. A preliminary assessment (Dillon 2002) concluded that the data were not in a form that was readily useable.

DFO, with financial assistance of BHP-Billiton Diamonds, Inc. and Diavik Diamond Mines Inc., contracted W. Tonn at the University of Alberta to see if the data problems could be overcome. The project had the following objectives:

1. develop a reference database;

2. assess the suitability of the fish population sampling methods and from this assessment, provide methodological recommendations for future baseline fisheries studies; and
3. if possible, quantify fish production, and productivity of lower trophic levels in barrenlands lakes.

The project results were presented in Tonn (2006) and Thistle and Tonn (2007). Problems encountered included inconsistencies in data integrity, data errors and the absence (or loss) of much data in useable digital format. Recommendations for standardizing data recording based on the database design were provided.

Given the variety of lake sizes, fish communities, and logistical considerations in the Northwest Territories and Nunavut, one detailed protocol is not practical for every potential application. A general protocol has therefore been developed with the expectation that more detailed, site-specific work plans would be drafted that incorporated objectives for each application yet still provided consistency with the general fish-out framework. This protocol incorporates the lessons learned from past fish-out programs as well as the recommendations from the data reviews and is presented in the following sections:

- Program Objectives – overall and guiding objectives of the program
- Project Management – roles and responsibilities of organizations and personnel
- Components – core components plus optional studies and applications
- Field Methodology – field components and equipment specifications and deployment
- Deliverables – sample and data analysis, data management, and reporting.

PROGRAM OBJECTIVES

The guiding principle of the fish-out program is to ensure that fish stocks in the waterbodies are fully utilized. Following this principle, value can be obtained from the fish stocks for both local traditional resource users as well as those agencies responsible for managing the stocks. Harvested fishes can be delivered to the communities for traditional uses while data of the kind not normally available can be collected during the fish-out for resource managers. In a few cases, fish stocks may be transferred from one waterbody to another or from an isolated area of a waterbody to the main waterbody (e.g. from Diavik's A154 pit into Lac de Gras). The program objectives are therefore:

1. To engage local communities and ensure that fish harvested during the fish-out are fully utilized by traditional resource users; and
2. To collect ecological information (biological, limnological, and habitat) on Arctic lakes in the Northwest Territories and Nunavut.

Full utilization of harvested fish can be achieved by engaging local communities. Most northern communities maintain a domestic fishery to supply fish for human consumption and dog food. Community members can be engaged to harvest, sort, dress, and deliver fishes to the communities. Material not prepared for human consumption, such as rough fishes, small-body fishes, and offal, can be frozen and delivered to the communities as dog food. The fish-out programs can have an added benefit within the communities in that fishing pressure on the usual domestic stocks can be offset by the amount of fish recovered from the fish-out.

Scientific data collection can be integrated with the fish harvesting by community members. The fishing crews can be trained and directed by biologists to record fishing effort and biological data. Biologists can also provide training and supervision for the harvest of ageing structures, fish stomachs, and any other biological samples, as well as the collection of water quality data. Data collected through the fish-outs will provide important information on the ecology of waterbodies in the Northwest Territories and Nunavut. As noted in the Introduction, fish-out programs can provide invaluable data for both fisheries and habitat managers. All data collected will be maintained in a database and be available for researchers and managers upon request.

A fish transfer is usually the least preferred method of fish disposal and should only be considered when fishes are transferred from a smaller, isolated portion of a lake to a larger main waterbody. Generally, barrenland lakes are oligotrophic with productivity limited by low levels of phosphorus and nitrogen and with a commensurately low standing stock of fish (Wetzel 2001). Though the small stocks might suggest that receiving lakes could easily assimilate the transferred fishes, the receiving lakes are likely already near their carrying capacity. Therefore, transferring fishes from one lake to another lake of similar size is not likely to enhance stocks but more likely to disrupt the fish community in the receiving lake by pushing the standing stock over the carrying capacity. As a result, fish condition in the receiving lake is likely to decline through competition for limited resources (Matthews 1998). The fish biomass of the lake receiving stocking will likely decline to the pre-transfer carrying capacity and result in no net increase in standing stock. The condition under which a transfer may succeed (and not cause damage) is when a small area of a large lake is isolated for dewatering. Less ideal would be if the fish community from a small lake is transferred to an adjacent and much larger lake to which there is good connectivity and significant fish movement. However, an estimate of productivity in the receiving lake should be undertaken to determine if the receiving waterbody has the capacity to absorb the additional stock with minimal impacts.

Other difficulties with stock transfers include fish handling mortalities, disruption of natural community composition, and locally adapted gene pools, and a reduction in the quality of scientific data. Though species such as Lake Trout (*Salvelinus namaycush*) are more robust and may have low mortality rates during transfer, coregonids such as ciscoes and whitefishes (*Coregonus* spp. and *Prosopium* spp.), as well as juveniles of other species, are sensitive to most capture and handling techniques and have high mortality rates. Data collected during fish transfers may not be directly relatable to data collected during a fish-out program. Because the priority during fish transfers is to minimize fish mortality, the unit of effort will likely differ from that of a fish-out. For example, in a fish transfer, short-term gill net sets may be used to capture fishes. As these nets are run several times a day and not set overnight, the unit of effort, even if expressed on a per-hour basis, will not be comparable to the overnight (18-24 hr) sets recommended for a fish-out program. Fish transfer therefore has limited applications and should be carefully considered prior to any decision to use this method.

PROJECT MANAGEMENT

The three stakeholders that manage or contribute to the project are: DFO, the proponent, and the local communities. It is the responsibility of the proponent to engage the local communities. There is nothing that precludes DFO participating as a research partner in the ecological and biological data collection. However, if DFO is to participate, the roles and responsibilities of DFO and the proponent should be clearly identified in the work plan. The protocols contained herein assume that DFO is not participating as a research partner and that the proponent will be conducting the fish-out program. An example of a fish-out program organizational chart is presented in Figure 1.

ROLES AND RESPONSIBILITIES

The DFO habitat biologist responsible for the project referral will be the principal contact with the project proponent. During the development of the work plan the habitat biologist will be responsible for seeking input from DFO Science, when required and providing timely communications and advice (technical and regulatory) to the proponent. Timely communications between the proponent and the DFO habitat biologist (or designate) should continue once the fish-out is underway. Following the fish-out program, it will be the responsibility of the habitat biologist to receive the deliverables from the project proponent, review the fish-out report, and coordinate with DFO Science to ensure the data are entered into the Arctic aquatic database. Compliance with the terms of the *Fisheries Act* s.35(2) authorization should also be noted in the referral file.

The project manager is the proponent's representative and has the responsibility of managing the fish-out program including developing the work plan, schedule and budget, staffing, communicating with DFO, and providing the deliverables (e.g. work plan, data, reports, etc.). The project manager may designate the project biologist to communicate directly with DFO during the fish-out.

The project biologist is the key technical position during the fish-out. The project biologist is responsible for meeting the technical requirements of the fish-out program; therefore, this position should be staffed by a qualified and experienced biologist. The project biologist should participate in the development of the work plan. The project biologist will be responsible for training field staff, supervising field activities and data collection, quality assurance/quality control, conducting data analysis, and preparing deliverables.

The field technicians will conduct the fish-out and data collection under the supervision and guidance of the project biologist. If possible, these positions should be staffed by members of the local communities with experience in operating boats, using gill nets, and handling fishes. Community members provide a valuable source of traditional knowledge and field skills. Field technicians will also record biological data, collect tissue samples, and sort and prepare fishes for community use.

WORK PLAN

The work plan is the document that clearly lays out how the particular fish-out project will be conducted, incorporating both the guiding principle and objectives of the fish-out program and any specific understandings agreed to by DFO and the proponent of the particular fish-out program. The work plan should include the following:

Objectives

The overall objectives of the fish-out should be clearly stated. This should also include specific study objectives of each component included in the project.

Project Management

The management plan for the project should be clearly detailed with roles and personnel identified. Lines of communication and decision makers should also be identified.

Components

The components to be included in the fish-out program should be identified as well as the goals of each. Decision criteria for proceeding from one phase to the next should be clearly identified. Existing data for the lake, particularly data used to estimate crew and equipment requirements, should also be identified and, if unpublished, included in the plan.

Field Methodology

The field methodology should include methods for fishing during each phase, biological data collection, aquatic biology/physical limnology, habitat assessment (if applicable), and any laboratory analyses. This section should also include estimates of crew and equipment required for each component and phase of the program.

Deliverables

The deliverables should be clearly stated. This should include the format and extent of analyses in the report as well as any samples and electronic data.

COMPONENTS

The core components of the fish-out program, as derived from the program objectives, are:

a) the recovery of fishes;

b) the distribution of fishes to communities; and

c) the collection of basic fish and fish habitat data.

A lake fish-out provides a rare opportunity to conduct intensive multidisciplinary research that can provide resource managers in the Northwest Territories and Nunavut with information that would otherwise be unavailable. In particular, a lake fish-out provides the opportunity to investigate linkages between fish community structure, composition, and productivity and fish habitat via whole-lake sampling. Given this opportunity, other components, such as a mark-recapture study, can be added to the fish-out program.

The basic program is divided into three general components:

1. Fish Community
2. Aquatic Biology/Limnology
3. Physical Habitat Inventory.

Baseline information for each of the above components should already exist prior to the development of the fish-out work plan. To reach the stage where a *Fisheries Act* s.35(2) authorization has been issued with the requirement for a fish-out, productivity in the candidate lake must have been previously evaluated. An example of a project schedule where all components, including a mark-recapture study, are conducted within the same open water season is presented in Figure 2.

FISH COMMUNITY

The fish community component is composed of (a) the CPUE phase, and (b) the final removal phase. The lake or waterbody should be isolated prior to the initiation of the CPUE phase and should remain so until the end of final removal phase to prevent immigration and emigration of fishes. As well, the CPUE and final removal phases should be conducted within the same open-water season to avoid the changes in growth, mortality, and recruitment resulting from reduced competition and predation (Tyson 2008; Tyson 1999a). An optional mark-recapture study, however, may require the marking phase in the year prior to the fish-out program to ensure dispersal of marked fishes and adequate time for the fish-out.

CPUE Phase

The objective of the CPUE phase is to collect fish community catch-per-unit-effort data for each population in the lake. These data will then be used to estimate the fish populations. Variously, this method of population estimation has been referred to as fishing success (Ricker 1975), removal (Kelso and Shuter 1989), and catch-effort (Gould and Pollack 1997) methods for estimating populations. Ordinary least squares (OLS) methods regressing CPUE with cumulative catch (Leslie method) and cumulative effort (DeLury method) are commonly used to estimate fish populations (Hayes et al. 2007). More recently, increasing computer capabilities have led to the development of computer programs allowing for maximum-likelihood estimators for catchability and population size.

The removal method has a number of assumptions most notably that of a constant catchability coefficient relating effort to catch and the probability of capture being equal among fish (Knight and Cooper 2008). Departure from these assumptions can result in an underestimation of the original population (Kelso and Shuter 1989). A number of studies have sought to address the bias (e.g. Akamine et al. 1992; Gould and Pollack 1997; Mantyiemi et al. 2005) during data analysis. Schwarz and Seber (1999) provide a review of recent analytical applications to the removal method. Gould and Pollack (1997) simulated population estimates under different population sizes and catchability coefficients for the Leslie, DeLury and maximum-likelihood methods. They found that the maximum-likelihood method consistently provided less biased and more precise estimates than the OLS methods.

It is critical that the standard unit of effort remain unchanged for the duration of the CPUE phase. Equipment type, fishing methods, and fishing periods must remain unchanged throughout the CPUE phase. For example, if trap nets are used at the start of the CPUE phase then the use of trap nets must be continued through the duration of the CPUE phase and not removed in later stages to make room for additional gill nets. Likewise, if trap nets are not deployed at the start of the CPUE phase, traps should not be added later in the phase. The only variable that will change will be the number units of effort. As CPUE declines, it is permissible to increase the unit of effort. For example, if five gangs of gill nets are being fished in a lake and the daily CPUE begins to decline, additional gangs may be added provided all other variables (e.g. fishing periods) remain the same.

The lake should remain physically and chemically unchanged during the CPUE phase. That is, no development activities, such as water transfers in or out of the lake should occur and seasonal changes to the environment and/or fish populations should be minimized. Dewatering has been observed to alter fish distribution through changes to available habitat while the re-suspension of sediments affects fish catchability (Tyson 1998a; Tyson 1998c; Tyson 1998d; Tyson and MacCarthy 1997). The CPUE phase should continue until the CPUE objective is met.

The ideal CPUE objective is achieved when no fish are captured for 24-48 hr of continuous netting, nets are removed for 48 hr, nets are then re-deployed for 24-48 hr of netting and fish are still not captured. In practice, this ideal should be weighed against the time required to achieve this, given the seasonal changes (e.g. water temperature and fish activities) that should be minimized, together with changes in catchability following intensive harvesting. At this point, the CPUE phase should be suspended. If the lake will be dewatered, this would be a time to begin, proceeding to a point where the remaining fish are sufficiently concentrated. The program may then continue with the final removal Phase.

Final Removal Phase

The transition from CPUE phase to final removal phase will be triggered when the lake has reached gear saturation and there have been no (or virtually no) fish captured for 48 hr. The objective of the final removal phase is to capture all remaining fishes in the lake to provide as complete a fish community census as conditions will allow. This can include using all available fish capture techniques, including methods not used in the CPUE phase, altering the distribution of mesh sizes that are fished, or even the development of new capture techniques. Lake dewatering can be initiated during the final removal phase and may assist by concentrating fishes into an ever decreasing lake volume. However, precautions should be taken to properly screen the intakes to avoid losses to pump entrainment (Tyson 1998a; Tyson 1998c; Tyson 1998d; Tyson and McCarthy 1997; DFO 1995).

The final removal phase can also be used as an extension of the CPUE phase. This would be done by adjusting the unit of effort to focus the numerically strongest size classes of the fish populations and then stratifying the effort accordingly during data analysis. Typically, larger fishes are removed most rapidly from the lake as they are susceptible to both the large meshes and, to a lesser degree, the smaller mesh sizes (e.g. Tyson 1999). As a result, even at gear saturation, the majority of the lake can be occupied by gear that will no longer catch fishes. By swapping out panels of mesh sizes that have the lowest CPUE for panels of mesh sizes that have the highest CPUE, fishing effort is concentrated on the remaining fish size classes. For example, if no fishes have been captured in the 4" panels for a week whereas the 1.5" panels were found to have captured the most fishes during the CPUE phase, most of the 4" panels can be swapped out for 1.5" panels. In order to allow for stratification of unit effort, it is important to continue fishing a few panels of each mesh size throughout the duration of the final removal phase.

Mark-Recapture Study (Optional)

A mark-recapture study can be included in the fish-out program. The study would include a marking period prior to the fish-out. The CPUE phase would then be used as the recapture period. Because Arctic summer fishing periods are short, the marking phase might need to be conducted during the previous year to allow for marking of an adequate number of individuals. This would avoid a potential encroachment on the time available for a fish-out and reduce the risk of an incomplete fish-out. Caution should be used in developing a mark-recapture study as handling mortality, especially amongst coregonids, may affect recovery during the CPUE phase, resulting in an underestimation of the original fish community populations (Tyson 1998c).

AQUATIC BIOLOGY/LIMNOLOGY

Basic aquatic biology and limnology information for the lake should already exist prior to the fish-out, but more detailed and/or updated sampling may be desirable to provide supporting data for the fish-out. Because the lower trophic levels of the lake community may be affected by the removal of fishes (Kitchell and Carpenter 1993), sampling should be conducted during the mark-recapture or early CPUE phase or during the prior open-water season.

HABITAT INVENTORY

A habitat inventory of the lake should also already exist prior to the fish-out, as habitat is often used as a surrogate for estimating productive capacity in the development a *Fisheries Act* s.35(2) authorization. A habitat inventory map will be used to ensure all habitats are fished adequately during the CPUE phase (e.g. using a stratified-random sampling design). A habitat inventory can also be conducted shortly before the CPUE phase. A habitat confirmation survey could also be conducted once the lake has been partially drained and the littoral areas have been exposed. Its goal would be to confirm the physical habitat features delineated during the initial habitat survey.

FISH TRANSFER

A fish transfer is a special situation where fish can be captured and transferred from one waterbody to another. This should only be conducted if there is no reasonable expectation for there to be significant effects on the fish community in the receiving waterbody. The species of fish being transferred must occur in both the donor and receiving waterbodies. Following are cases in which fish transfers might be considered worth the additional effort: (1) the fish community in a small portion of a large lake that has been isolated for dewatering can be captured and transferred to the main lake; (2) the small-body fish community from a small lake could be captured and transferred to a much larger lake (>1,000 ha) with few effects on the receiving lake, where both lakes support all species considered for transfer. In the case of the latter smaller lake transfer, all components of the fish-out program should be conducted. In the case of the transfer of fishes from an isolated portion of a lake, the emphasis should be on minimizing capture and handling mortality. Because it is likely that the habitat has already been disturbed and the fish community may have been altered during the process of isolation, the aquatic biology/limnology and habitat inventory components would not be required. The biological and CPUE information on the fish, however, may still be collected.

FIELD METHODOLOGY

Ideally, the fish-out methodology should be consistent with the methodology used during the lake assessment. The Northwest Territories and Nunavut, however, do not have standard fish community survey or biological sampling protocols; rather, a variety of lake assessment methodologies are currently used, depending upon the choice of the lead investigator. A recent project to construct a database from a number of lake assessment and fish-out projects encountered significant challenges due to the variable quality of data and inconsistencies in methodologies (Tonn 2006). Various jurisdictions in Canada and abroad have sought to address similar challenges by developing standard sampling methods for fish community characterization and assessment (e.g. Cavanagh et al. 1997; Appelberg 2000; Environment Canada 2002; Morgan and Snucins 2005; Sandstrom et al. 2008; Beauchamp et al. 2009; Lester et al. 2009). The development of standard sampling methods is beyond the scope of this document, therefore, the methods developed during the initial fish-out programs will be continued herein. Ideally, if a proponent (or DFO) wants to adopt one of the 'standard' protocols from other jurisdictions, both the 'original' and 'new' protocols should be used side-by-side, at least initially, to allow for the conversion of one protocol to the other and thus insure continuity and consistency in the accumulating data base.

PROJECT TIMING

Unless specified otherwise, all components should be conducted during the same open-water season. The one exception could be that the marking phase of a mark-recapture component might be conducted during the previous open-water season. Because the open-water season in the Northwest Territories can be very short, preparations should be made to have sufficient crews and gear to provide a high level of effort to the fish-out program. Consideration must also be given to selecting fishing gear that provides high rates of capture (Tyson 1998a; Tyson 1998c). For example, trap nets tend to have lower rates of capture per unit area fished than gill nets; therefore trap nets may not provide sufficient captures to complete a fish-out during one open-water season. Winter fishing should not be conducted. Winter fishing is logistically difficult, labour intensive and, because of the thick surface ice, does not allow fishing of the shallower littoral areas. In addition, CPUE during winter fishing is lower than and not comparable to open-water fishing (Tyson and McCarthy 1997).

FISH COMMUNITY

The goal of the fish community component is to provide an accurate description of the fish community, including population estimates, size distributions, and age structures of its component populations. Fishing methods will depend on the size of the lake.

Fishing Gear

Gill nets are the primary gear type to be used to capture fishes during the fish-out. Gill nets can be readily standardized, provide good rates of success in a variety of habitats, catch a wide variety of fishes and fish sizes, and are easy to transport and use. Trap nets can also be used but because of lower CPUEs when compared with gill nets (except during lake dewatering after littoral habitat has been exposed; Tyson 1998a, Tyson 1998c), trap nets generally require longer periods of deployment which are not always available during the short Arctic summers. As a rule of thumb, gill nets should be used exclusively to fish-out lakes with large-body fishes while trap nets and Gee minnow traps can be used with small-mesh gill nets for lakes with only small-body fish species.

Standardized gill nets should be used to capture fishes during the CPUE phase while additional gear types may be used during the final removal phase. Gear should be checked daily for damage. Small tears in gill nets can be repaired using monofilament line, however, panels with large or numerous holes should be replaced. A sufficient stock of equipment should be available prior to the start of fishing to provide replacement panels as required due to wear and tear, as well as to ensure gear saturation during the late CPUE and final removal phases.

Gill Nets – All nets should be bottom setting and constructed of monofilament. Stretched mesh-sizes to be used are 102 mm (4"), 76 mm (3"), 51 mm (2"), 38 mm (1½"), 25 mm (1"), and 13 mm (0.5"). Standard single-mesh panels are 45 m (150') long by 2.4 m (8') deep. Panel lengths may be increased or decreased depending upon the size of the lake, however, panels used in any lake should all be the same dimensions and dimensions of all nets must be clearly recorded on data sheets.

Trap Nets – Where appropriate (e.g. small lakes dominated by small-body fish species), small-mesh trap nets can be used for all phases of a fish-out program. The traps should be constructed of 6 mm square mesh with a house of 1.23 x 1.23 x 1.23 m. The leads should measure 61 m in length and 1.83 m in depth.

Gee Minnow Traps – Minnow traps can be used for fish-outs of small lakes or ponds that are dominated by small-bodied fish. Standard traps are constructed of 1/4" (6.4 mm) square galvanized wire mesh and measure 16" (42 cm) long and 9" (23 cm) wide with a 7/8" (22 mm) entrance hole. Bait can be used in the minnow traps but the use of bait and bait type should remain consistent through out the CPUE phase.

Other gear – During the final removal phase, additional gear types may be used in order to conduct a complete census of the fish community. Active fishing methods, such as electrofishing and seining, can be effective at capturing benthic and/or less-active species but only if the substrate conditions allow. Baited set lines or baited traps may be effective for catching burbot.

Gear Deployment

Gill net, trap net, and minnow trap sites and identifications should be drawn on a map of the lake and GPS coordinates (easting/northing) recorded on the field data sheet. Date, time of setting (24 hour clock), and time of retrieval should also be recorded for each net and trap. Water depths at the start and finish of the gill nets and trap net leads are to be recorded, based on field measurements (e.g. fish finder) or from a bathymetric map. Mesh sizes (gill nets) and lengths and heights (trap net leads, gill nets) are also to be recorded. Gill net panels should each have a unique identity code attached to allow quick identification and data recording in the field. A master list with codes, mesh sizes, and dimensions should be maintained onshore.

The trap leads should be anchored to shore and set perpendicular to the shoreline. Trap nets must be moved regularly (every 2-3 days) around the shoreline to ensure full coverage of the available habitat in the lake.

Net checks could initially be conducted once per day. Nets should be moved daily such that all available habitats are fished and avoidance behaviour minimized. However, since fish abundance and biomass are generally highest in the littoral zone, fishing effort should be more intense in (but not exclusive to) shallower depths. Daily gear redeployment will also serve to rotate of panels and mesh sizes through any given patch of habitat. As catch decreases, effort (amount of gear) should be increased. Eventually, the lake will become saturated with gear.

Field Crews

Generally, crews setting and picking gear also conduct the biological data collection from the catch. Care should be taken to balance the amount of gear being fished and the capacity of the crews to pick and move nets and to record biological data. Catches at the start of the CPUE will be highest and setting too much gear at that time can overwhelm the crews. The majority of the larger fishes tend to be removed early, therefore it is preferable that sufficient personnel should be available at the start of the CPUE phase to ensure all large-body and adult fishes can be processed without the risk of sub-sampling. As the fish-out continues, the majority of the later catches will be juveniles, which can then be sub-sampled.

At the start of the CPUE phase, one crew of three (boat operator, net picker, and data recorder/helper) can manage at least one and perhaps two complete standard gangs. This includes picking and moving nets as well as processing the catch for biological information. As CPUE declines, more gangs can be deployed. If sub-sampling of the juvenile and small-body fishes is being conducted then the proportion of time crews spend picking and moving nets increases while the proportion of time spent processing the catch decreases. Preparations should therefore be made to adjust the crew complement to meet the fishing and data collection needs as required. Preparations should also be made to rotate crews offsite and fresh crews onsite without interruption to the program.

CPUE Phase

During the CPUE phase, gear types, including mesh-sizes and lengths of individual nets, should remain constant such that a standard “unit of effort” can be defined. However, additional units may be required as stocks, and hence catch rate, decrease. The full range of gill net mesh-sizes must be fished at all times; there should also be a consistent proportion of the different panels used for each set during the CPUE phase. The total number of sets should be increased as CPUE decreases.

It is critical that all fishing methods that make up the standard unit of effort be held constant during the CPUE phase. For example, if trap nets are used at the start of the

CPUE phase, then trap nets should be continued to be fished through the duration of the CPUE phase and not removed in later stages to make room for additional gill nets. Likewise, if minnow traps are used in a pond fish-out, they should be continued throughout the CPUE phase and seining and electrofishing held off until the final removal phase.

Final Removal Phase

To assess the accuracy of the population estimates, as well as to achieve the program objective of removing all fish from the lake, a total census of the lake's fish community must be completed. Every effort should be made to capture every fish in the lake. During the CPUE phase, the goal is to capture and remove as many fish as possible while keeping the gear types constant and effort standardized. During the Final Removal Phase, *every* effort will be made to capture *all* remaining fish in the lakes, thus, additional capture methods may be added (see "Other gear", above) and the number of gill-net panels of each mesh size may be increased disproportionately, e.g. to favour mesh sizes that continue to catch fish. Proposed methods will be presented to, and reviewed by, DFO.

After the lake volume has been sufficiently reduced for lakes being 'de-watered' (possibly during the winter) the fish-out will resume. The final removal phase will continue until the removal objective is met. This objective should be presented to, and reviewed by, DFO prior to the start of the field work. Possible benchmarks could include the capture and removal of marked fish (fin clips and/or numbered tags) that exceed a certain percentage (e.g. >99%) of all fish marked by that method. Another objective could be based on CPUE, e.g. no fishes are captured for 48 hr of continuous sampling (with sufficient effort), sampling is halted for 48 hr, sampling then resumes for 48 hr and fish are still not captured.

Captured and removed fish should be treated as in the CPUE phase: counted and classified, biological data (and tissues) extracted, fish sacrificed, and/or distributed, in accordance with agreements.

Mark-recapture (Optional)

The fish-out program can be used to conduct a mark-recapture population estimate to complement the CPUE estimates. The mark-recapture phase of the program requires a period of catch and marking (marking phase) followed by a period of dispersal prior to the CPUE (recapture phase) and final removal (Figure 2).

For the mark-recapture phase, the goal is to release fish back to the lake alive, therefore either trap nets or short-set small-mesh gill nets (e.g. 38 mm stretched mesh, set for 30 to 60 min) should be used to minimize mortalities. If the marking phase is during the same open-water season as the fish-out phases, marking should commence soon after ice out and before surface water temperatures above 10°C increase the risk of capture mortality. Detailed set data should be recorded for each net and trap and full biological data (see below) should be collected from fish mortalities. Due to low survival rates of whitefishes during netting and marking procedures, the use of a mark-recapture component should be carefully considered with respect to program goals before being included. Small-mesh trap nets and minnow traps could also be used if there are substantial numbers of small fish present and the schedule allows.

Partial fin clips, removing ⅓ to ½ of a fin, can be used to mark fish. It is important to minimize stress on fish and to return the marked fish to the water as soon as possible. However, live wells/holding tanks should be available during the marking phase, as needed, to allow stressed fish some recovery time before being returned to the lake. If anaesthetic is being used, fish must be held until they have recovered from the anaesthesia.

Record the counts of all fish captured during this phase by species and fate category (see Fish count record form). Based on prior information about the fish populations, separate mark-recapture estimates could be made on different size/age-classes (e.g. juveniles vs. adults) or sexes within (some) species. If so, clip different fins to avoid confusion and record the distinction. As the phase progresses, more and more of the fish being captured will already have been marked (i.e. will be recaptures). Although marking and recapturing a greater proportion of fish in a population will produce more precise estimates of abundance (see Ricker 1975 or Krebs 1999), it is often not practical to maximize precision for all species in a lake. The work plan for the fish-out program should indicate *a priori* the recapture rate (e.g. 10%) that will be used as the target objective for the mark-recapture phase and whether the phase will be terminated when all, half, or some other proportion of species reach that target objective.

<u>Note</u>: If a substantial time gap is anticipated between any of the three phases of the fish-out program, then a sizeable number of fish should be given more permanent marks such as tags or adipose fin clips during the marking phase. These can subsequently be used to assess the effectiveness of the complete censuses during the CPUE and final removal phases.

Fish Transfer

If fish are to be transferred to another waterbody (but see earlier discussion and caveats), the goal is to release fishes alive, similar to the marking phase of the optional mark-recapture component. Care must therefore be taken to minimize capture, handling, and transportation mortality. Capture and handling methods should follow the methods above described for catching and marking fishes. The receiving waterbody should be adjacent to the source lake and there should be easy access between the two. If fishes cannot be reliably captured and transferred with minimum fish mortality then a fish-out should be considered.

Biological Data Collection

All fishes must be removed from the lake, sacrificed, and distributed in accordance with any agreements between the proponent and the communities. A count of all captured fish, by species (and size-class, if appropriate), must be made and recorded, along with their "fate" or category, e.g. whether the fish had previously been marked or not, and whether it was removed or escaped. The proportion of marked fish (from the optional marking phase) that was captured and removed during the CPUE phase can be used as an index of the proportion of all fish in a population captured and removed. Biological data (see "Fish sample record" form) should be taken on every fish or on a substantial sub-sample as noted below.

Data codes and sample data sheets are provided in Appendix A. Biological data collection procedures should be developed prior to the field program and should include QA/QC procedures. Data collection procedures should follow established procedures (e.g. Cavanagh et al. 1997; EC 2002; and Sandstrom et al. 2008).

During the optional marking phase of the program, fish stress and mortality must be minimized. For fishes marked with unique identifiers (e.g. Floy tags), the following data should be recorded:

- Species
- Length
- Weight
- Tag number
- Mark type

Batch-marked fishes should only be marked and/or examined for marks before being released. Full biological data should be taken from any mortalities. For each fish species or category (which may be a size-, age-, or sex-class of a species), record only the number and category ("fate") of all fish captured in each trap or net (see "fish count record" data form, Appendix A).

During the CPUE and final removal phases, biological data and/or samples should be collected for each fish captured. The following data should be recorded from a sub-sample of the smaller, younger fishes and all of the larger, older fishes (see "fish sample record" data form, Appendix A):

- Species
- Unique fish number
- Weight (to the nearest 0.1 g)
- Length (fork or total length; to the nearest mm)
- Sex
- Maturity
- Reproductive status
- Ageing structure (s) taken
- Biological tissues collected (e.g. muscle tissue, stomachs, whole carcass)

- Marks
- Tag number

Fish dissections should be conducted in the field at the time of collection.

Ageing Structures

Ageing structures should be removed from a sub-sample of the smaller, younger fishes and all of the larger, older fishes. A list of the appropriate structures by group is provided in Table 1. Methods for the collection, storage, and reading of ageing structures can be found in Mackay et al. (1990) and Mann (2004). Procedures should be part of the Project Biologist's QA/AC procedures.

AQUATIC BIOLOGY/PHYSICAL LIMNOLOGY

One of the principal goals of the fish-out program is to identify fish and fish habitat relationships. Therefore, information about lake ecosystem components other than the fish community must be collected. Generally, this information is collected during the fish and fish habitat assessment of the lake prior to the development of a fish habitat compensation plan. In the event that this information has not been collected, an aquatic biology/physical limnology program should be conducted prior to the fish-out field work. The Northwest Territories and Nunavut do not have standard biological sampling procedures, however, a number of other jurisdictions do provide manuals that may be used as references when designing a sampling program (e.g. Cavanagh et al. 1997; EC 2002; USEPA 2007).

The aquatic biology/physical limnology program should include the following:

- Physical Limnology
- Water Quality/Nutrients
- Chlorophyll *a*
- Zooplankton
- Benthos
- Habitat Mapping

Ecosystem sampling should be conducted during the open water-season. Permanent survey sites should be established at the deepest portions of each basin within each lake (e.g. a lake with three basins will have three survey sites for physical limnology, water quality/nutrients, chlorophyll *a*, and zooplankton). Samples from these sites will be considered representative of the basin. Except for benthos, sampling surveys should be carried out at each site during three, equally spaced sampling visits. The benthos survey should be conducted once, during the late summer or fall.

Physical Limnology

Record wind (direction and speed), cloud cover, air temperature, and surface water temperature in the field notebook and data form comments box during *every* visit to the lake.

The following components will be carried out at each site during each of the three limnological sampling visits:

- Dissolved oxygen and temperature profiles (1-2 m intervals)
- Secchi depth.

Water Quality/Nutrients

A minimum of two water samples should be taken: (a) at a depth of one metre (or from the epilimnion with an integrated tube sampler), and (b) at a depth below the thermocline (in stratified lakes) or at a depth three-quarters of the maximum depth in fully mixed lakes. Samples should be analyzed for:

- Total phosphorus
- Total nitrogen
- Total dissolved solids
- Dissolved nutrients – ammonia, nitrate, nitrite, ortho-phosphate, silica
- Total dissolved nitrogen
- Total dissolved organic carbon

***Chlorophyll* a –** Samples for chlorophyll *a*, as an index of primary productivity, should be taken from each of the water quality/nutrient sampling locations. Samples will be handled and analyzed following standard protocols.

***Zooplankton* –** Zooplankton is the dominant group of primary consumers in the pelagic zone and an important component of the diets of fish inhabiting that zone. Zooplankton sampling should be conducted during the water quality/nutrient sampling periods. Sampling should consist of four hauls per station, from about one metre off the bottom to the surface (recording the total length of the haul), using a 25-30 cm diameter net with 70 to 100 micron mesh. Samples should be preserved and analyzed for total biomass and taxonomic composition using standard procedures.

Benthos – Macroinvertebrates are dominant consumers in the littoral and profundal zones of a lake and important components of fish diets. Benthos samples should be taken once during late summer. A total of 21 dredge hauls should be taken below 5 m in each basin, in areas of softer sediments, distributed amongst the following depth intervals: six between 5-10 m; four between 10-15 m; three between 15-20 m; one between 20-25 m; and two deeper than 25 m. Dredge samples should initially be washed through a 250 or 500 µm mesh and preserved. One dredge haul from each depth interval should be analyzed for taxonomic composition, whereas the remaining 15 hauls should be used for biomass determinations.

Habitat Mapping

The Northwest Territories and Nunavut do not have standard fish habitat inventory protocols but rather a variety of inventory methodologies are currently used, depending upon the choice of the proponent project manager. Some jurisdictions in Canada have developed locally applicable standard inventory methods (see Resource Inventory Standards Committee for British Columbia and Bradbury et al. 2001 for Newfoundland and Labrador) which may be adapted for use in the Territories. Armantrout (1998) provides a glossary of habitat inventory terminology.

DELIVERABLES

SAMPLE ANALYSIS AND DATA MANAGEMENT

The analyses of all samples, from water quality to aging structures, are the responsibility of the proponent. All sample analyses will be conducted by qualified laboratories/ personnel. QA/QC results and analysis should be included.

DFO will provide the MS Access data entry template to the proponent. Field data forms, designed to be consistent with the fish-out database, are provided in the Appendix for gear-set data, fish counts, and fish biological data, along with a page of codes for these forms. Data should be entered from these field sheets directly into the MS Access database forms.

REPORTING

A daily CPUE report should be submitted electronically to DFO during the CPUE and final fish-out phases. Data should be in the form of a total daily fish count and the amount of fishing effort (e.g. number of gill nets). This information will be used by DFO to determine when to transition from CPUE to final fish-out phases as well as the end point to the final fish-out phase.

At the conclusion of the fish-out program, the proponent will provide the data in a summary data report that should present and discuss the data in relation to the objectives of the fish-out program. In addition to the biological and survey data, sample analyses of results will be provided that demonstrate the suitability, precision, and accuracy of the data. The report will also include mark-recapture and CPUE population estimates and comparisons to baseline data, assessments, and predictions. QA/QC results, analysis, and discussion should be included in the report.

In addition to the report, the proponent will supply DFO with:

- Photocopies of all field data/notes
- Copies of photographs
- An electronic database in Microsoft Access of all data collected, including the results of all sample analyses.

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Table 1: Ageing structures to be collected by species group and listed in order of reliability (after EC 2002 and Mann 2004).

Species	Structure
Lake Trout and other salmonids	a) ototliths b) 1st four leading pectoral rays c) scales
Whitefish and other coregonids	a) ototliths b) 1st four leading pectoral rays c) scales
Smelt	a) ototliths b) 1st four leading pectoral rays c) scales
Northern Pike	a) cleithrum b) scales
Burbot	otoliths
Suckers	a) ototliths b) 1st four leading pectoral rays c) scales
Cyprinids	a) otoliths b) scales
Sticklebacks	otoliths
Sculpins	otoliths
Walleye and other percids	a) ototliths b) 1st three dorsal spines c) opercules d) scales

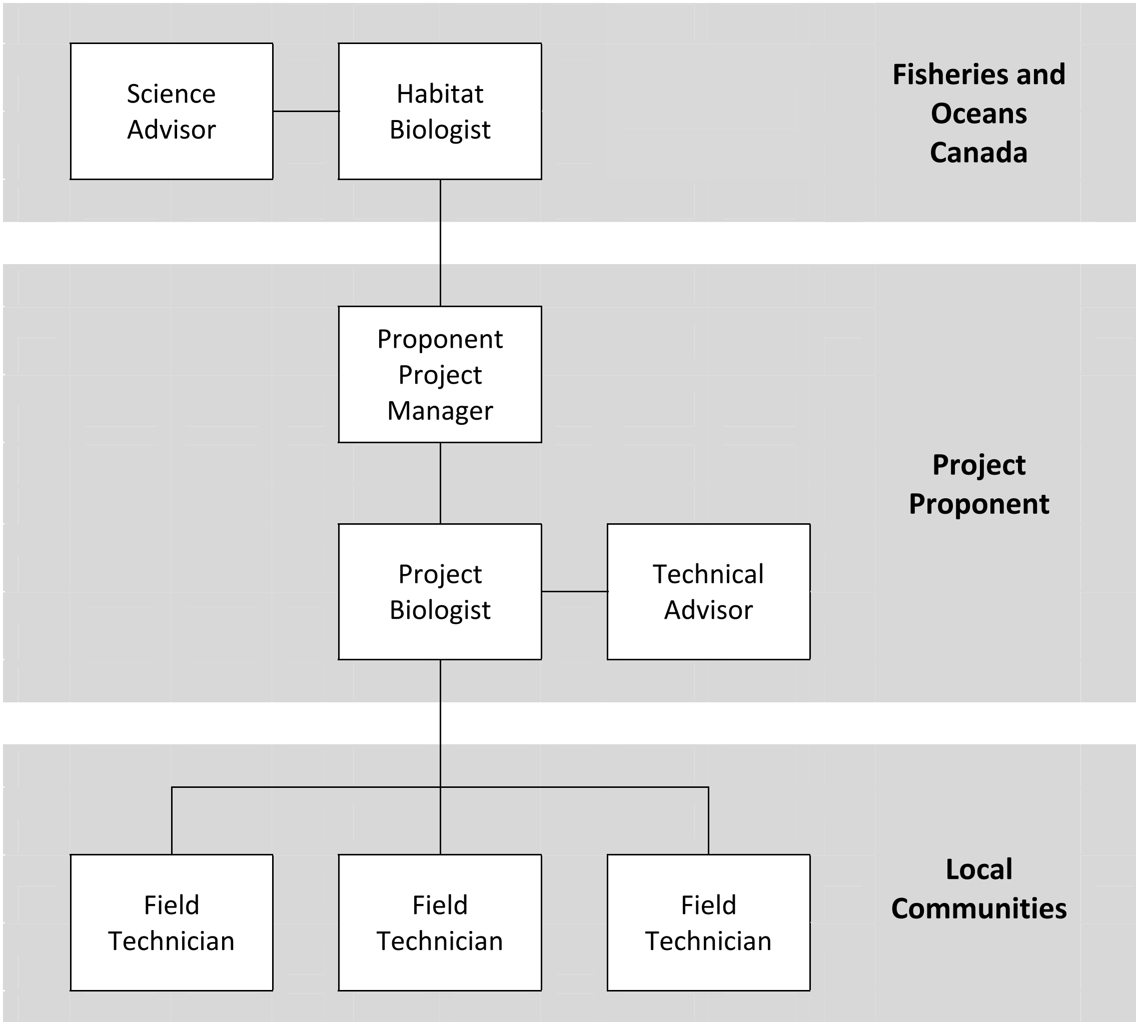

Figure 1: Example of a fish-out program organizational chart.

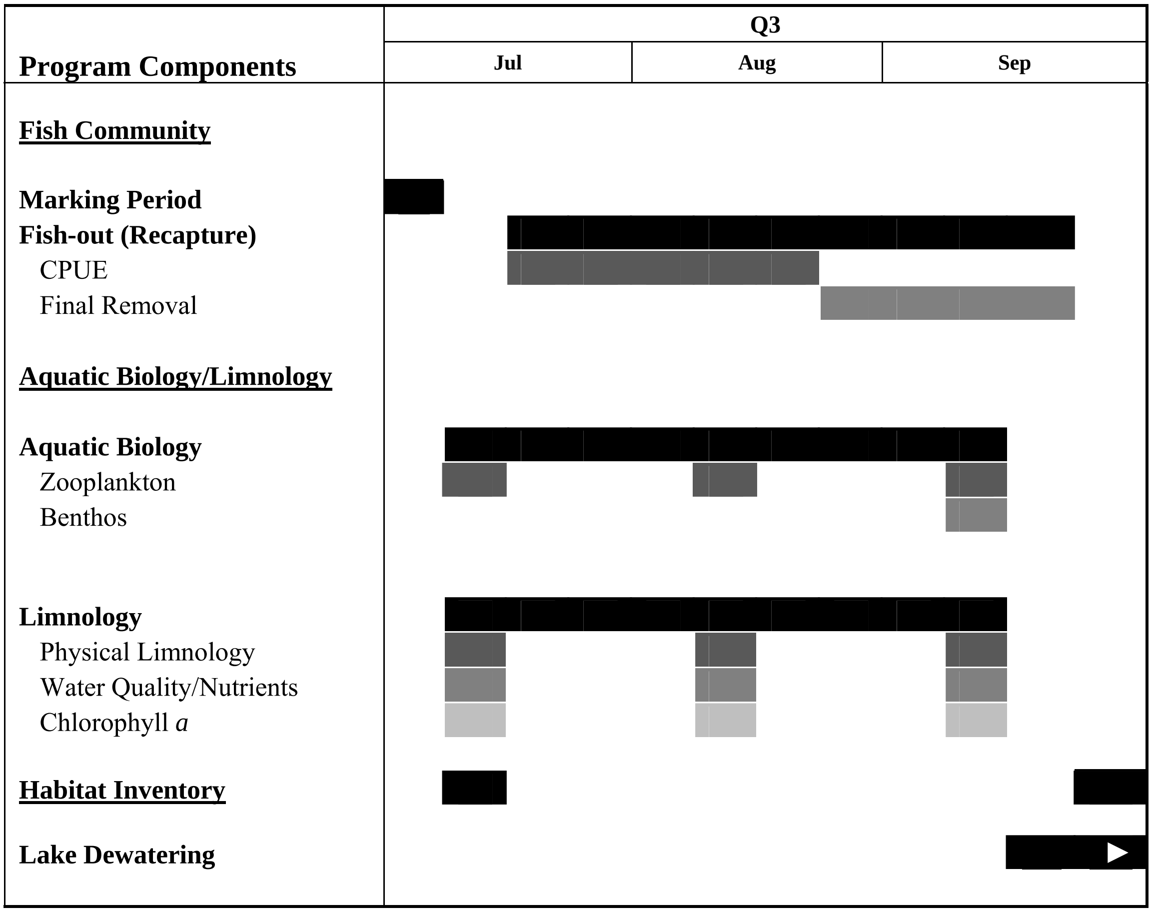

Figure 2: Example of a fish-out program field schedule where the fish-out, aquatic biology, physical limnology, and habitat assessment occur during the same year and dewatering begins following the conclusion of the fish-out program.

APPENDIX A

DATA CODES

Appendix A.1: Species codes for freshwater and anadromous fishes in the Northwest Territories and Nunavut, Canada (after Sawatzky et al. 2007).

Species Code	Scientific Name	Common Name
ARLM	*Lampetra camtschatica*	Arctic Lamprey
GOLD	*Hiodon alosoides*	Goldeye
PNSL	*Oncorhynchus gorbuscha*	Pink Salmon
CHSL	*Oncorhynchus keta*	Chum Salmon
COSL	*Oncorhynchus kisutch*	Coho Salmon
RNTR	*Oncorhynchus mykiss*	Rainbow Trout
SCSL	*Oncorhynchus nerka*	Sockeye Salmon
CNSL	*Oncorhynchus tshawytscha*	Chinook Salmon
ARCH	*Salvelinus alpinus*	Arctic Char
BLTR	*Salvelinus confluentus*	Bull Trout
DLVR	*Salvelinus malma*	Dolly Varden
LKTR	*Salvelinus namaycush*	Lake Trout
CISC	*Coregonus artedi*	Cisco
ARCS	*Coregonus autumnalis*	Arctic Cisco
LSCS	*Coregonus sardinella*	Least Cisco
SHCS	*Coregonus zenithicus*	Shortjaw Cisco
LKWH	*Coregonus clupeaformis*	Lake Whitefish
BRWH	*Coregonus nasus*	Broad Whitefish
PGWH	*Prosopium coulterii*	Pygmy Whitefish
RNWH	*Prosopium cylindraceum*	Round Whitefish
MNWH	*Prosopium williamsoni*	Mountain Whitefish
INCO	*Stenodus leucichthys*	Inconnu
ARGR	*Thymallus arcticus*	Arctic Grayling
PDSM	*Hypomesus olidus*	Pond Smelt
RNSM	*Osmerus mordax*	Rainbow Smelt
NRPK	*Esox lucius*	Northern Pike
LNSC	*Catostomus catostomus*	Longnose Sucker
WHSC	*Catostomus commersoni*	White Sucker
LKCH	*Couesius plumbeus*	Lake Chub
PRDC	*Margariscus margarita*	Pearl Dace
PEAM	*Mylocheilius caurinus*	Peamouth
EMSH	*Notropis atherinoides*	Emerald Shiner
SPSH	*Notropis hudsonius*	Spottail Shiner
NRDC	*Phoxinus eos*	Northern Redbelly Dace
FNDC	*Phoxinus neogaeus*	Finescale Dace
FTMN	*Pimephales promelas*	Fathead Minnow
FLCH	*Platygobio gracilis*	Flathead Chub
LNDC	*Rhinichthys cataractae*	Longnose Dace
TRPR	*Percopsis omyscomacus*	Trout-Perch
BURB	*Lota lota*	Burbot
BRST	*Culaea inconstans*	Brook Stickleback
THST	*Gasterosteus aculeatus*	Threespine Stickleback
NNST	*Pungitus pungitus*	Ninespine Stickleback
SLSC	*Cottus cognatus*	Slimy Sculpin
SPSC	*Cottus ricei*	Spoonhead Sculpin
DPSC	*Myoxocephalus thompsonii*	Deepwater Sculpin
IWDR	*Ethiostoma exile*	Iowa Darter
YLPR	*Perca flavescens*	Yeloow Perch
WALL	*Sander vitreus*	Walleye

Appendix A.2: Biological data codes to be used with the field data sheets.

Assess Code	Assessment Type
FO-MR	Fish-out: Mark-Recapture phase
FO-CPUE	Fish-out: CPUE/Removal phase
FO-FREM	Fish-out: Final Removal phase
B-line	Base line sampling
AEMP	Aquatic Effects Monitoring Program

Gear Code	Gear Type
AN	Angling
BS	Beach seine
DN	Dipnet
EF	Electrofisher
GN	Gill net
MN	Minnow trap
TN	Trap net
OT	Other

Length Code	Length
F	Fork
T	Total

Sex Code	Sex
F	Female
M	Male
U	Unknown

Maturity Code	Maturity
IM	Immature
MA	Mature
SD	Seasonal development
UN	Unknown

Reprod Code	Reprod Status
GR	Green
RI	Ripe
RU	Running
SP	Spent
UD	Undeveloped
UN	Unknown

AgeStruct Code	Aging Structure
FR	Finray
OT	Otilith
SC	Scale
NO	None
CL	Cleithrum
OP	Operculum bone

Fate Code	Fate
NR	New, released marked
NM	New, mortality
RR	Recapture, released
RM	Recapture, mortality
E	Escaped unmarked

Tissue Code	Tissue Sample
ST	Stomach
MU	Muscle
LV	Liver
EG	Eggs
GO	Gonad
NO	None

Fin Code	Fin Clip
AD	Adipose
LPc	Left Pectoral
RPc	Right Pectoral
LPv	Left Pelvic
RPv	Right Pelvic
DO	Dorsal
AN	Anal
UC	Upper Caudal
LC	Lower Caudal

APPENDIX B

FIELD DATA SHEETS

Gear set data and fish sample record

Page___of___

Lake:	Set date:	Net Length (m):	Recorder:
Assessment type:	Set time:	Net Height (m):	Comments:
Gear type:	Lift date:	Net depth (m): /	
Site ID:	Lift time:	Surface temp:	
Easting:		Mesh size(s):	
Northing:	NAD: 83 27		

Species Code	Sample No.	Mesh Size (cm)	Length (mm)* F or T	Weight (g)	Sex	Maturity Code	Reprod Status Code	Aging Struct Code	Fin Clip	Fate Code	Tissue Sample Code	Liver Weight (g)	Gonad Weight (g)	Comments

*Total length (T) for burbot, sculpin, Stickleback sp.; Fork length (F) for all others.

Gear set data and fish sample record Page___of___

Lake:	Set date:	Net Length (m):	Recorder:
Assessment type:	Set time:	Net Height (m):	Comments:
Gear type:	Lift date:	Net depth (m): /	
Site ID:	Lift time:	Surface temp:	
Easting:		Mesh size(s):	
Northing:	NAD: 83 27		

Species Code	Sample No.	Mesh Size (cm)	Length (mm)* F or T	Weight (g)	Sex	Maturity Code	Reprod Status Code	Aging Struct Code	Fin Clip	Fate Code	Tissue Sample Code	Liver Weight (g)	Gonad Weight (g)	Comments

	Set date:	Net Length (m):	Recorder:
Assessment type:	Set time:	Net Height (m):	Comments:
Gear type:	Lift date:	Net depth (m): /	
Site ID:	Lift time:	Mesh size(s):	
Easting:	Northing:	NAD: 83 27	

	Set date:	Net Length (m):	Recorder:
Assessment type:	Set time:	Net Height (m):	Comments:
Gear type:	Lift date:	Net depth (m): /	
Site ID:	Lift time:	Mesh size(s):	
Easting:	Northing:	NAD: 83 27	

*Total length (T) for burbot, sculpin, Stickleback sp.; Fork length (F) for all others.

Gear set data and fish count record

Page___of___

Lake:	Set date:	Net Length (m):	Recorder:
Assessment type:	Set time:	Net Height (m):	Comments:
Gear type:	Lift date:	Net depth (m): /	
Site ID:	Lift time:	Surface temp:	
Easting:		Mesh size(s):	
Northing:	NAD: 83 27		

Species Code	Number Captured							Comments
	Fin clip	New, released marked	New, mortality	Recapture, released	Recapture, mortality	Escaped, unmarked	Total	

Biological data for some/all fish have been recorded on Fish Sample Record. Yes___ No___

Gear set data and fish count record

Page___of___

Lake:	Set date:	Net Length (m):	Recorder:
Assessment type:	Set time:	Net Height (m):	Comments:
Gear type:	Lift date:	Net depth (m): /	
Site ID:	Lift time:	Surface temp:	
Easting:		Mesh size(s):	
Northing:	NAD: 83 27		

Species	Number Captured							Comments
Code	Fin clip	New, released marked	New, mortality	Recapture, released	Recapture, mortality	Escaped, unmarked	Total	

Biological data for some/all fish have been recorded on Fish Sample Record. Yes___ No___

	Set date:	Net Length (m):	Recorder:
Assessment type:	Set time:	Net Height (m):	Comments:
Gear type:	Lift date:	Net depth (m): /	
Site ID:	Lift time:	Mesh size(s):	
Easting:	Northing:	NAD: 83 27	

Species	Number Captured							Comments
Code	Fin clip	New, released marked	New, mortality	Recapture, released	Recapture, mortality	Escaped, unmarked	Total	

Biological data for some/all fish have been recorded on Fish Sample Record. Yes___ No___

Appendix III – Cott et al. 2008. Effects of Water Withdrawal from ice-covered Lakes on Oxygen, Temperature and Fish

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EFFECTS OF WATER WITHDRAWAL FROM ICE-COVERED LAKES ON OXYGEN, TEMPERATURE, AND FISH[1]

Peter A. Cott, Paul K. Sibley, Andrew M. Gordon, R.A. (Drew) Bodaly, Kenneth H. Mills, W. Murray Somers, and Gerald A. Fillatre[2]

ABSTRACT: In northern regions, large volumes of water are needed for activities such as winter road construction. Such withdrawals, particularly from small lakes, can reduce oxygen concentrations and water levels, potentially affecting aquatic organisms. Withdrawal limits have been developed by regulatory agencies, but are largely theoretical. Water withdrawal thresholds were tested in two small lakes by removing 10% and 20% of their respective under-ice volumes and comparing oxygen parameters, temperature, over-wintering habitat, and northern pike (*Esox lucius*) abundance to reference conditions. Because of a milder winter, oxygen parameters were elevated in reference lakes in the period following withdrawal compared to the prewithdrawal period. The 10% withdrawal resulted in a −0.2 m shift in the oxygen concentration profile at 4 mg/l in that lake, but had no effect on total volume-weighted oxygen, or volume of over-wintering habitat. In contrast, the 20% withdrawal caused 0.7 m reduction in the oxygen concentration profile at 4 mg/l compared to the previous year, a 26% decline in the volume-weighted oxygen concentration, and a 23% reduction in the volume of over-wintering habitat compared to prewithdrawal conditions. Water temperatures were slightly (≤ 10%) colder in the upper strata in the year following the withdrawal in both withdrawal and reference lakes. Northern pike abundance was not impacted by water withdrawals in either of the lakes. The results of this study show that the effects of water withdrawal on the parameters investigated reflected the characteristics of the lakes, and would therefore be expected to vary from lake to lake. Policy development to mitigate impacts must therefore reflect the site-specific nature of water withdrawal.

(KEY TERMS: water withdrawal; ice roads; oil and gas; mining; Northwest Territories; water use; fish; fish habitat; oxygen; temperature; northern pike.)

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INTRODUCTION

Water withdrawal from lakes during the winter has the potential to affect aquatic biota (Gaboury and Patalas, 1984; Jansen, 2000; Turner *et al.*, 2005). In the Northwest Territories (NWT) resource development is increasing, with oil and gas exploration and diamond mining being the two most active industry sectors (Cott *et al.*, 2003; Birtwell *et al.*, 2005). Large-scale projects such as the Mackenzie Gas Project, a pipeline bringing Arctic gas to southern markets, require large volumes of fresh water for construction and development activities (IORLV, 2004). Due to the protracted winter in these northern regions, many developments occur during the winter, as it is possible to use the frozen terrain as a basis for land transportation with reduced impact on sensitive environments. Water is required for exploratory drilling, winter road, ice-bridge and ice pad construction, camp use (Baker, 2002; Miller, 2005; Nolan, 2005), and hydrostatic testing of pipelines (IORLV, 2004). Additionally, 40% of NWT's highway infrastructures are ice roads (GNWT, 2007). Winter roads have less inherent environmental impact than permanent roads because they are seasonal and constructed using clean ice and snow (Adams, 1978; Hinzman *et al.*, 2005), but are expensive to construct because of high fuel and transport costs in remote locations. Therefore, winter roads need to be constructed efficiently and close to water sources to be financially viable (Adams, 1978). Often the only available water sources are small lakes (< 50 ha) that serve as over-wintering habitat for fish. Due to their small size and ice captivity, such waterbodies often have limited winter volumes and normally do not have water inputs during the winter months to renew dissolved oxygen reserves. During the ice-covered period, there are no oxygen inputs from wave action and photosynthetic oxygen production is greatly reduced (Welch *et al.*, 1976; Wetzel, 2001). Winter oxygen reserves are further reduced by biologic oxygen demands, primarily from decomposition of organic material (Greenbank, 1945; Davis, 1975; Wetzel, 2001). Collectively, these conditions limit the available habitat for over-wintering fish when compared with open water conditions (Casselman, 1978; Stefan *et al.*, 2001).

For winter road construction, water is normally withdrawn using pumps (either at a fixed station or from multiple sources using water trucks) often with the intake positioned just under the ice surface. In winter, lakes often have the highest oxygen concentrations near the water-ice interface (Casselman, 1978). Withdrawing water from directly under the ice removes water from the most oxygenated zone of a lake. Low winter oxygen concentrations can seriously stress fishes and can lead to mass fish mortality known as "winterkill" (Greenbank, 1945). Fishes in low oxygen environments may survive the winter, but may experience sublethal effects and physiologic stress that will impede their ability to perform basic life requirements, such as foraging, which can affect growth, reproduction, and the long-term viability of the population (Evans, 2007). In addition, lowering water levels can cause deeper than normal freezing in the littoral zone, damaging benthic invertebrate and littoral plant communities, and destroying fish eggs (Jansen, 2000; McGowan *et al.*, 2005; Turner *et al.*, 2005).

The Department of Fisheries and Oceans (DFO) "DFO Protocol for Winter Water Withdrawal in the Northwest Territories" (DFO, 2005) (hereafter the DFO protocol) was developed as a tool to guide water withdrawal activities. The goal of the DFO protocol is to mitigate negative impacts to fishes by stipulating water withdrawal thresholds dependant on lake characteristics. Due to the limited information that was previously available, the DFO protocol was largely developed in the absence of science-based evidence that the prescribed thresholds are effective, and as such is conservative, utilizing principles of the precautionary approach (DFO, 2002). The DFO protocol defined limits to water withdrawal as a percentage of available under-ice volume, taking into consideration latitude and maximum water depth; ice thicknesses are prescribed for broad regions based on maximum ice thickness data. A 5% threshold was suggested for lakes with a maximum depth of ≥ 1.5 m plus the predicted maximum ice thickness. A 0% threshold is suggested for lakes with a maximum depth < 1.5 m plus the maximum predicted ice thickness, as any fish living in these shallow lakes could be particularly vulnerable to water level and oxygen perturbations. A threshold of up to 100% can be used if the maximum depth of the waterbody was less than predicted maximum ice thickness, as the waterbody would likely freeze to the bottom and preclude it from being over-wintering habitat for fish. No limit to withdrawal was suggested for large lakes due to the large volume of water available compared to the volumes required for ice road construction (determined on a lake by lake basis).

In a study examining the effects of water withdrawal at the Experimental Lakes Area (Lake 226 study) it was found that 30% and 45% winter water withdrawal from a Boreal Shield lake had significant impacts on lake whitefish abundance, benthos, and aquatic plants (Jansen, 2000; Mills *et al.*, 2002; Turner *et al.*, 2005). It is hypothesized that recruitment failures of lake whitefish were due to the desiccation and freezing of eggs because of the drawdown (Mills *et al.*, 2002). However, this study was designed to evaluate large-scale water level fluctuations associated with hydroelectric projects, and the authors did not investigate lower percentages of water removal which form the basis of the other water withdrawal threshold recommendations and policies reviewed (Berger, 1977; Miller, 2005; Nolan, 2005). Winter water reductions, even on the order of 45-50% of under-ice volume have not shown a marked effect on plankton or water chemistry in small-lake studies (Jansen, 2000; McGowan *et al.*, 2005; Turner *et al.*, 2005). In addition, effects on the littoral zone were correlated with the extent of ground-fast ice and impacts in this area can be assumed (McGowan *et al.*, 2005; Turner *et al.*, 2005).

In this study, the impacts of winter water withdrawal were assessed by removing 10% of the under-ice water from one small lake, and 20% from another and comparing changes in oxygen concentrations, temperature, over-wintering habitat, and fish population parameters to reference lakes. The objectives were to test the impacts of winter water withdrawal of volumes corresponding to industrial norms on fishes, by measuring indices of oxygen concentration, temperature, and fish population parameters. In addition, recommendations are made regarding practical winter water withdrawal thresholds that can be used by industry and regulators to minimize or avoid impacts to over-wintering fishes in small lakes from associated activities, such as winter road construction. The biotic focus of this study complements the winter water withdrawal studies being conducted on the Alaskan North Slope where the current focus is on hydrological and geochemical factors (Chambers *et al.*, 2007; White *et al.*, 2007a,b).

MATERIALS AND METHODS

Site Description

This study was conducted at DFO's Scientific Reserve, 30 km northeast of Yellowknife, NWT, situated on the Canadian Shield (Figure 1). The reserve is within the Taiga Shield ecozone, in the Tazin Lake Upland ecoregion, in the Yellowknife and Northeast Great Slave Lake secondary watershed, within the Arctic watershed. The area is underlain with Pre-Cambrian granitic bedrock, with an undulating landscape and a low slope gradient of 4-9%. The vegetation is primarily coniferous, dominated by black spruce (*Picea mariana*) and jack pine (*Pinus banksiana*), with shallow, well-drained mineral soils offering a rooting depth of 20-75 cm. The annual average temperature in the Yellowknife area is −5.4°C, with an average nighttime temperature of −29.9°C between December and February. The average total precipitation is 259.5 mm, and average maximum snowfall is between 30 and 49 cm (Natural Resources Canada, 2006). Small lakes in this area typically freeze over in early October with ice break-up occurring in the middle or latter part of May. Lakes in this area are nutrient poor with low biologic productivity, typical of many Pre-Cambrian Shield lakes (Healey and Woodall, 1973; Pientz *et al.*, 1997).

The initial reconnaissance of small lakes within and around the reserve boundary was conducted in the late summer and fall of 2004 to select appropriate lakes. Out of 51 small waterbodies that were surveyed, four study lakes were selected: Tees Lake, Lake Batwing, Sid Lake, and Blitzen Lake (Figure 1 inset). These are oligotrophic/oligo-mesotrophic lakes (Wetzel, 2001) of similar size ranging from 16.1 to 30.0 ha (Table 1), have similar positions in the watershed, do not have inlets, and have ephemeral outlets with the exception of Tees Lake, which drains through a culvert into an adjacent lake. Area and perimeter calculations were derived from the National Topographic Database using a resolution of 1:50,000. Habitat surveys were conducted during the summer of 2005 on Tees, Sid, and Blitzen lakes. Estimates (% cover) for substrate and vegetation were made, and coarse woody debris was noted. In general, the lakes have a narrow zone that is vegetated and with rocky substrates present. The majority of the substrate in these lakes is organic muck, especially Sid Lake where large (< 1m in diameter) mats of floating organic matter were observed. Tees, Sid, and Blitzen lakes support limited fish communities with northern pike (*Esox lucius*) as the top predator, while Lake Batwing has no fish populations (Table 2). Although not fish bearing, information collected from Lake Batwing is pertinent to this study, as it illustrates how a lake of a different basin shape, maximum depth, and volume responds to winter conditions relative to the other lakes.

Volume Estimates

To obtain water volume estimates, detailed bathymetric surveys were conducted in the summer of 2005 on Tees, Sid, and Blitzen lakes using narrow-beam hydrographic grade echo-sounding equipment with transect widths of approximately 25 m (see Cott *et al.*, 2005). No summer sampling or bathymetry was conducted on Lake Batwing as it is not likely fish bearing, and the information obtained from it is supplemental to the study. Target volumes of water to be

FIGURE 1. Winter Water Withdrawal Study Location, 30 km Northeast of Yellowknife, Northwest Territories, Canada. Inset—study lakes are: Tees Lake, Lake Batwing, Sid Lake, and Blitzen Lake. Tees Lake is located 16 km due south of Sid Lake.

TABLE 1. Location, Treatment, and Physical Characteristics of Study Lakes, Northwest Territories, Canada.

Lake	Treatment	Latitude	Longitude	Area (ha)	Perimeter (km)	Volume (m^3)	Z_{max} (m)
Tees Lake	Reference	62°33′30″	114°02′19″	16.9	2.2	879,200	7.3
Lake Batwing	Reference	62°40′49″	114°10′08″	20.3	4.1	ND	4.6
Sid Lake	10% withdrawal	62°41′72″	114°09′12″	30.0	5.8	538,300	6.8
Blitzen Lake	20% withdrawal	62°41′07″	114°09′49″	16.1	2.5	542,700	7.0

Note: ND, no data.

TABLE 2. Fish Species Occurring in Tees, Sid and Blitzen Lakes, Northwest Territories, Canada.

Species Name	Scientific Name	Lake
Northern pike	*Esox lucius*	Tees, Sid, Blitzen
Trout-perch	*Percopsis omiscomaycus*	Sid, Blitzen
Lake whitefish	*Coregonus clupeaformis*	Tees, Blitzen
Ninespine stickleback	*Pungitius pungitius*	Tees
Cisco	*Coregonus artedi*	Blitzen
Slimy sculpin	*Cottus cognatus*	Tees, Sid

withdrawn were calculated using the volume estimations coupled with maximum ice thickness data from the previous year. Actual water volumes were back-calculated using the maximum recorded ice thickness from 2006 for Sid and Blitzen lakes, incorporating a factor of 9% to accommodate the expansion of water as it transforms to ice. During the construction of bathymetric images, volumes of lake strata were calculated by removing "layers" of lake water in 1 m increments, and back-calculating to the true volume.

Water Withdrawal

Treatments were randomly selected, with Sid Lake being assigned the 10% withdrawal treatment, Blitzen Lake the 20% treatment, and Tees Lake and Lake Batwing, along with prewithdrawal Sid and Blitzen lakes, used to establish reference conditions. Water was withdrawn using a water pump, powered by a diesel engine. The intake hose consisted of 10 m of 12.2 cm (6 inch) rigid corrugated hose with the water intake positioned 1 m below the ice surface simulating a typical water withdrawal scenario. The water was discharged through approximately 300 m of 12.2 cm lay-flat hose. Withdrawal volumes were tracked using an analog meter expressing total volume in (gallons ×100) and rate (gallons per minute). Water withdrawal was initiated on February 17, 2006, on Sid Lake and continued for 10 days until 38,000 m^3 was withdrawn, or 9.4% of the lake's under-ice volume. Water withdrawal at Blitzen Lake commenced on February 28, 2006, and continued for 22 days until 85,090 m^3 was withdrawn amounting to 19.6% of the lake's under-ice volume. All water was transported outside the immediate catchment areas of each lake to avoid flow-back.

Water Chemistry

Chemical parameters were monitored on each lake on a monthly basis from December until mid-April during 2005 and 2006. Oxygen and temperature profiles were taken at a fixed station in the deepest basin of each lake using a Hydrolab® Quanta analyzer. The oxygen probe is of the polar graphic Clarke cell type. Profiles were also taken in July 2005 and July 2006 in Tees, Sid, and Blitzen lakes. Ice thickness and snow depths were monitored on each lake at the same frequency as the chemical parameter monitoring.

Volume-weighted mass for each lake was calculated by multiplying the volume for each meter of water per lake by the oxygen concentration measured at each meter (e.g., the volume of water between 1.0 m and 2.0 m was multiplied by the oxygen concentration measured at 1.0 m, and so on) and expressed as tonnes/lake (Quinlan *et al.*, 2005).

A similar method was used as an approximate estimate of overall over-wintering fish habitat (i.e., water containing oxygen concentrations of 4 mg/l or greater). An oxygen concentration value of 4 mg/l was selected as a minimum concentration to be viable over-wintering habitat for the average northern freshwater fish (Davis, 1975; Doudoroff and Shumway, 1970). The volumes for each 1.0 m layer of lake having at least this minimum oxygen concentration were added to give a relative estimate of overall over-wintering habitat per lake (m^3).

Fishes

Fishing was conducted using small mesh 6.4 mm (¼ inch) trap nets of a modified Beamish design (Beamish, 1972) and set during June 2005, August 2005, and June 2006. Three trap nets were employed per lake and were monitored every four to five days over a period of approximately 20 days. Trap nets are a passive and nonevasive sampling gear type. Fish are funneled with mesh fences to a large central holding box where fish remain until the net is fished. Sampling effort was supplemented with angling during the August 2005 and June 2006 sampling periods to minimize sampling bias from fish habituating to traps. Fishes were measured for length (to the nearest millimeter) and weight (to the nearest gram), respectively, and scale samples were taken. The first three rays of the right pectoral fin of northern pike captured were removed as an indication of catch, and these fish were batch-marked to identify the sample period using a soft fin ray scarring technique (Welch and Mills, 1981). Once processed, fish were released away from the trap nets to encourage mixing of marked and unmarked fish (Schneider, 1998), which also minimized individual fish being captured multiple times within the same capture period. A Chapman variation of the Petersen formula for bi-census was used to establish population estimates for northern pike in the fish-bearing study lakes before and after withdrawal (Ricker, 1975) with the assumptions required to perform the Peterson method met (Krebs, 1998). These estimates, along with catch-per-unit-effort (CPUE) were used to determine whether changes to fish populations occurred in conjunction with the withdrawals.

Statistics

Regression analysis and graphic presentation were performed using SigmaPlot®10 (Systat Softwear Inc, 2006). Variance, standard error, and confidence intervals for population estimates were calculated as per Krebs (1998).

Due to the scale and cost of this study, the use of multiple lakes to facilitate replicate withdrawals was not logistically feasible. It is often undesirable or unfeasible when studying large-scale systems, such as whole lakes, to apply replicated treatment experiments (Hulbert, 1984). As such, this experiment was designed as a comparative observational study (Kuehl, 2000). The primary strength of this study was the ability to test two different water withdrawal thresholds under realistic conditions (e.g., *in situ* whole ecosystem manipulations of natural lakes). Also, the environmental conditions during the study were analogous to conditions that would be faced during winter road construction or other water withdrawal activities.

RESULTS AND DISCUSSION

Effects of Water Withdrawal on Oxygen Concentrations

The oxygen concentration profiles for January show higher concentrations in 2006 than in 2005 for all lakes at most depths (Figure 2). The higher concentrations in 2006 were likely due to greater snow load and thicker ice in 2005 compared to 2006. For the most part, snow depths during this study were within the normal seasonal range for the area; however, total snowfall accumulation for 2005 was, on average, 27% greater than that in 2006. Despite the thicker blanket of snow in 2005, the mean ice thickness for the study lakes was 7% thicker in 2005 compared to 2006. Snow and ice depths have an inverse relationship with dissolved oxygen concentrations in lakes. Thicker ice and snow limit air-water oxygen exchange and effectively block light penetration and thereby reduce the ability for algae, phytoplankton, and vascular plants to photosynthesize and produce oxygen (Schindler, 1971; Welch *et al.*, 1976; Stefan *et al.*, 2001). Without adequate inputs of oxygen from waves, inlets, or photosynthesis, oxygen reserves in the lakes deplete through respiration of lake

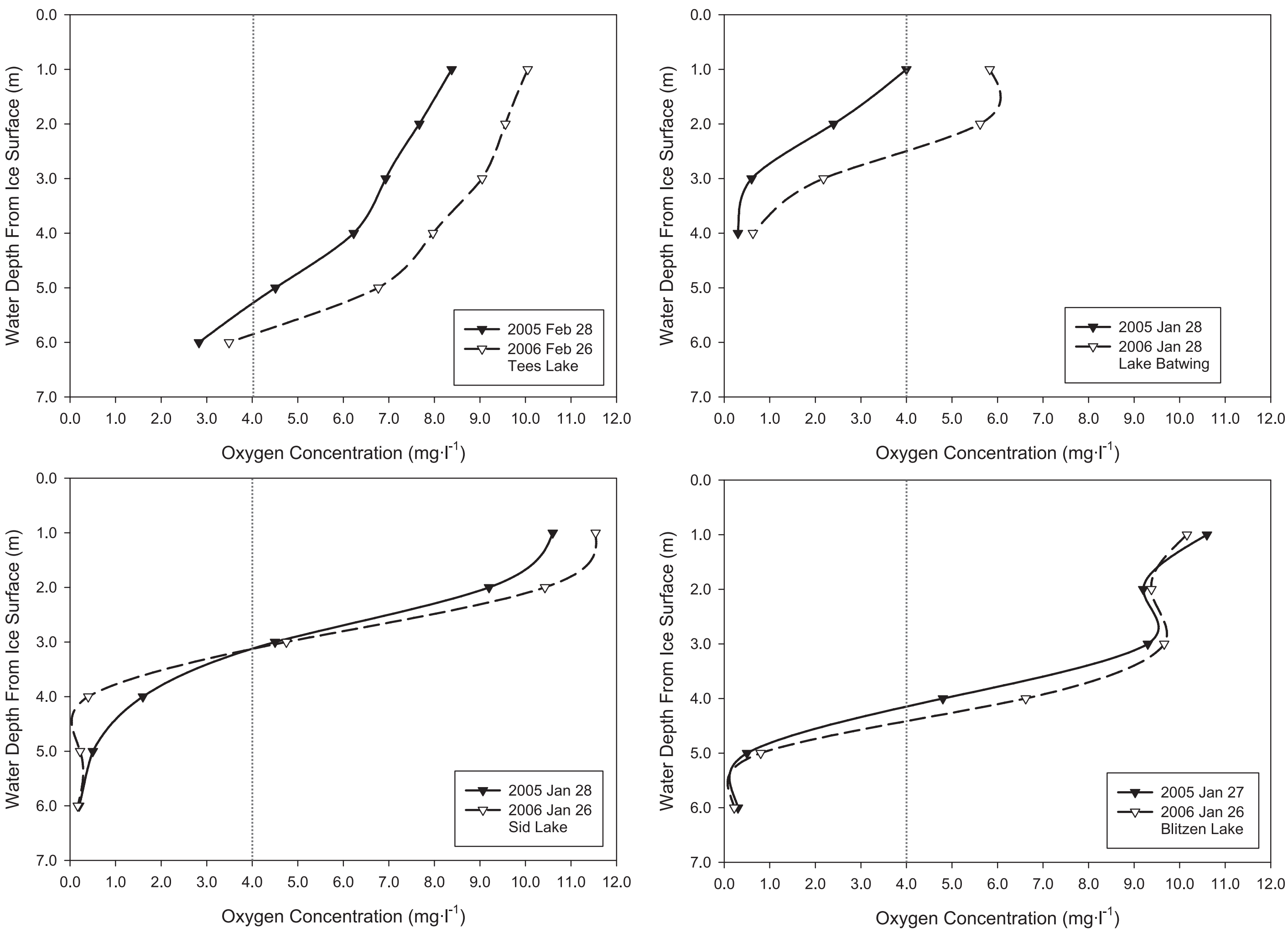

FIGURE 2. A Comparison of Oxygen Concentration Profiles in Study Lakes, Mid-Winter 2005 *vs.* Mid-Winter 2006, Before Water Withdrawals Had Occurred. For reference, the red vertical line delineates oxygen concentration of 4 mg/l, below which overwintering fishes may become stressed.

organisms, primarily through decomposers in lake sediments (Greenbank, 1945; Nelson and Paetz, 1992). Despite their differences in morphology, the 2005 oxygen concentrations remained lower than those in 2006 in both Tees Lake and Lake Batwing. However, this trend reversed in Sid and Blitzen lakes. These lakes were subjected to water withdrawal after the January 2006 profiles were taken and prior to April 2006 (Figure 3). The withdrawal from Sid Lake was approximately 10%, half that of Blitzen Lake, and the shift in the oxygen concentration responded accordingly with a smaller change than that observed in Blitzen Lake. Here, the shifts in oxygen concentration profile can be clearly seen. The 10% water withdrawal from Sid Lake resulted in a reduction in the oxygen concentration profile of 0.2 m at 4 mg/l than in the previous year, almost the same as that of the natural climate-driven influences of 2005 (Figure 3). After the 20% withdrawal in 2006, the Blitzen Lake oxygen concentration profile was 0.7 m shallower at 4 mg/l than in the previous year (Figure 3). This post-water withdrawal reduction in oxygen concentration occurred despite the more favorable winter conditions (less snow and ice) of 2006. This is in contrast to Tees Lake and Lake Batwing which both had a shallower oxygen concentration profile in 2005 than in 2006, despite the pronounced differences in their lake depths and oxygen content (Figure 3).

Similar trends were observed when comparing the volume-weighted mass of oxygen for each lake between years (Figure 4). The estimated total volume-weighted mass of oxygen in each of these lakes (tonnes/lake) in 2005 was compared with that of 2006 for January (February for Tees Lake) and April, respectively. With the milder winter, all lakes held more oxygen in January 2006 than in January 2005

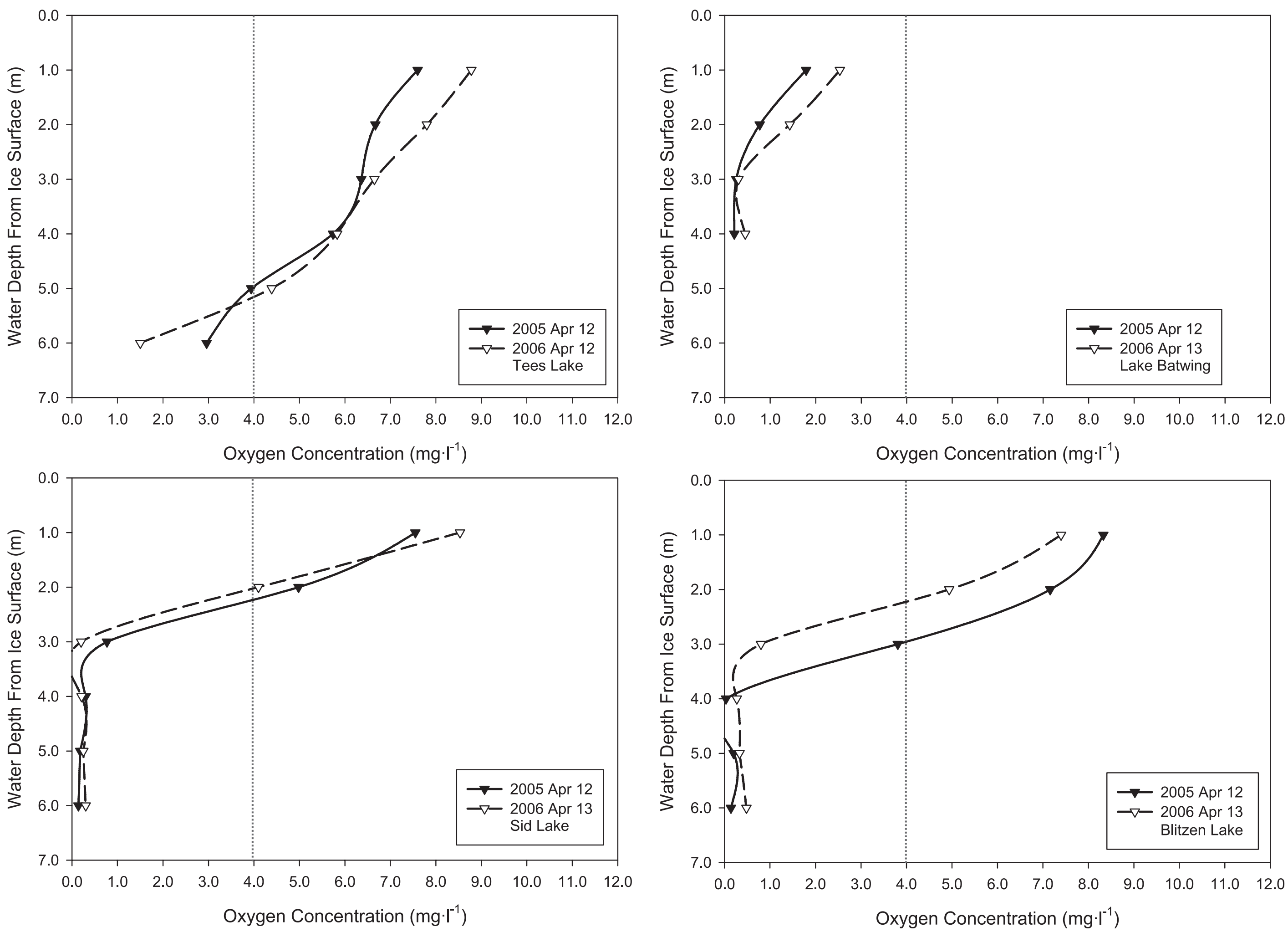

FIGURE 3. A Comparison of Oxygen Concentration Profiles in the Study Lakes, April 2005 *vs.* April 2006. April 2006 represents postwater withdrawal profiles for Sid and Blitzen lakes. For reference, the red vertical line delineates oxygen concentration of 4 mg/l, below which overwintering fishes may become stressed.

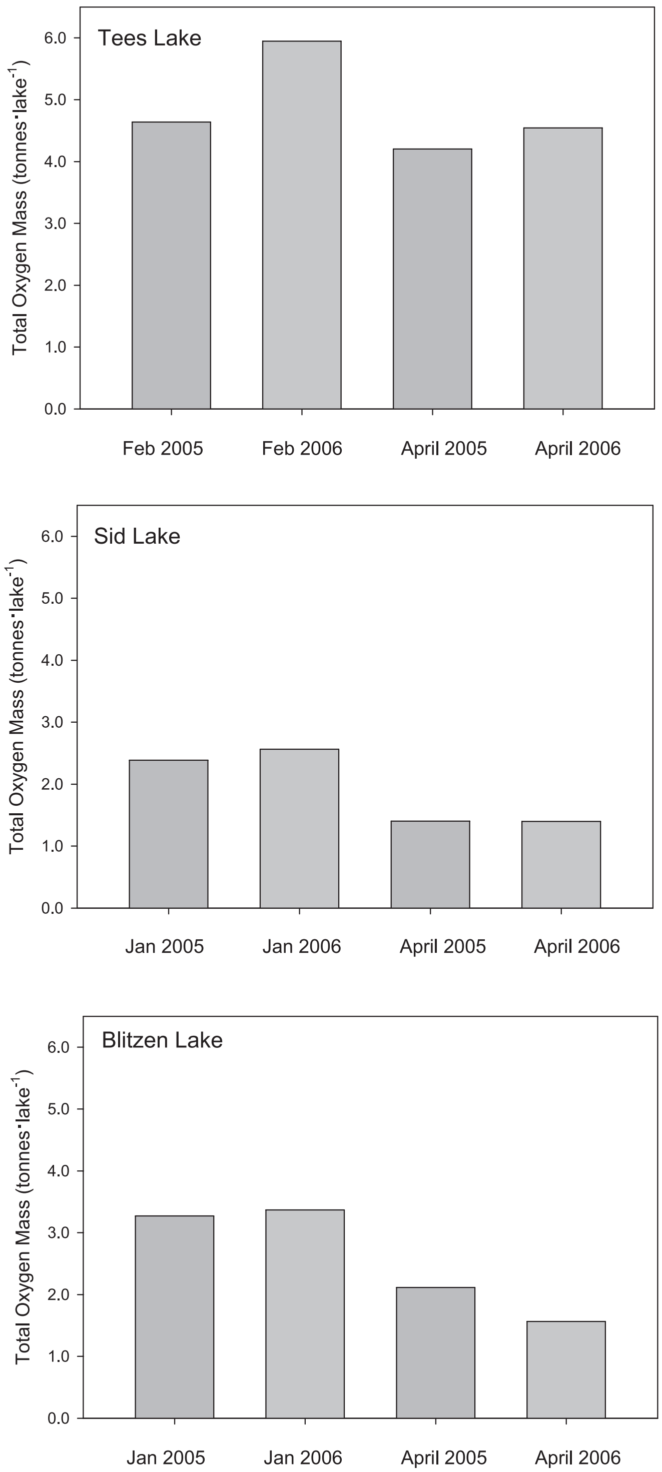

FIGURE 4. A Comparison of Total Volume-Weighted Oxygen in Tees, Sid, and Blitzen Lakes for Different Sampling Periods. April 2006 represents the postwater withdrawal condition of Sid and Blitzen lakes. Note that Tees Lake has a greater total basin volume than Sid and Blitzen lakes.

with 128%, 107%, and 103% of the previous years total oxygen for Tees, Sid, and Blitzen lakes, respectively (Figure 4). The total volume-weighted mass of oxygen in Tees Lake for April 2006 was also greater than that of the same month in the previous year, at 108% (Figure 4).

Upon the 10% water withdrawal of Sid Lake in February 2006, again this lake behaved very similar to how it did in the harsher winter of 2005 with the April 2006 oxygen mass being 99% of April 2005 mass. The impact was more pronounced in Blitzen Lake following the 20% water withdrawal with the volume-weighted oxygen mass in April 2006 being only 74% of that in 2005 (Figure 4).

These results suggest that if winter water withdrawal was conducted in a year that also had adverse environmental conditions, the withdrawal could further reduce oxygen concentrations and increase stress to overwintering fish populations. Lakes that support oxygen-sensitive fish species would normally have sufficient depth and oxygen concentrations for those fishes to survive through even the most severe winters, as evident by the presence of those species in such lakes. In lakes where sensitive fish species occur, but live precariously close to their oxygen thresholds, reductions in oxygen concentrations from water withdrawals, like those in Blitzen and Sid lakes, can compound natural depletions. If natural depletions in oxygen concentrations are aggravated further, by a longer winter for instance, removing more oxygen through winter water withdrawal may induce winterkill. Sid Lake appeared to be somewhat resilient to a water withdrawal of 10%, but appears to be on the cusp of a shift. Under natural conditions, Blitzen Lake holds more oxygen than Sid Lake, 27% more in January 2005, 33% more in April 2005, and 29% more in January 2006. Yet in April 2006, after withdrawal, Blitzen Lake had only 11% more oxygen than Sid Lake. Doubling the water withdrawal from 10% to 20%, increased depletion of oxygen by 67%. It is likely that this depletion would have been greater if the 20% withdrawal was conducted on the less oxygenated Sid Lake. Lakes that may be marginal as over-wintering habitat for sensitive species should be avoided as water sources for winter withdrawals, and a "worst case" scenario of ice and snow cover should be assumed as a margin for an extreme winter. In normal weather years, lakes that support only species tolerant of low oxygen, such as ninespine stickleback, would not be sensitive to winter water withdrawal, as these fish may have survived natural oxygen fluctuations that would kill more sensitive species. However, ninespine stickleback are tolerant of a wide variety of habitat types, including lakes with abundant winter oxygen reserves (Scott and Crossman, 1973), and as such their presence should not imply the absence of oxygen-sensitive fish species in a waterbody.

Effects of Water Withdrawal on Temperature

Water temperatures were lower in all lakes in January 2006 than in 2005 (Figures 5 and 6), the exception being the April profile of Lake Batwing (Figure 6). The slightly warmer 2005 water temperatures may be a result of increased insulation offered by the thicker snow cover in 2005 compared to 2006. Water temperatures were also lower in April 2006 than the previous year in Tees Lake; however, the temperature profiles for the other lakes, including Lake Batwing, indicate warmer lake waters in April 2006 compared to the same month in 2005 (Figure 6). These changes may be natural, like in Lake Batwing, or possibly a result of the cooler upper layers of water being withdrawn and leaving only the comparatively warm water from deeper in the lake. Dissolved oxygen is retained more effectively in cold water, with optimal oxygen retention at 4°C when water is densest (Wetzel, 2001), and fish have lower metabolic rates at colder temperatures, thus requiring less oxygen (Evans, 2005).

Water temperatures only responded with minor shifts following the 10% and 20% water withdrawals in the study lakes when compared with the previous year. The temperature profiles for Sid and Blitzen lakes for April 2006 were 10% and 8% warmer (maximum), respectively, than for April 2005. The reason for warmer water temperatures in Lake Batwing in April 2006 compared to April 2005 is not certain. None of the shifts were not outside normal variation and would not likely have an influence on the fishes in the lakes. Large-scale winter water withdrawals can break stratification altering the temperature regime in a lake (Heman *et al.*, 1969). If the temperature regime in a lake was altered to a large degree, the metabolism of fishes could be affected, which would then impact life processes, such as growth and

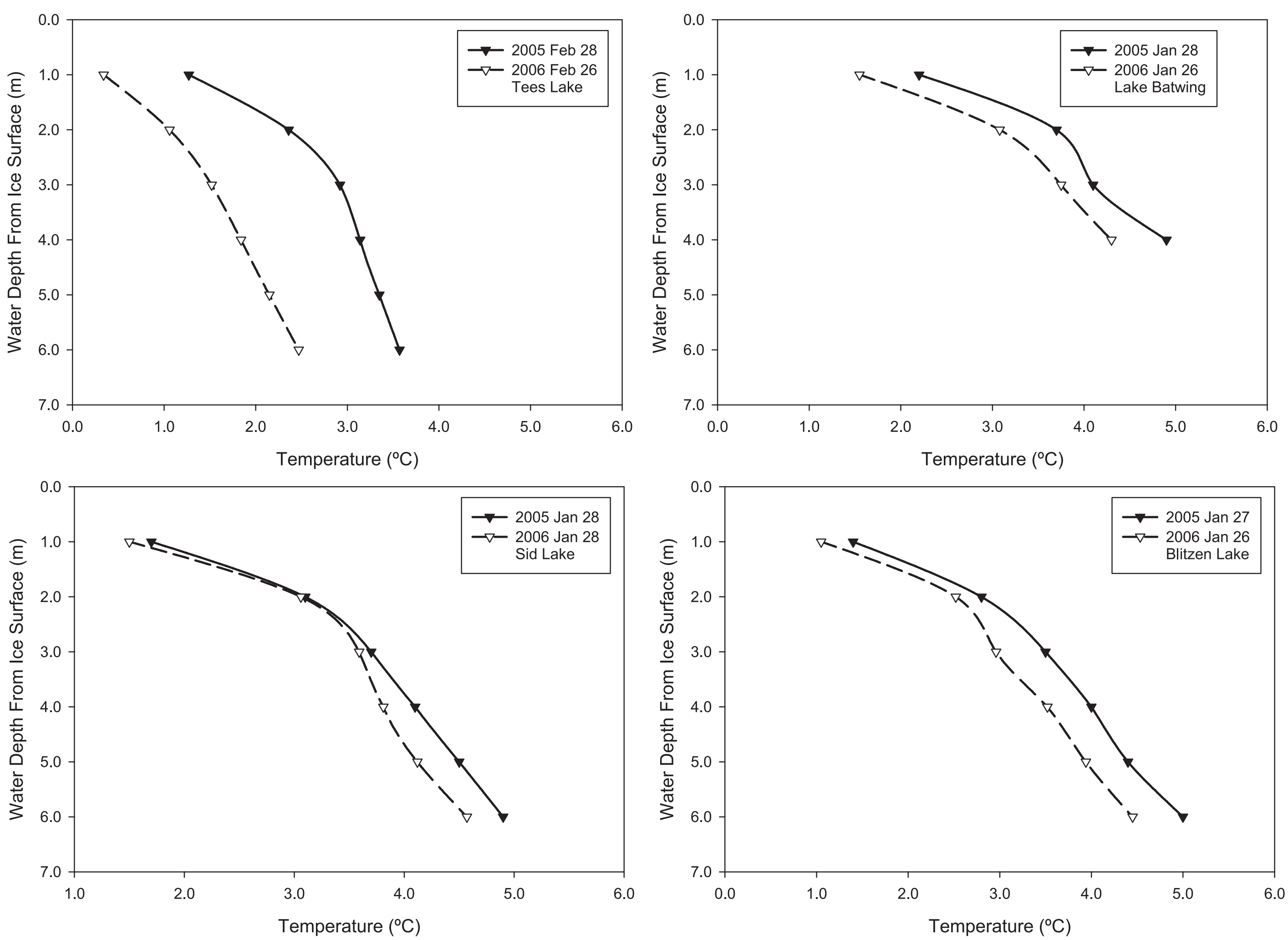

FIGURE 5. A Comparison of Temperature Profiles in the Study Lakes, Mid-Winter 2005 *vs.* Mid-Winter 2006. No water withdrawals had occurred on any of the lakes.

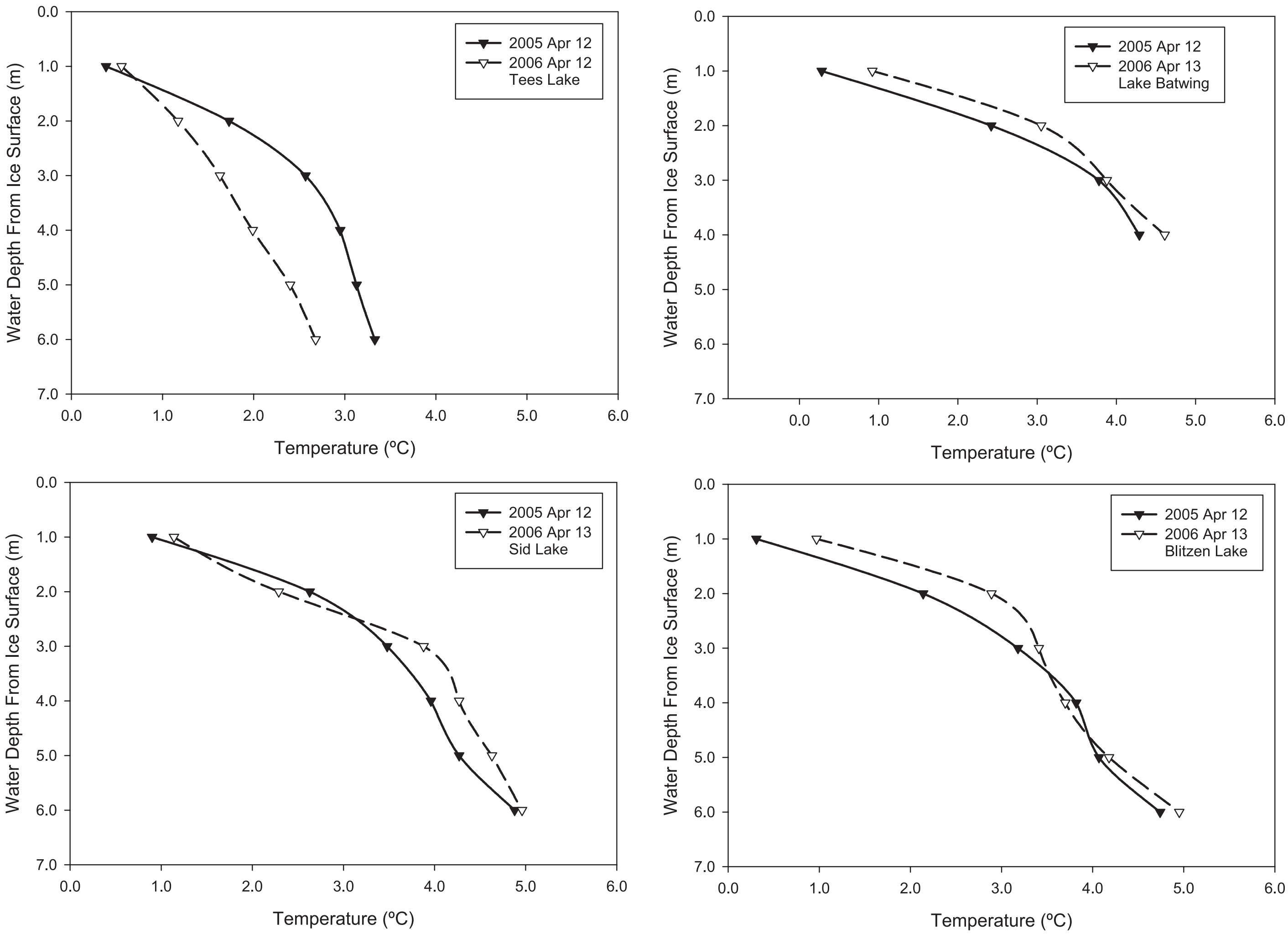

FIGURE 6. A Comparison of Temperature Profiles in the Study Lakes, April 2005 *vs.* April 2006. April 2006 represents postwater withdrawal profiles for Sid and Blitzen lakes.

reproduction (Evans, 2005). However, the data of this study indicate that the aforementioned scenario is unlikely to occur from normal winter water withdrawals for the purpose of winter road construction-related activities in the types of lakes studied.

Effects of Water Withdrawal on Overwintering Fish Habitat

For the purposes of this estimation, available overwintering habitat was defined as volumes in lakes below the late (April) winter ice where the water column has an oxygen concentration of approximately 4.0 mg/l or greater. Below this concentration many freshwater fishes may experience physiologic stress (Doudoroff and Shumway, 1970; Davis, 1975; Stefan *et al.*, 2001). Fishes will use areas of lowered oxygen concentrations if required, for instance, for feeding or predator avoidance (Magnuson and Karlen, 1970; Evans, 2005). Therefore, the volumes of available habitat discussed below are not finite, as different fish species have different oxygen thresholds, but are within a range that most fishes require to carry out regular life processes.

Tees Lake had the largest basin volume of the three lakes measured with an overall volume that is approximately 40% larger than both Sid and Blitzen lakes (Table 1). The volume of overwintering habitat in Tees Lake was 10% higher during February 2006 than in February 2005. The habitat volume was the same in April for both years, which was also the same as in February 2005 (Figure 7). The minimum volume of overwintering habitat for Tees Lake during the study period was approximately 650,000 m^3, or 74% of the lakes total volume in open water conditions. In Sid Lake, the volume of overwintering habitat decreased by 21% between January and April.

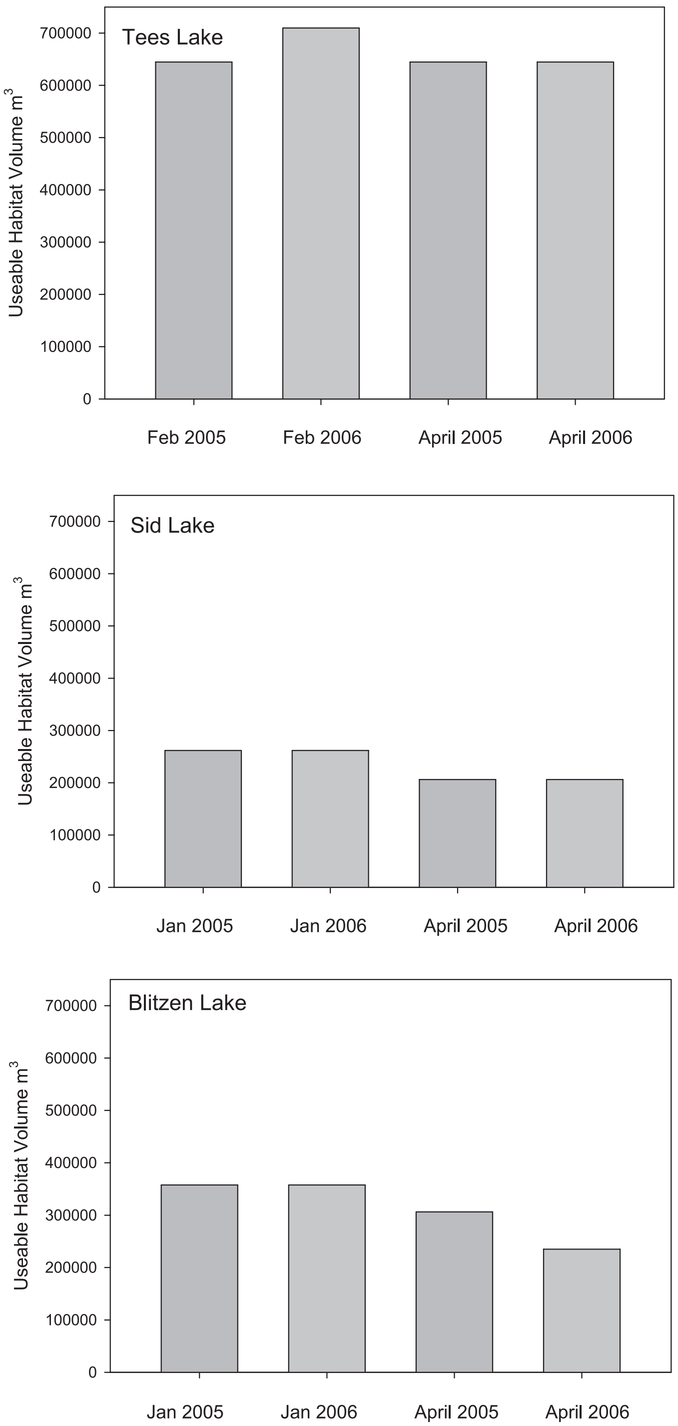

FIGURE 7. A Comparison of Total Available Overwintering Habitat in Tees, Sid, and Blitzen Lakes for Different Sampling Periods. April 2006 represents the postwater withdrawal condition of Sid and Blitzen lakes. Note that Tees Lake has a greater total basin volume than Sid and Blitzen lakes.

This was consistent between years with no change detected at this scale after withdrawing 10% of the lakes under-ice volume (Figure 7). The overwintering habitat remaining in April of both years was 21,000 m^3, only 38% of the lake's total volume in open water conditions (Figure 7). Like Sid Lake, the amount of overwintering habitat in Blitzen Lake was greater in January than in April for both years and was the same in January between years. However, there was 14% less overwintering habitat in April 2005 than in January, and 34% less in April 2006 following 20% water withdrawal (Figure 7). The volume of late winter overwintering habitat, expressed as a percentage of the lake's open-water volume, dropped from 56% in 2005 to 43% following water withdrawal in 2006. These results show that impacts from the 20% water withdrawal on overwintering habitat are apparent even when using a coarse indicator such as estimated overwintering habitat volume.

Ice subsided in Sid and Blitzen lakes because of the lowering water levels from the withdrawals. Due to the large surface area to volume ratio of Sid Lake (Table 1), the water level only lowered by about 10 cm (the depth difference between January and April, measured from the top of the ice). In comparison, the water level in Blitzen Lake dropped by approximately 55 cm. The difference in water level, which partially reflected basin morphology, underscored a potentially important impact of water withdrawal: exposure of littoral areas. The area of littoral zone devoid of water and/or exposed to ground-fast ice from lowering water levels would be dependant on the slope of the littoral zone and the amount of water withdrawn.

Littoral zones are often the most productive areas of lakes and serve as critical feeding and breeding areas for many fish and invertebrate species (Scott and Crossman, 1973; Bronmark and Hansson, 2005). Extreme winter water withdrawals have been shown to affect littoral vegetation, benthic invertebrates, and over-wintering fish eggs (Jansen, 2000; Mills *et al.*, 2002; Turner *et al.*, 2005). If water is drawn down to the extent that lake levels do not return to regular spring levels, fishes and other aquatic organisms that rely on flooded supra-littoral areas for breeding and foraging could be significantly affected. For example, northern pike spawn shortly after ice out on flooded terrestrial vegetation (Inskip, 1982). If the shoreline does not flood, pike would be forced to spawn on less suitable habitat and this may affect recruitment (P.A. Cott, Fisheries and Oceans Canada, 2007, unpublished data).

Effects of Water Withdrawal on Fishes

Fishes were captured in Tees, Sid, and Blitzen lakes in the year preceding and following winter water withdrawals (Table 3). Water withdrawals did not affect the abundance of northern pike. Abundance

TABLE 3. Northern Pike Abundance Estimates for Tees, Sid, and Blitzen Lakes.

Lake/Year	NRPK/ Lake	NRPK/ ha	SE	d.f.	70% CI	95% CI
Tees 2005	67.9	4.0	20.37	23	46.3-89.5	25.6-110.2
Tees 2006	273.6	16.2	103.67	34	164.6-382.6	62.8-484.4
Sid 2005	158.4	5.3	33.65	52	123.17-193.6	90.86-225.9
Sid 2006	168.31	5.6	23.73	42	143.4-193.2	120.4-216.2
Blitzen 2005	71.4	4.4	18.01	32	52.4-90.4	34.7-108.1
Blitzen 2006	82.1	5.1	18.86	28	62.2-102.0	43.5-120.7

Note: NRPK, Northern pike.

estimates for Sid and Blitzen lakes were similar between the prewithdrawal and postwithdrawal years (Table 3) with postwithdrawal abundance being 5% and 14% higher for Sid and Blitzen lakes, respectively. In the withdrawal lakes, oxygen concentrations, and the volume of overwintering habitat, remained suitable in upper water strata under ice to support overwintering northern pike (Figure 3). Northern pike abundance estimates for Tees Lake were hampered by compromised data as river otters (*Lutra canadensis*) fished the nets in 2005, until they became entangled, requiring the nets to be pulled from the lake. As a result the confidence intervals for Tees Lake were very large and the abundance estimated for 2006 was 75% greater than that of 2005 (Table 3). In 2006, floats were placed in traps to provide airspace in the event a mammal or bird was accidentally captured. This technique has been used successfully by commercial fishermen to prevent drowning of turtles trapped in hoop nets (Colin Lake, Fisheries Biologist, Ontario Ministry of Natural Resources, personal communication, August 2005).

In Tees Lake, the trap net CPUE for northern pike was 27% greater in 2006 than in 2005. This increase in fishing success for 2006 is likely due, in part, to the reduced otter effect compared to the year prior (Table 4). The trap net CPUE for both Sid and Blitzen lakes was lower postwithdrawal than prewithdrawal with a 64% decline in trapping success in Sid Lake and 42% less for Blitzen Lake (Table 4). The discrepancy between the large change in CPUE, and the small change in abundance estimates can be explained by the habituation of fishes to passive fishing gear such as trap nets and avoiding them. Catches of northern pike were supplemented with angling, and with angling being a different sampling method, angling catches were not included in trap net CPUE calculations. However, all northern pike collected, regardless of method, were used for abundance estimates. Trout-perch (*Percopsis omiscomaycus*) were caught 34% less frequently in Sid Lake after water withdrawal, and the CPUE for Blitzen Lake was also lower, by 22%, in 2006 (Table 4). Cisco (*Coregonus artidi*) (n = 7) were collected in Blitzen Lake before but not after withdrawal. However, one juvenile lake whitefish was collected postwithdrawal. Cisco and lake whitefish, like other Coregonids and Salmonids, require relatively high oxygen concentrations to survive (Nelson and Paetz, 1992). The presence of fish species sensitive to low oxygen indicates that the minimal observed effect on northern pike was not simply a result of investigating a low oxygen-tolerant species. Although there were fewer cisco caught in 2006 after withdrawal, the small sample of both years makes inferences of potential effects unreliable.

TABLE 4. Catch-per-Unit-Effort (CPUE) for Northern Pike and Trout-Perch Collected in Trap-Nets From Tees, Sid, and Blitzen Lakes.

Lake	Sample Period	Northern Pike NRPK/ h	Northern Pike NRPK/ Day	Trout-Perch TRPR/ h	Trout-Perch TRPR/ Day
Tees	2005 June	0.02	0.37	ND	ND
Tees	2006 June	0.02	0.49	ND	ND
Sid	2005 June	0.03	0.84	0.15	3.54
Sid	2006 June	0.01	0.30	0.96	2.32
Blitzen	2005 June	0.01	0.36	1.66	39.87
Blitzen	2006 June	0.01	0.21	1.29	31.02

Note: ND, no data; NRPK, Northern pike; TRPR, trout-perch

Northern pike are tolerant of low oxygen conditions but may succumb in oxygen concentrations of ≤ 2.3 mg/l (Doudoroff and Shumway, 1970). It is important to realize that fish survival does not mean that fishes will not be affected by a reduction in oxygen. Reduced oxygen can have sublethal effects on fish manifesting in a reduced capacity to carry out regular life processes, such as feeding. This can have repercussions on growth and reproduction and the long-term health of the fish population. Evans (2007) found a sharp decline in lake trout recruitment when the mean hypolimnetic oxygen was reduced from 7 to 4 mg/l, and significant effects to lake trout growth and metabolism with a reduction of oxygen concentration to just 6 mg/l.

Fishes in shallow lakes with long-lasting ice-cover (6 months or more) may be vulnerable to hypoxia (Evans, 2005), although under natural conditions, winterkill is unlikely to occur in lakes deeper than 5 m (Nickum, 1970), such as Sid, Blitzen, and Tees lakes. Partial winterkill can greatly reduce fish abundance and change the aquatic community by inducing trophic shifts. Large fishes, such as northern pike, are usually also top-level predators, and are often more susceptible to oxygen depletion than small fish (Casselman and Harvey, 1975). If these fish succumb as a result of depleted oxygen, the outcome may be a cascade in the trophic structure in the lake. Like many northern lakes, Sid and Blitzen are isolated, with no possibility of mixing or introductions of new populations from other lakes. If a complete winterkill were to occur in such a waterbody, the effect would be permanent, as the fish would be extirpated from the lake. This may have occurred at some time in the shallower Lake Batwing.

With the onset of spring, water from melting snow, ephemeral and seasonal streams, wind-induced wave action, and increasing photosynthetic activity will introduce oxygenated water back into the lakes (Wetzel, 2001). The effects of water withdrawal on oxygen concentrations would not persist past the ice-covered season; however, the effects on fishes from lowered oxygen may be long lasting or permanent.

CONCLUSIONS

In Sid Lake, a winter water withdrawal of approximately 10% of the under-ice volume had an impact on the oxygen concentration profile similar to the climate-related effect of the prior winter. No changes were observed with total volume-weighted oxygen or the volume of overwintering habitat following the 10% withdrawal. When compared with the prior year, the 20% winter water withdrawal from Blitzen Lake resulted in a shift in the oxygen profile that was 0.7 m shallower, reduced the volume-weighted oxygen by 26%, and reduced the overwintering habitat by 23%. Temperature did not appear to be affected by either level of water withdrawal treatments. The abundance of adult northern pike was not affected by the water withdrawals or by changes to oxygen concentrations or temperature induced by withdrawals in either lake. Whether the reductions in oxygen observed in this study would be harmful to fishes in other lakes or not would depend on the characteristics of the particular lake (e.g., basin shape, lake chemistry, substrate type, species composition) as well as environmental conditions such as snow load, ice thickness, and temperature. However, if coupled with precautionary measures, a withdrawal threshold of 10% can be used with minimal risk to over-wintering fishes. A withdrawal of 20% of the under-ice volume of a lake is more likely to deplete the oxygen concentrations to a level that is harmful to over-wintering fishes, particularly if the oxygen budget in the lake is being stressed by environmental or (and) anthropogenic factors, in addition to the withdrawal. Precautionary mitigative measures include: identifying and selecting nonfish-bearing waterbodies as water sources, using very large waterbodies and avoiding sensitive overwintering fish habitats, using only the maximum ice thickness in a region for lake volume calculations, estimating water volumes using detailed bathymetric surveys, and establishing site-specific thresholds based on the overwintering requirements of the most sensitive fish species. Also, water intakes should be positioned lower in the water column, drawing water of a lower oxygen concentration than that from directly under the ice.

It must be stressed that the conclusions of this study are specific to these lakes and inferences should only be applied to lakes with similar physical, chemical, and biologic characteristics. However, in the absence of information obtained through detailed limnological assessments of all possible lake types, applying precautionary mitigative measures, such as those outlined above, to regionally specific water withdrawal thresholds, can reduce the risk to overwintering fishes from winter water withdrawal activities. The general trends observed in this study can be used to aid decision making for water withdrawal in other lakes as presented in Cott *et al.* (2008).

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