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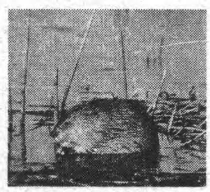
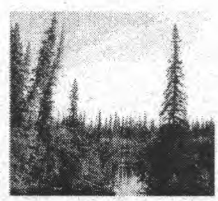
Northern River Basins Study



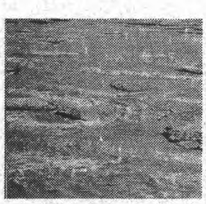


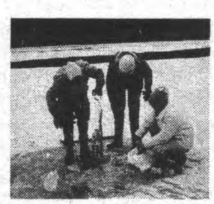




NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 91

DISSOLVED OXYGEN REQUIREMENTS FOR FISH OF THE PEACE, ATHABASCA AND SLAVE RIVER BASINS: A LABORATORY STUDY OF BURBOT (*Lota lota*)






DATE DUE

Prepared for the
Northern River Basins Study
under Project 3221-D1

by

M. A. Giles, S. B. Brown, M. Van der Zweep,
L. Vandenbyllaardt, G. Van der Kraak* and K. Rowes
Department of Fisheries and Oceans, Freshwater Institute and
*Department of Zoology, University of Guelph, ON

NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 91

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
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F. J. Wrona — 14 Feb 96

(Dr. Fred J. Wrona, Science Director) — (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
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this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

P. A. Larkin — 14 Feb 96

(Dr. P. A. Larkin, Ph.D., Chair) — (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

Lucille Partington — 14/02/96

(Lucille Partington, Co-chair) — (Date)

Robert McLeod — 14/02/96

(Robert McLeod, Co-chair) — (Date)

DISSOLVED OXYGEN REQUIREMENTS FOR FISH OF THE PEACE, ATHABASCA AND SLAVE RIVER BASINS: A LABORATORY STUDY OF BURBOT (*LOTA LOTA*)

STUDY PERSPECTIVE

Diminishment of dissolved oxygen (DO) in waters that experience ice cover during winter is a common occurrence. DO is essential for the survival of many life forms that exist in the aquatic environment. Prior to the beginning of the Northern River Basins Study, concerns were identified over dissolved oxygen (DO) levels in northern rivers and its effect combined with effluent on fish inhabiting these receiving waters. The effect of contaminants and their affects on a fishes ability to deal with reduced levels of DO was largely unknown.

DO was identified as an area of concern and a 3 step approach was taken to answer the Study Board question. The steps included: literature review, laboratory investigations, field studies. In the initial step, a determination was made of what was already known about the oxygen requirements of fish species inhabiting the waters of the study area. From that project came a series of recommendations on fish species requiring additional work. Those species included: bull trout, mountain whitefish, burbot, rainbow trout and longnose sucker. Four of the identified species are fall spawners and their eggs develop under ice cover.

Related Study Questions

6 What is the distribution and movement of fish species in the watersheds of the Peace, Athabasca and Slave rivers? Where and when are they most likely to be exposed to changes in water quality and where are their important habitats.

7 What concentrations of dissolved oxygen are required seasonally to protect the various life stages of fish, and what factors control dissolved oxygen in the rivers?

14 What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems? These programs must ensure that all stakeholders have the opportunity for input.

This report chronicles the findings of a second laboratory investigation into the response of burbot spawners and their developing eggs to low DO levels and low water temperatures. Because burbot spawn in the late winter under ice cover (broadcast eggs **onto** substrate) they are not readily available. Consequently, there was anticipated to be a significant risk in assuming the capture of sufficient mature burbot in spawning condition to extract the required spawn. Combined with the fact that diminished DO levels during periods of ice cover may also affect the development of eggs and spawn within adult spawners, the laboratory design was modified to include the monitoring of adults under laboratory conditions. Since much of the published DO literature deals with fish species not common to the Study area and typically involves water temperatures not found under ice cover conditions, a decision was made to undertake an investigation of spawners and eggs.

Difficulties were encountered in obtaining a sufficient supply of burbot spawners and eggs to investigate gonad maturation and egg development under different DO concentrations. Spawners and eggs were only subjected to 6 mg/l concentrations of DO and the results were inconclusive. However, preliminary observations suggest that burbot subjected to 6 mg/l altered / delayed their spawning. Additionally, there appeared to be some delay in the timing of hatching and diminished viability of burbot eggs and sperm. Recommendations for additional laboratory work are made and will be reflected in the science recommendations provided to the Study Board.

REPORT SUMMARY

Adverse effects of low environmental oxygen tensions on fish reproduction represents a distinct possibility in the Athabasca and Peace drainages. Species spawning in the late fall and winter would be the most likely to be impacted by low dissolved oxgen (DO) because developing eggs and larvae would be subjected to the full extent of hypoxia during the winter (Giles and van der Zweep 1996). In particular, burbot spawn under the ice in mid- to late-winter, mainly from January to March and their gonadal development occurs in the fall and early winter. The winter habitat of burbot is not well known but it is likely that many move to the tributaries of major rivers (and away from hypoxic conditions) for spawning. It is also probable that some populations reside in the major river channels throughout all or part of the ice-covered period.

This project represents a step towards the larger goal of providing criteria to assess the impact of reduced levels of dissolved oxygen upon the survival and biological state of selected fish species residing in the Northern River Basins Study Area. The study objective was to define the temporal changes in reproductive hormones, identify changes in blood electrolytes, hemoglobin, hematocrit, and blood oxygen content, and evaluate the viability of the eggs and sperm for this species during the period of sexual development under normoxic and hypoxic conditions. The results evaluate the potential of realistic winter water temperatures (3°C) and hypoxic condition (O_2=6.0 mg/L; 45% air saturation) to impair reproductive performance and induce stress in spawning burbot in the Northern River Basins Study Area. Hypoxic conditions were similar to the lowest levels reported in the upper Athabasca River (Chambers et al. 1996). Blood hematocrit and hemoglobin measurements assessed the carrying capacity of the gas transport system. Plasma electrolytes and glucose were used to monitor potential ionoregulatory disturbances and associated stress under hypoxic conditions. In addition to spawning activity, embryo survival, and larval development reproductive parameters analyzed included adult steroid hormones (17ß-estradiol, testosterone & 11-ketotestosterone) as well as attempts to determine gonadotropin II (GTH II) and vitellogenin.

Comparison of burbot exposed to hypoxic and normoxic conditions showed few consistent treatment-related differences in blood hematocrit and hemoglobin or plasma electrolyte balance and glucose. Thus, the hypoxic conditions (6 mg/L DO) used lie within the compensatory scope of homeostatic processes in burbot. However, the metabolic costs of this compensation remain to be established for the longterm.

Spawning activity suggested that the period of spawning could be extended by as much as 5 weeks in at least some burbot exposed to hypoxic conditions. While maintinance of maturing burbot under hypoxic conditions produced only minor changes in the reproductive steroids, the differences were consistent with the extended spawning. There may be several reasons for the extended spawning activity but given the strong behavioral reactions of fish to low DO (reviewed in Barton and Taylor 1996), interactions between hypoxic conditions and spawning behavior merit investigation.

Survival of eggs incubated from the early spawn dates were variable and unrelated to either the source of the eggs or the dissolved oxygen concentration during embryological development. Consistent with previous observations in mountain whitefish (Giles and van der Zweep 1996), the

hypoxic incubation conditions did seem to extend the time required for hatch. However, indices of embryological development were unaffected by incubation conditions. Eggs produced from delayed spawnings of hypoxic fish did not survive, possibly suggesting a problem with gamete viability or fertilization.

Because it proved impossible to burbot manually strip eggs from female burbot, difficulties were encountered in following individual spawners and their gametes. Thus, observations about the effects of hypoxic conditions on spawning activity, embryo survival, development and hatch are regarded as preliminary.

This study represents the first attempt to perform a detailed investigation of burbot reproduction. Future investigations need to consider that it is extremely difficult to spawn burbot manually and that they spawn at night. Multiple holding exposure facilities for rearing spawning adults are required to provide verification and the appropriate replication. Temporal changes in reproductive processes during normal gonadal development in burbot have not been described previously.

The physiological and reproductive paramters found in the laboratory-held burbot in this study were similar to those observed in burbot collected from the reference areas in the Peace, Athabasca and Slave rivers (Brown et al. 1996). Thus, the results reported here provide important comparative information for the coincident field collection programs (i.e. Basin-Wide Fish Survey) in the Northern River Basins Area.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

Recent work emphasizes the possibility of deficiencies in the required dissolved oxygen (DO) levels for certain species of fish residing in the Peace and Athabasca drainages (Barton and Taylor 1996). Pronounced mid- to late-winter declines in DO have been documented in the Athabasca River (Noton and Shaw 1989) as well as in tributaries of the Peace River (Shaw et al. 1990). The lower DO is a result of biological oxygen demand arising from the oxidation of organic materials during periods of ice-cover when surface exchange is limited. Non-specific sources and pulp mill and domestic effluents contribute to this organic load (Chambers and Mill 1996). Aeration through turbulence and surface exchange is expected to satisfy the biological oxygen demand during ice-free periods.

Adverse effects of low environmental oxygen tensions on fish reproduction represents a distinct possibility in the Athabasca and Peace drainages. Species spawning in the late fall and winter would be the most likely to be impacted by low DO because developing eggs and larvae would be subjected to the full extent of hypoxia during the winter (Giles and van der Zweep 1996). Burbot spawn under the ice in mid- to late-winter, mainly from January to March in Canada (Scott and Crossman 1973). Gonadal development occurs in the fall and early winter (Chen 1969; Brown et al. 1996). The winter habitat of burbot is not well known but it is likely that many move to the tributaries of major rivers (and away from hypoxic conditions) for spawning. It is also probable that some populations reside in the major river channels throughout all or part of the ice-covered period.

In accordance with the terms of reference for Project 3221-D1, we held maturing burbot in the lab under normoxic and hypoxic conditions through the mid- to final stages of gonadal development. Fish were maintained near environmentally realistic winter water temperatures (3°C) and hypoxic condition (O_2=6.0 mg/L; approx. 45% air saturation) was similar to the lowest levels reported in the upper Athabasca River (Noton and Shaw 1989; Chambers et al. 1996). Blood hematocrit and hemoglobin measurements assessed the carrying capacity of the gas transport system. To monitor potential ionoregulatory disturbances and associated stress under hypoxic conditions, we evaluated plasma electrolytes and glucose. Reproductive parameters analyzed include steroid hormones found in females (17ß-estradiol & testosterone) and males (testosterone & 11-ketotestosterone) as well as attempts to determine gonadotropin II (GTH II) and vitellogenin. We also evaluated the subsequent viability of spawned gametes.

2.0 METHODS

2.1 Fish Collection and Maintenance

During the period of October 25 to November 17, 1994, 109 adult burbot, *Lota lota*, were collected by gill net in the vicinity of Elks Island on Lake Winnipeg, Manitoba (50°N; 96°33'W). The fish were caught in 4¼″ mesh nets, transferred into water-filled tubs, and transported to a net enclosure in a shallow bay for up to four days before being moved to the laboratory. Water temperature in the bay declined from 13 to 3°C during the collection period. The fish were transported to the

Freshwater Institute in Winnipeg in a 300 L transport tank containing 0.5% salt water at the temperature in the bay. The transfer to the laboratory was completed within 2 h. The burbot were held in temperature controlled, 1500 L tanks and gradually acclimated to 3°C. Injured or diseased fish were removed and gonad development examined. During the acclimation and experimental period in the laboratory fish were subjected to prophylactic treatments with 0.5% salt water at weekly intervals in order to control fungal development. The iodine-free salt was dissolved in laboratory water and introduced into the tanks in one dose to achieve the desired concentration. The salt water was washed from the tanks by dilution at 50 and 90 percent replacement times of approximately 6 and 19 hours, respectively.

2.2 Experimental Conditions

Burbot were exposed to normoxic and hypoxic conditions in two 990 L fibreglass tanks (3.15x1x0.5 m; LxWxD), each of which was divided into two compartments by 1 cm plastic mesh. The compartments were designated OF and OB for the front and back compartments, respectively, of the normoxic system, and HF and HB for the respective compartments of the hypoxic system. Two compartments were set up to allow sampling of only half the fish at each time. This minimizes stress due to handling and blood sampling. Each tank was supplied with 80 L/min of temperature-controlled water from a 530 L recirculation system which incorporated a 5 hp stainless steel chiller, a 0.5 hp pump, a 30 L biofilter, and four gas equilibration columns (120x20 cm; HxD) filled with porcelain gas exchange chips. Fresh water was supplied to each system at a rate of 3 L/min which provided a 90% replacement time of approximately 19 h. The tanks were enclosed in a light-tight shroud made from a double layer of 6 mil black polyethylene. Two 25 watt aquarium lights were mounted inside the shroud and the photoperiod was controlled with a Sun Tracker controller (Model EC72ST; Paragon Electric Canada Ltd.) set to provide a natural photoperiod for Victoria Beach, MB (Lat. 50°N). Light intensity at the surface of the tanks was regulated at 4.3±2.8 lumen/m^2 with a variable resistor on the lights. Water temperature was regulated at a nominal value of 3°C throughout the exposure period. Dissolved oxygen concentration was maintained at near-saturation or 6 mg/L by fitting gas-exchange columns to each tank and purging with air or an air:nitrogen mixture. Dissolved oxygen concentration was monitored at two minute intervals in the hypoxic system with a dissolved oxygen meter (model 59; Yellow Springs Inc.) coupled with a data-logger software system (Pro-Comm version 2.4.3) and an IBM 286 computer. Water temperature in both systems was recorded at 2.6 h intervals with a HOBO-TEMP data-logger (Onset Instruments). Total NH_4-nitrogen was measured colorimetrically (Stainton et al., 1977) and un-ionized ammonia concentrations were calculated by extrapolation of the data of Trussell (1972) for the appropriate water temperature and pH. Adult burbot were fed once weekly with live goldfish (mean weight approximately 4 g) which were released into the experimental tanks at a rate of 6 goldfish per burbot. After the goldfish had been eaten the tanks were given their weekly treatment with 0.5% salt.

2.3 Fish Sampling

Between November 14 and 16, 1994, 80 burbot were removed individually from the holding tank, anesthetized in buffered MS-222 (1:3500 aqueous solution; Sigma Chemical Co.), and measured for total length and weight. A 4x8 mm plastic tag was attached with a polyethylene suture to the dorsal surface immediately anterior of the insertion of the dorsal fin. A 1.5 mL sample of blood was collected from the hemal arch into a heparinized (ammonia heparin, approximately 50 USP units/ml of blood; Sigma Chemical Co.) syringe using a 23 G short-bevel needle. The tagged fish were placed sequentially into the two compartments of each tank and both systems were treated with 0.5% salt. Water temperature was 3°C and dissolved oxygen was maintained at saturation in both tanks until November 28 when dissolved oxygen was reduced to 6 mg/L in the treatment system. At intervals, fish in both normoxic and hypoxic treatments from either the front or the back compartment were anesthetized and a 1.5 mL blood sample was removed from the tail. Fish from the front compartments were sampled on January 4, February 8, and March 22 while fish from the back compartment were sampled on December 14, January 24, March 1, and March 14 and 15. On the last sampling date for each group a blood sample was taken and the fish were weighed, measured, and dissected to determine the weights of the gonads, liver, and digestive system. During the initial phases of the experiment a small number of fish in both treatment groups developed fungal infections and became moribund. These fish were removed from the tanks and frozen for later examination. The burbot were also examined for readiness to spawn during the process of blood sampling. A gentle pressure was applied to the abdomen to determine if eggs or sperm could be expressed. In some cases sperm was collected in polyethylene tubes and used to measure sperm viability and motility. Attempts to express eggs from female burbot were unsuccessful. The tanks were examined daily for eggs which had been released the previous night and any eggs which had gathered near the outlet of the tank were collected. Subsets of these eggs were incubated under normoxic and hypoxic conditions (see *Embryological Survival and Development*).

2.4 Blood and Plasma Analyses

The heparinized blood was processed immediately following extraction from the fish. A sample was removed for determination of hematocrit and hemoglobin concentration. The remaining blood was centrifuged at 13700 g for 5 min and the plasma removed and stored in polyethylene vials at -80°C until analysis of plasma electrolyte and hormone concentrations.

Blood Hematocrit and Hemoglobin. Hematocrit was determined by centrifugation at 13700 g for 5 min and hemoglobin estimated on 20 µL subsamples as cyanmethemoglobin at 540 nm with spectrophotometer.

Plasma Electrolytes. Plasma sodium, potassium, magnesium, and calcium concentrations were determined by plasma emission spectrophotometry (Spectrametrics, Spectraspan 3B) at wavelengths of 588.995, 769.80, 279.553, and 396.847 nm, respectively, after appropriate dilution with distilled, deionized water containing a cesium chloride internal reference. Standard solutions of each electrolyte were prepared in control serum (Sigma Chemical Co.; Type 1A-normal, lot # 33H-62428) and incorporated into each set of analyses.

Hormone Extraction. Prior to assay for reproductive steroids, duplicate plasma samples (250 µL) were extracted in 2.5 mL of ethyl acetate:hexane (3:2, v/v). The dried extracts were redissolved in assay buffer (250 µL). After appropriate dilution, aliquots of this redissolved extract were then used for either 17ß-estradiol, testosterone or 11-ketotestosterone analysis (see below). The percent recovery of hormones from each extracted sample was determined by addition of a mixture of ^{3}H-labelled steroid tracers (1500 cpm each of 17ß-estradiol, testosterone & 11-ketotestosterone) to every sample and counting an aliquot (25 µL) of the redissolved extract by liquid scintillation counting. We have previously demonstrated that each hormone is extracted with nearly identical efficiency. Extraction efficiencies were 81.8±1.9% (mean±SE) for the samples processed. Extraction efficiency did not differ between times. For calculating the final hormone concentration the extraction efficiency for each individual sample was used to correct for losses.

Plasma 17β-Estradiol. An enzyme-immunoassay (EIA) was used to assess plasma estradiol (Brown et al. 1993). The coefficient of reactivity at 50% displacement (CR50%) of estradiol tracer was determined for each of 8 steroids (17ß-estradiol, 17α-estradiol, estrone, estriol, progesterone, 17α,20ß-dihydroxy-4-pregnen-3-one, testosterone and cortisol). Steroids giving greater than 0.1 CR% with the estradiol antibody were: 17ß-estradiol (100), estrone (1.7), 17α,20ß-dihydroxy-4-pregnen-3-one (0.3) and testosterone (0.1). Intraassay coefficient of variation (CV), from 10 duplicate analyses of the same sample was 6.9%. Interassay CV of duplicate analysis from 10 assays was 9.8%. Recoveries of estradiol (0.25-2.0 ng/mL) added to burbot plasma was 97.8±3.5 % (mean±SE). The minimum level of sensitivity, defined as that dose level 2 standard deviations away from the 0 dose measurement, averaged 0.004 ng/mL over 9 assays. Serial dilutions of plasma extracts were parallel to the standard curves and gave estimates of hormone concentrations within 10%.

Plasma Testosterone. An enzyme-immunoassay (EIA) was used to determine plasma testosterone levels (Brown et al. 1993). The coefficient of reactivity at 50% displacement (CR50%) of testosterone tracer was determined for each of 8 steroids (11-ketotestosterone, testosterone, 11ß-hydroxytestosterone, androstenedione, cortisol, progesterone, 17α,20ß-dihydroxy-4-pregnen-3-one and estradiol). Steroids giving greater than 0.1 CR% with the testosterone antibody were: testosterone (100) 11-ketotestosterone (5.1), androstenedione (3.6) and 11ß-hydroxytestosterone (1.2). Intraassay coefficient of variation (CV), from 10 duplicate analysis of the same sample was 8.8%. Interassay CV of duplicate analyses from 10 assays was 10.9%. Recoveries of testosterone (0.63-2.5 ng/mL) added to fish plasma ranged from 88.9 to 101.3%. The minimum level of sensitivity, defined as that dose level 2 standard deviations away from the 0 dose measurement, averaged 0.002 ng/mL over 5 assays. Serial dilutions of plasma extracts were parallel to the standard curves and gave estimates of hormone concentrations within 7%.

Plasma 11-Ketotestosterone. A radioimmunoassay (RIA) was used to assess plasma 11-ketotestosterone. RIA antibody was obtained from Helix Biotech and ^{3}H-labelled 11-ketotestosterone was synthesized in-house from ^{3}H-cortisol. The prepared 11-ketotestosterone tracer was purified by high-performance liquid chromatography prior to use. The coefficients of reactivity at 50% displacement (CR50%) of 11-ketotestosterone tracer was determined for each of 8 steroids (11-ketotestosterone, testosterone, 11ß-hydroxytestosterone, androstenedione, cortisol, progesterone, 17α,20ß-dihydroxy-4-pregnen-3-one and estradiol). Steroids giving greater than 0.1 CR% with the 11-ketotestosterone antibody were: 11-ketotestosterone (100), testosterone (7.0%), 11ß-hydroxytestosterone (4.8%) and androstenedione (4.6%). Intraassay coefficient of variation (CV), from 10 duplicate analyses of the same sample was 9.2%. Interassay CV of duplicate analyses from 5 assays was 12.8%. Recoveries of 11-ketotestosterone (2.5-5.0 ng/mL) added to fish plasma ranged from 90.7 to 104.5 %. The minimum level of sensitivity, defined as that dose level 2 standard deviations away from the 0 dose measurement, averaged 0.5 ng/mL over 5 assays. Serial dilutions of plasma extracts were parallel to the standard curves and gave estimates of hormone concentrations within 9.5%.

2.5 Analysis of Sperm Activity

Spermatocrit was determined by centrifugation at 13700 g for 5 min. Sperm samples from individual male burbot were collected in sterile polyethylene tubing and stored at 3°C for a maximum of 90 min before analysis. Sperm motility and swimming speed were determined from video-taped recordings of activity following sperm activation with water from the experimental tanks containing the adult fish. All activation and video recording was performed in a coldroom at 3°C. A Zeiss Photomicroscope III with a magnification of 100X was fitted with a video camera (Panasonic model WV-1504) coupled with a video-recorder (Sony; model EVV-9700). The recorder automatically recorded the frame number (30 frames/sec) and had a microphone attached to record the sample identification and start time for the activation of the sperm. A Neubauer hemocytometer slide (0.1 mm depth, 0.025 mm^2 grid) was mounted on the microscope stage and the well filled with tank water. A small amount of sperm was placed on an applicator and transferred to the water. At this time the start of activation was indicated by voice on the tape and the cover slip placed on the slide. Approximately 20 sec was required from the initiation of sperm activation for adequate recording of the swimming activity. This activity was recorded until all motion ceased. The tapes were analyzed on a video editor (Sony; model EV09720) with stop-motion capability. The sperm activity was determined at intervals of 30, 45, and 60 sec following activation by estimating the proportion of sperm actively swimming as 75 to 100, 50 to 75, 25 to 50, or <25 percent. Swimming speed was estimated by identifying five sperm swimming in a straight path over the hemocytometer grid and measuring the distance travelled and elapsed time for each spermatozoa. This procedure was repeated at 30, 45, and 60 sec intervals following activation. In addition the total time elapsed from activation to cessation of movement of all sperm cells was recorded. Sperm from a total of 14 normoxic and 9 hypoxic males was analyzed in this manner.

2.6 Embryological Survival and Development

When spawning occurred, aliquots of approximately 1600 burbot eggs were collected from the exposure tanks the following morning. These eggs represent a mixture from all burbot that spawned the previous night. The eggs were placed in incubators receiving water at 3°C containing 13.2 or 6 mg/L of dissolved oxygen. The egg incubation system has been described in detail by Giles and van der Zweep (1996) and consisted of 4 stainless steel tanks, each containing 28 incubators and a recirculating water supply in which dissolved oxygen was regulated by passage through a gas equilibration column. The water in each system was replaced at a rate of 100 ml/min to provide a 95% replacement time of 33.4 h (Sprague, 1973). Two incubation systems received water equilibrated at air saturation while the remaining two systems received water at 6 mg/L of dissolved oxygen. Replicates (2 to 3) of 1600 eggs from each spawning were placed in each system. Twice weekly aliquots of 50 to 100 eggs were removed from each incubator and examined for mortality, fungal development, embryological development, and hatching. These eggs were then preserved for future analysis. During the period of hatching all visible larvae were removed, enumerated and preserved in 4 percent buffered-formalin for future measurement of length and yolk utilization. The incubators were treated once, on February 7, 1995, with formalin (1:1000) for 15 min to reduce fungal development. Groups of eggs incased in fungus tended to float to the surface of the incubator and were removed without enumeration. One normoxic and one hypoxic incubation system were exposed to a physical disturbance which resulted in death of all the eggs in these systems. The results from these two systems were excluded from the study. A code was developed to identify both the treatment experienced by the adult burbot and the treatment experienced by the eggs during incubation. The first letter of the code is capitalized and refers to the adult treatment whereas the second letter is lower case and refers to the treatment of the eggs. Thus Hh, Ho, Oo, and Oh refer to hypoxic adult:hypoxic egg, hypoxic adult:normoxic egg, normoxic adult:normoxic egg, and normoxic adult:hypoxic egg treatments, respectively.

Embryological measurements were obtained from preserved eggs and larvae using a BioScan Optimas image analysis system. Images were generated by an Ikegami CCD camera with a zoom macro lens. Egg diameter, area of yolk, and area of the oil droplet in the yolk were measured on individual eggs while total length and yolk and oil area were measured on larvae.

2.7 Statistical Analyses

Bartlett's test was applied to test for homogeneity of variance and, where necessary, data were log transformed. Differences among groups of fish sampled at one time for any given variable were tested by one-way or two-way analysis of variance (ANOVA) computed using the Systat statistical package (Wilkinson et al. 1992). Analysis of covariance was used to compare length/weight relationships. Data from the temporal blood sampling were analyzed for each sex using a mixed model ANOVA which took into account that fish were nested within treatments (normoxic vs hypoxic) and also that fish were repeatedly sampled over time. This ANOVA had elements of a split-plot and of a nested design. The significance of the treatment effect was tested with the fish within treatment term used as error. The significance of the time effects and the time by treatment interaction were tested with the residual mean square for error. Pairwise comparisons were conducted by applying the LSD test to the least squared means produced by the ANOVAs. The rate of inactivation of sperm between normoxic and hypoxic males was examined by chi square contingency analysis. A probability <0.05 was considered significant. Arithmetic means and standard errors are given in the figures.

3.0 RESULTS AND DISCUSSION

3.1 Experimental Conditions for Adult Burbot

Dissolved oxygen concentration for these respective treatments was 13.2±0.2 and 6.0±0.33 mg/L (Figure 1). Late-winter declines in DO have been well documented in the Athabasca River (Noton and Shaw 1989). Less pronounced winter DO declines have been reported for tributaries in the Peace River drainage (Shaw et al. 1990). The hypoxic condition used in this study (6.0 mg DO/L) was similar to the lowest reported level (6.0-7.7 mg/L) upstream of the inflow of the Lesser Slave River on the upper Athabasca River (Noton and Shaw 1989). Un-ionized ammonia was 1.4±0.5 and 1.0±0.4 µg/L, respectively, during the study period. Fish were maintained near environmentally realistic winter water temperatures, throughout the entire experimental period. Mean (±1 standard deviation) water temperature during the period of sexual maturation and spawning was 3.0±0.02 and 3.0±0.06 °C for normoxic and hypoxic treatments, respectively, (Figure 1).

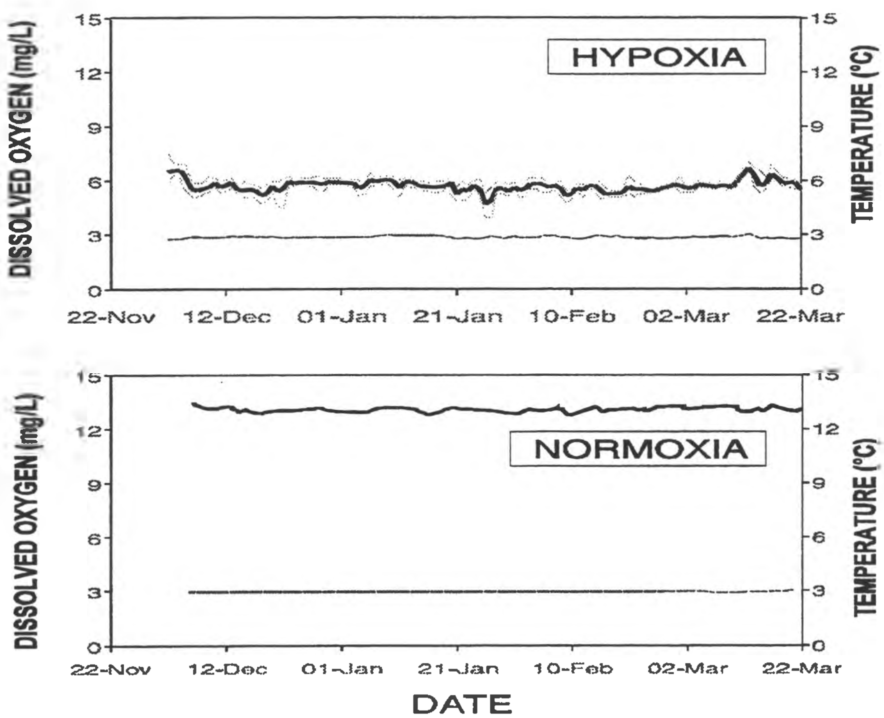

Figure 1. Dissolved oxygen concentration and water temperature during the experimental period.

3.2 Adult Characteristics, Mortality, and Spawning

Mean weights and lengths (±1 standard deviation) for the OF, OB, HF, and HB experimental groups were 993±350 g and 51.4±6.7 cm, 999±432 g and 51.5±8.4 cm, 1093±483 g and 52.6±8.2 cm, and 988±405 g and 52.5±7.4 cm, respectively. We analyzed the initial blood sample from each fish for 11-ketotestosterone or 17ß-estradiol titres to determine sex and sexual maturity. For fish judged to be sexually mature on the basis of their hormone analysis, no significant difference ($F=0.78$, $P<0.38$) in the length:weight relationship was observed between males and females:

Females	$\log W = -2.089+2.951(\log L)$ $R^2=0.94$, N=40
	SE(a)=0.047
	SE(b)=0.116;
Males	$\log W = -1.870+2.830(\log L)$ $R^2=0.86$, N=35
	SE(a)=0.068
	SE(b)=0.195
where,	W=wet weight in grams;
	L=total length in centimetres.
	SE=standard error.

Thus in contrast to feral burbot populations, there was no size differential between sexes in the experimental fish. At maturity female fish are generally larger than males (Scott and Crossman 1973). As no age analysis was performed, it is possible that the male experimental fish were slightly older than females. Results from dissection of all experimental burbot at the termination of the experiment indicated that the actual sex ratio (female:male) for each treatment group was 6:9, 11:8, 8:10, and 7:9 for the OF, OB, HF, and HB groups respectively.

The fungal infection and salt treatments represented an undesirable complication because some studies suggest the possibility that hypoxia may increase susceptibility to pathogens (reviewed by Barton and Taylor 1996). Initial capture, transport and handling of burbot in the laboratory proved sufficiently stressful that control of the subsequent fungal infection was essential to experimental conduct. The problem arose prior to hypoxic exposure and control could only be effected by prophylactic treatments with salt. Overall, the experimental mortality was limited to 14 % and it was unrelated to hypoxic conditions. A total of 11 burbot died or appeared moribund during the course of the study and of these 5 were from the OF group and died before mid-December. To further reduce handling and to avoid altering blood parameters from repeated sampling (Brown et al. 1986), the treatment tanks were divided into two compartments and the fish were sampled on alternate dates.

Several groups of burbot were obtained from the vicinity of Victoria Beach during the experimental period to provide estimates of the gonadosomatic index (GSI=100xgonad weight/body weight) throughout development in the wild (Figure 2). The GSI of 14 female and 12 male burbot in early November was 4.5±2.3% and 11.3±2.8%, respectively. Whereas GSI of females tended to increase until late January and subsequently decline after spawning many males tended to maintain relatively large gonads well into March (Figure 2). Considering temporal differences, the GSI values of the wild stock from Lake Winnipeg were similar to that reported for burbot from other locations (Chen 1969; Bailey 1972) and for fish taken in the Peace and Athabasca drainages (Brown et al. 1996). Larger gonad size (higher GSI) in male fish compared to females was consistent with observations in burbot from the Peace and Athabasca drainages (Brown et al. 1996).

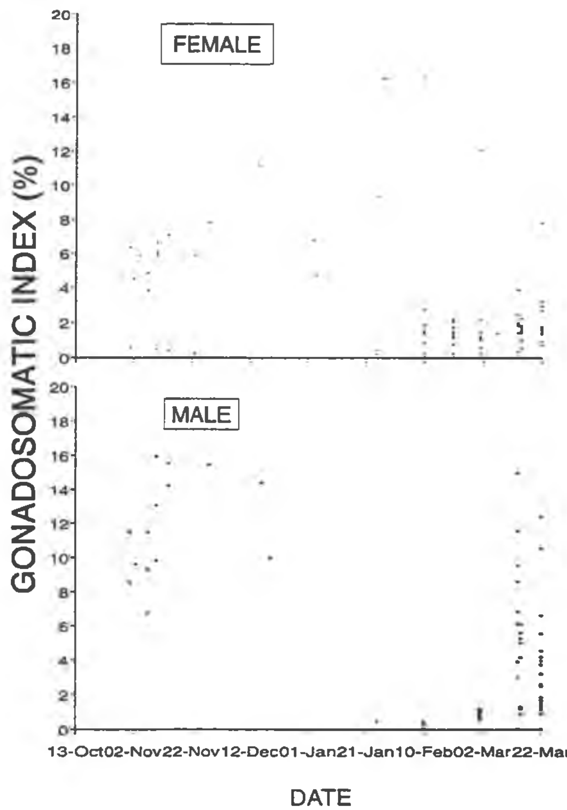

Figure 2. Gonadosomatic index in burbot collected from Lake Winnipeg during the experimental period.

Actual spawning activity was not observed in burbot from either treatment. With one exception, attempts to express eggs from females were totally unsuccessful. Eggs were observed and collected in the normoxic treatment tanks on January 26 and 31, and February 1, 4, and 6. Fish in the hypoxic treatment spawned on January 26, February 6, 9, and 21, and March 11. The spawning of the laboratory-held burbot in late January was similar to that reported in feral fish (McPhail and Lindsey 1970; Scott and Crossman 1973). From observations on the presence of eggs swirling in the troughs and the rapid settling rate of fertilized eggs it is probable that most spawning occurred just before sunrise. Moreover, completion of spawning activities at night was consistent with observations in the wild (McPhail and Lindsey 1970; Scott and Crossman 1973).

The spawning of normoxic females was completed over a two week period but the period of spawning was extended to seven weeks in burbot exposed to hypoxic conditions. It is difficult to ascertain the importance of this observation because, due to their nocturnal spawning habits, the number of females participating in each spawning could not determined. Sperm could be expressed from male fish from both normoxic and hypoxic conditions well before (4-6 weeks) female spawning and continuing to mid-March. This may suggest that differences in spawning activity among individual females burbot may be common. More information about the variability in normal burbot reproductive activities would help establish the significance of our observations in the hypoxic fish.

Two females and two males from each treatment were isolated in cages within the treatment troughs, and the females were given a single intraperitoneal injection of [D-Ala^6]-luteinizing hormone (10 µg/kg body weight; Sigma Chemical Co., lot 88F05551) in an attempt to induce ovulation. Daily attempts to express eggs from the females were unsuccessful and the females released all their eggs on the fifth night after receiving the hormone treatment. Attempts to express eggs from spent females were also unsuccessful. These observations would suggest that females completed their spawning activity in a single event. In one case approximately 10 mL of eggs were expressed from one female in the treatment group (HB on February 6) and fertilized with milt from two males. These eggs were viable and 18 to 21 percent survived to hatch.

3.3 Blood Hematocrit and Hemoglobin

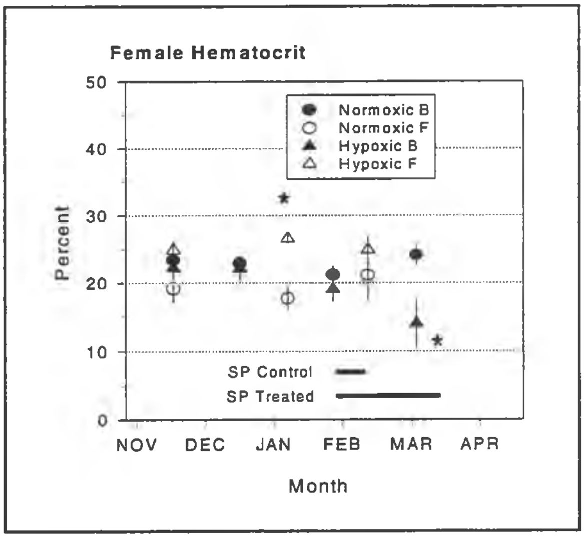

Figure 3. Hematocrit in female burbot. Time of spawning (SP) indicated by bars. Asterisk indicates difference from control.

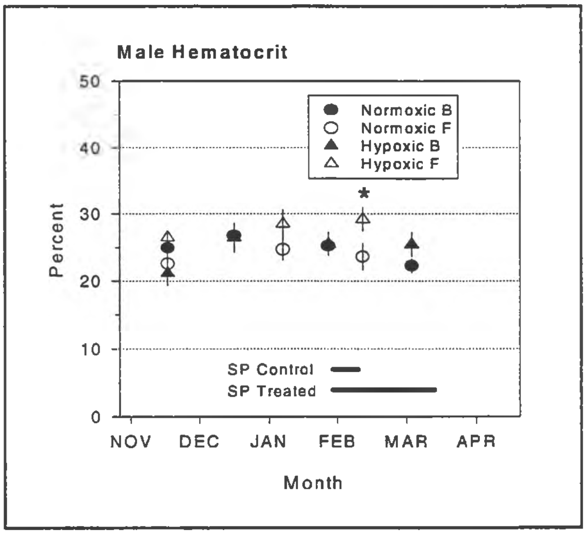

Figure 4. Hematocrit in male fish. Time of spawning (SP) indicated by bars. Asterisk indicates difference from control.

Hematocrits (Hct) and hemoglobin concentrations (Hb) from blood of burbot exposed to normoxic and hypoxic treatments are presented in Figures 3-6. The lack of anemia in normoxic fish supported the handling protocol we used. The effects of hypoxia upon blood hematocrit and hemoglobin were confounded by an apparent difference in response by fish in the front versus the rear compartments for both treatment groups. Burbot in the rear compartments exhibited significant sex-related differences in hematocrit and hemoglobin concentration but no treatment-related effects. Because fish from only the front hypoxic compartment showed slightly higher hematocrit and hemoglobin, exposure to 6 mg/L DO was likely near the threshold for effects on these parameters. Increased blood hematocrit and hemoglobin are common hematological responses to low DO in fish (Swift 1981; Scott and Rogers 1981; Marinsky et al. 1990). The causes of the differences in response between the front and rear compartments are unknown. The system incorporated a forward mixing chamber to eliminate localized water currents between the gas exchange columns and the treatment tanks. However, it is possible that a small localized differences in DO existed in the vicinity of the inlets for the front compartments. These localized water currents would have dispersed as the water moved down the troughs. When fish from both front and rear compartments were considered, there was no clear effect of hypoxia on hematocrit, hemoglobin.

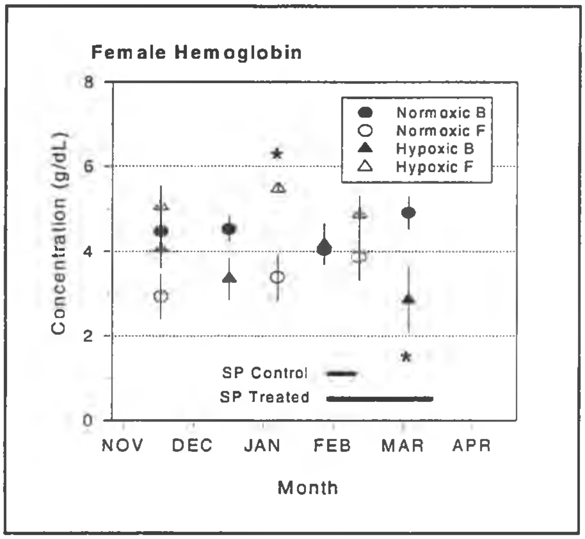

Figure 5. Hemoglobin in female burbot. Time of spawning (SP) indicated by bars. Asterisk indicates difference from control.

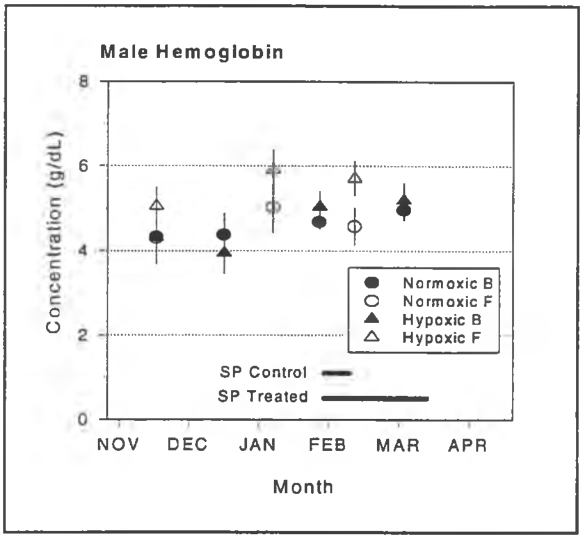

Figure 6. Hemoglobin in male burbot. Time of spawning (SP) indicated by bars.

3.4 Plasma Electrolytes and Glucose

Plasma sodium varied with sampling time but did not differ between male and female fish. Data for combined sexes are given in Figure 7. Because there were no treatment related effects with respect to levels of plasma sodium in burbot, ion losses due to hypoxic conditions probably fell within the compensatory scope of ionoregulatory mechanisms. Physiological responses to low DO include increased respiratory rate and increased functional surface area of the gills. These represent responses which also increase ion loss form plasma and extracellular fluid (Gonzales and McDonald 1992).

Plasma potassium levels tended to increase after the first sampling but did not differ between sexes. Data for combined sexes are shown in Figure 8. At some sampling times potassium levels were lower in hypoxic fish however the effect was not consistently observed throughout the experiment. Lower plasma potassium levels at certain times in hypoxic fish was opposite to the expected response. Potassium is the major intracellular cation and elevated levels in plasma or extracellular fluid are indicative of disruptions in cell membrane integrity. Intracellular shifts in plasma potassium also occur during acidosis and tissue hypoxia (Kleiman and Lorenz 1984). Thus, higher not lower plasma potassium levels would be expected in hypoxic fish.

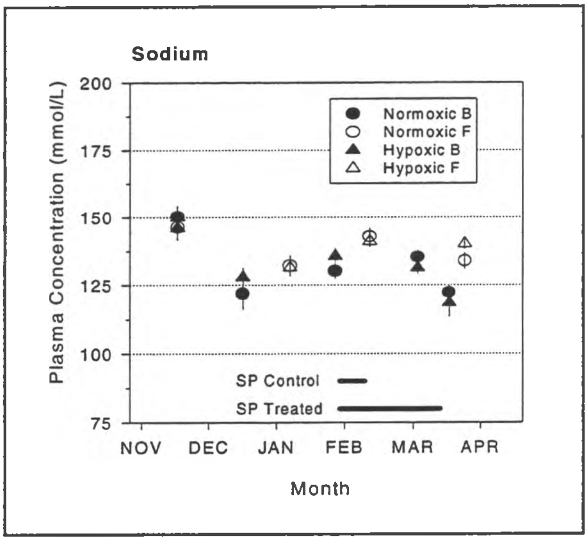

Figure 7. Plasma sodium in burbot (combined sexes) held under normoxic and hypoxic conditions. Time of spawning (SP) indicated by horizontal bars.

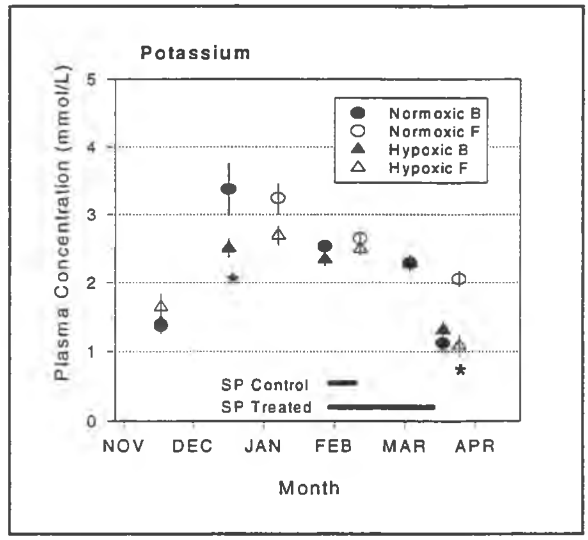

Figure 8. Plasma potassium in normoxic and hypoxic burbot (combined sexes). Spawning (SP) indicated by horizontal bars. Asterisk indicated means different from control.

Plasma magnesium levels were marginally but significantly higher in female burbot (Figure 9) compared to male fish (Figure 10). However, there were no treatment or time related differences in plasma magnesium for either sex.

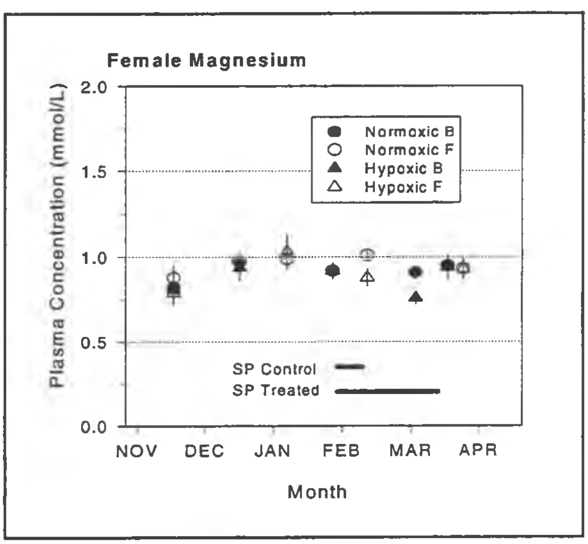

Figure 9. Plasma magnesium in female burbot. Time of spawning (SP) indicated by horizontal bars.

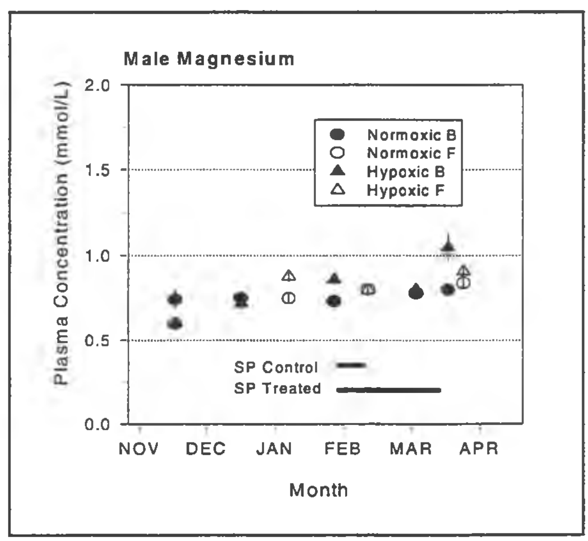

Figure 10. Plasma magnesium in male burbot. Time of spawning (SP) indicated by horizontal bars.

Generally, much of the yolk material of the eggs of fish is synthesized under estrogen control in the liver as a complex lipophosphoprotein precursor of vitellogenin (Plack et al. 1971; Wallace 1978). This precursor is then carried by the blood to the growing ovary as a vitellogenic complex of calcium, and deposited in the developing oocyte as a phosphoprotein-lipoprotein. As a consequence, plasma Ca levels were much higher in the female burbot (Figure 11). The elevated plasma calcium at the beginning of the experimental period suggests that exogenous vitellogenin production was well underway when the fish were first sampled in November. Female plasma Ca levels declined towards levels found in males (Figure 12) as fish approached spawning condition. Post spawning levels were similar to concentrations found in male fish. Based on plasma calcium concentrations, vitellogenin production was unaffected by hypoxic conditions. To further investigate the calcium difference between male and female fish plasma samples from pre-selected female and male burbot were screened for vitellogenin content using an immunoassay specific for goldfish vitellogenin. Burbot plasma samples did not cross-react with the available antisera. While the assay has been used for several other species (suckers, fathead minnows), it seems that burbot vitellogenin is immunologically distinct and will likely require the development of an homologous assay.

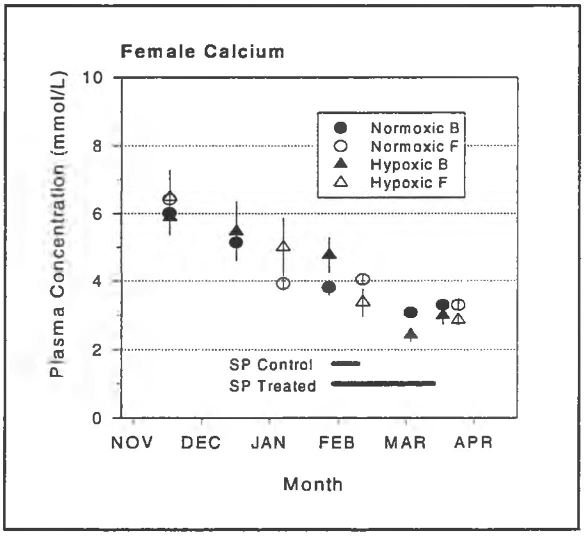

Figure 11. Plasma calcium in female burbot held under normoxic and hypoxic conditions. Time of spawning (SP) indicated by horizontal bars.

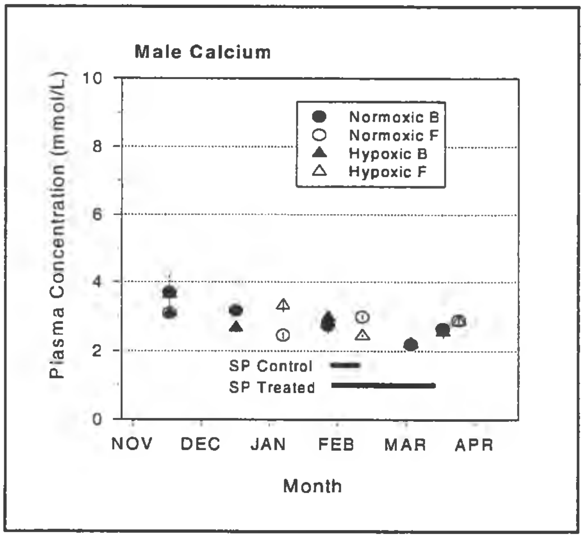

Figure 12. Plasma calcium levels in male burbot held under normoxic and hypoxic conditions. Time of spawning (SP) indicated by horizontal bars.

Plasma glucose levels were similar between sexes. High variability was evident at two sampling times in specific groups. Overall, glucose tended to decline throughout the experiment (Figure 13). The slightly higher initial levels of plasma glucose possibly reflect the effects of the initial capture and handling of experimental fish or changes in feeding rates while spawning. Plasma glucose in burbot was unresponsive to the hypoxic conditions supporting the contention that exposure to 6.0 mg/L DO did not elicit a marked stress response in adult fish. In other fish species elevated plasma glucose can represent a sensitive indicator of numerous environmental stressors including more severe chronic hypoxia (Mazeaud et al. 1977).

3.5 Reproductive Hormones

Gonadotropin II. Burbot samples were screened for their cross-reactivity in radioimmunoassays using purified carp GTH II as the label and antisera against carp and salmon GTH II. Burbot plasma did not react in either assay again indicating that burbot GTH II is immunologically distinct and will likely require the development of an homologous assay.

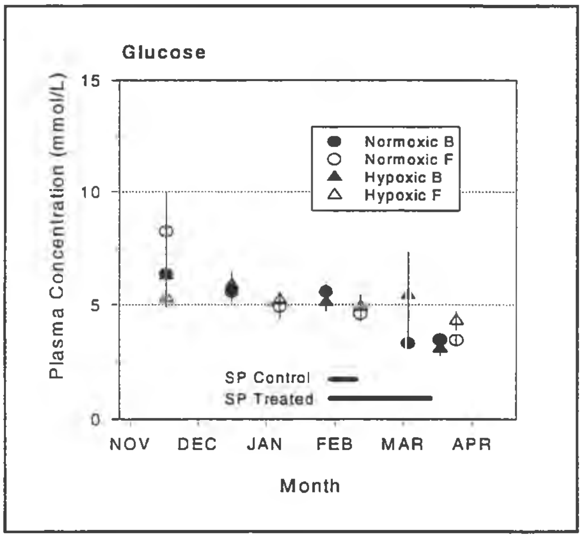

Figure 13. Plasma glucose levels in burbot (combined sexes) held under normoxic and hypoxic conditions. Time of spawning (SP) indicated by horizontal bars.

Testosterone. Testosterone serves as a precursor to 17ß-estradiol in female fish and as a precursor to 11-ketotestosterone in male fish. For the most part, plasma testosterone concentrations in female fish (Figure 14) were near levels found in male (Figure 15) burbot. In both sexes plasma levels peaked at the January 4 sampling. As the fish approached spawning toward the end of January, plasma levels of testosterone declined in both sexes. The decline tended to be slower in fish from the hypoxic treatment.

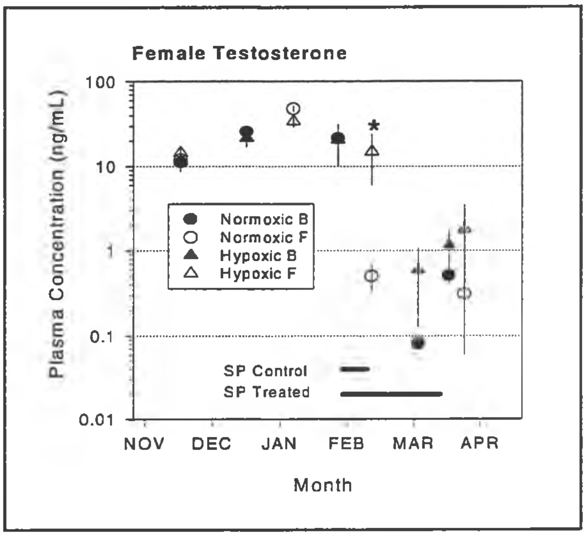

Figure 14. Plasma testosterone levels in female hypoxic and normoxic burbot. Time of spawning (SP) is indicated by the horizontal bars. Asterisk indicates mean different from control.

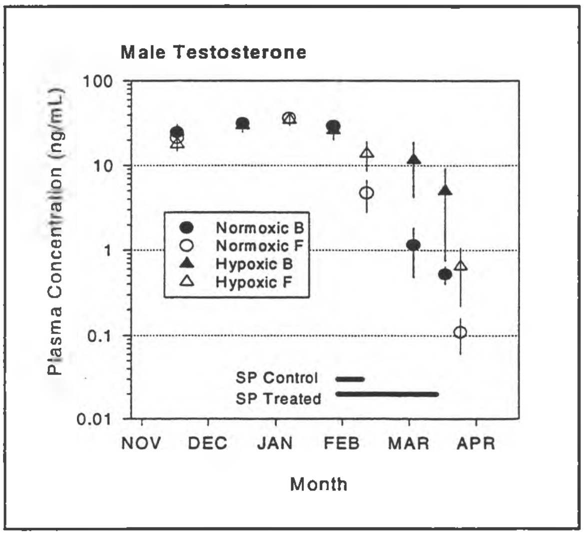

Figure 15. Plasma testosterone levels in hypoxic and normoxic male burbot. Time of spawning (SP) is indicated by the horizontal bars.

17β-Estradiol. Under the control of pituitary gonadotrophins, 17ß-estradiol is produced in the ovary and is carried by the circulatory system to the liver where it stimulates the production of yolk proteins for incorporation into developing clutch oocytes (Wallace 1978). Corresponding to plasma calcium levels, estradiol levels in female burbot were highest when the fish were first sampled. Plasma concentrations declined as the fish approached spawning, however, levels tended to remain higher in females from the front hypoxic treatment tank.

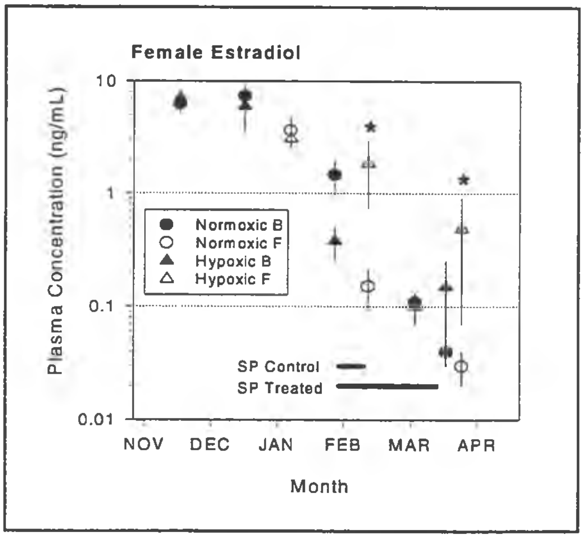

Figure 16. Plasma 17ß-estradiol levels in female hypoxic and normoxic burbot. Time of spawning (SP) is indicated by the horizontal bars. Asterisk indicates mean different from control.

11-Ketotestosterone. Levels of 11-ketotestosterone were initially high and climbed until the January 24 sampling, just prior to spawning. For the pre-spawning samples peak levels were highest in fish held under normoxic conditions. As spawning progressed levels of 11-ketotestosterone declined in fish held under normoxic conditions. In the burbot held under hypoxic conditions the higher 11-ketotestosterone concentrations were more sustained. The exact role of 11-ketotestosterone in male reproduction has yet to be elucidated, however, its presence is associated with the appearance of sperm in the testes (Schulz and Blum 1990). Spermatocrits provide information about the amount of spermatozoa in seminal fluid. Spermatocrits from normoxic and hypoxic males on February 6 were 78.5±13.0% (N=7), and 52.4±9.7% (N=7), respectively. These lower spermatocrits in hypoxic males were consistent with their lower prespawning 11-ketotestosterone levels. Because it was impossible to assess the degree that individual males had participated in spawning activities this difference in spermatocrit may reflect the degree that each male had spawned.

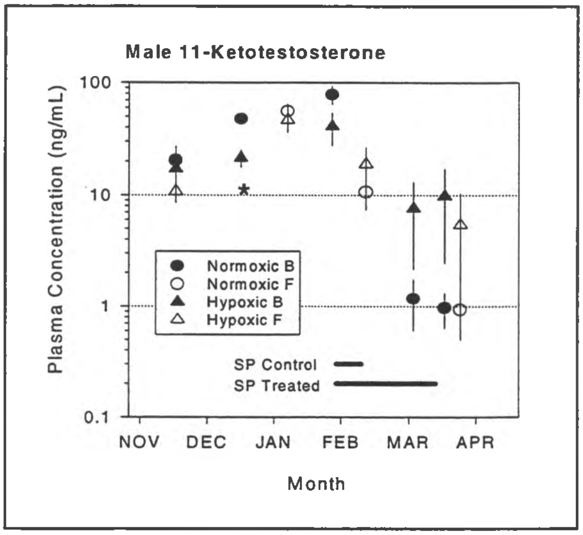

Figure 17. Plasma 11-ketotestosterone levels in male hypoxic and normoxic burbot. Time of spawning (SP) is indicated by the horizontal bars. Asterisk indicates mean different from control.

Comparative information regarding steroid hormone levels in burbot is limited to the recently reported values from the fall burbot survey in the Peace and Athabasca drainages (Brown et al. 1996). When comparable sampling times are considered steroid hormone levels found in the laboratory-held burbotin this study are similar to the values found for burbot in the Peace and Athabasca drainages (Brown et al. 1996). The prolonged maintenance of higher levels of reproductive steroids in burbot exposed to hypoxic conditions was consistent with their extended spawning activity.

3.6 Analysis of Sperm Activity

Sperm could not be expressed from any of the male burbot during the November 14 to 16 sampling and tagging period. Small amounts of sperm were released from one or two fish sampled on December 14 while about 50 percent of the males were running on January 4. Thereafter, some sperm could be expressed from most males until mid-March. Sperm was analyzed from both treatment groups on February 6 to 8. Swimming velocity was similar for sperm from both treatment groups and decreased in a linear fashion with time after activation (Table 1) from about 75 µm/sec at 30 sec to about 33 µm/sec after 60 sec. The time from activation to cessation of all movement was approximately 80 sec in both treatment groups. The rate of inactivation of sperm did not differ between normoxic and hypoxic males by chi square contingency analysis.

Table 1. Swimming velocity, activity, and inactivation time of sperm from male burbot reared in normoxic and hypoxic water during the period of sexual maturation. Values for swimming velocity and inactivation time are the mean±1 standard deviation for a sample sizes of 13 and 9 for normoxic and hypoxic treatments, respectively.

Dissolved Oxygen	Swimming Velocity (µm/sec)			Proportion (%) of Sperm Active After									Inactiv-ation Time
				30 sec			45 sec			60 sec			
(mg/L)	30 sec	45 sec	60 sec	>75%	50-75%	<50%	>75%	50-75%	<50%	>75%	50-75%	<50%	(sec)
13.2	76	48	29	11/13	2/13	0/13	5/13	5/13	3/13	0/13	2/13	11/13	79.0
	±25.6	±18.9	±11.6										±9.7
6.0	74	56	36	5/7	2/7	0/7	1/9	4/9	4/9	0/9	0/9	9/9	80.1
	±18.1	±21.9	±15.6										±10.6

3.7 Embryological Survival and Development

Incubation Conditions. Water temperature and dissolved oxygen concentrations maintained in the egg incubation units during the period of embryological development and hatch of the burbot eggs are given in Figure 18. Dissolved oxygen concentrations (mean ±1 standard deviation) over the period of development were 12.9±0.3, 13.0±0.2, 6.1±0.3, and 6.0±0.4 mg/L for tanks 2, 4, 3, and 5, respectively. These values represent levels of approximately 97 and 45 percent of air saturation for the normoxic (tanks 2 and 4) and hypoxic (tanks 3 and 5) incubators, respectively at a temperature of 3°C. Water temperature was maintained at 3.0±0.2°C over the period of incubation.

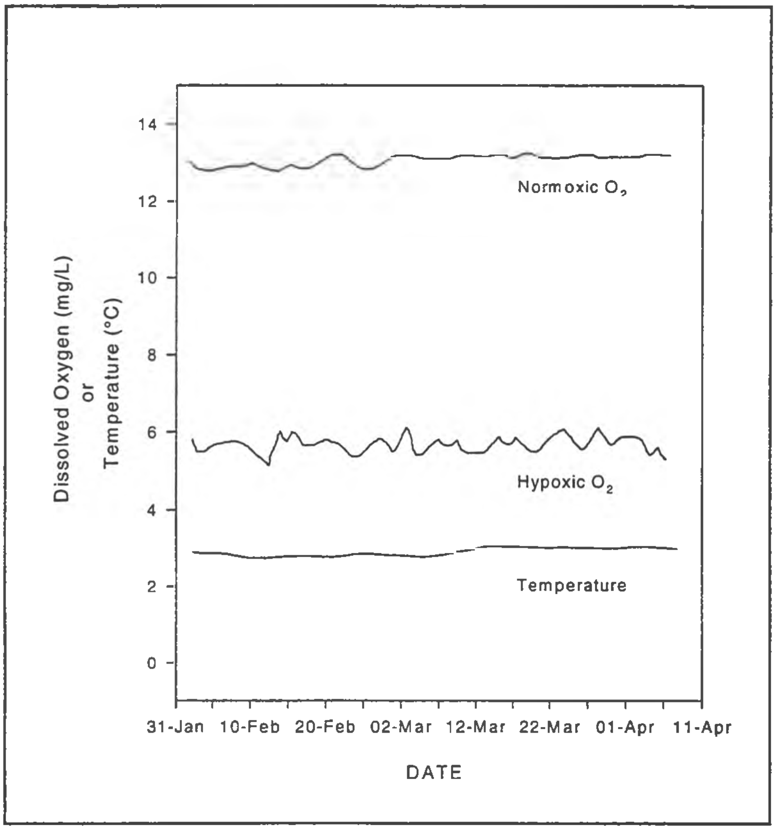

Figure 18. Dissolved oxygen concentrations and water temperature during egg incubation.

Survival and Hatching. Because it proved impossible to spawn female burbot manually and track the offspring of each individual, detailed statistical analysis could not be performed on embryological survival and hatching data. Exposure facilities where fish could be held and treated in replicate groups are required. Construction of such facilities clearly lay outside the budgetary constraints of the present study. Embryological survival and hatching was variable, however there were some indications of adverse effects due to hypoxic conditions. Adult burbot spawned on five separate dates in each of the normoxic and hypoxic treatments (See *Adult Characteristics, Mortality, and Spawning*). Egg survival exceeded 1% in eggs from four normoxic spawnings (Jan. 26, Feb. 1, Feb. 4, and Feb. 6) and from two hypoxic spawnings (Jan. 26 and Feb. 6). Eggs produced by hypoxic females after the first week in February were nonviable. This may indicate over-ripe eggs or impaired fertilization.. Dead eggs were extremely fragile and tended to disintegrate when they were aspirated from the incubators. For this reason it was not possible to estimate the mortality rate over the course of incubation. Overall survival of eggs to hatch was estimated from the cumulative numbers of live larvae extracted from each incubator as a fraction of the initial number of eggs at the start of incubation. Hypoxic incubations conditions did not affect the survival of viable eggs originating from either normoxic or hypoxic parents because survival among viable eggs cultured in hypoxic water was as good or better than eggs cultured under normoxic conditions (Table 2).

Table 2. Effect of normoxic and hypoxic incubation conditions on development time and survival of burbot eggs originating from parents reared under normoxic and hypoxic water during sexual maturation. Upper and lower case treatment codes refer to adult treatments and egg incubation treatments, respectively, where the letters 'o' and 'h' refer to normoxic (DO≥13 mg/L) and hypoxic (DO=6 mg/L) treatments, respectively. Percent survival is given as mean±1 standard deviation for (N) incubators.

	TREATMENT							
Spawn Date	Oo		Oh		Ho		Hh	
1995	50 % Hatch (days)	Percent Survival	50 % Hatch (days)	Percent Survival	50 % Hatch (days)	Percent Survival	50 % Hatch (days)	Percent Survival
26-Jan	n/a§	1.6±0.2 (2)	53	7.8±3.1 (2)	50	10±9.5 (6)	55	13.6±5.0 (6)
01-Feb	43	11.6*±4.8 (2)	53	6.8±2.8 (4)	n/a		n/a	
04-Feb	43	21.1±10.0 (4)	46	31.1±20.0 (4)	n/a		n/a	
06-Feb	47	2.5±2.2 (4)	52	6.6±1.9 (4)	47	4.9±3.6 (4)	50	4.8±2.8 (4)
06-Feb	n/a		n/a		51-52	18.8⁺ 1 sample	51-52	18.5±2.3 (2)

* The eggs in 2 of 4 incubators were lost during malfunction of the incubation system. No results from that system were included in report.

\+ These eggs were spawned artificially from one female and one male from the adult Treatment Tank (back compartment).

§ Survival of these eggs was too low to estimate time to hatch.

Survival of eggs incubated from the different spawn dates were highly variable but these differences were not related to either the source of the eggs or the dissolved oxygen concentration during embryological development. Egg survival ranged from 1.6 to 31.1% in eggs from normoxic parents and from 4.8 to 18.8% in eggs from hypoxic parents. The pattern of hatching of eggs over time from all spawnings and all egg treatments was essentially sigmoidal in all treatment groups. A small number of eggs hatched as early as 24 to 28 days after fertilization. This early hatching may have resulted from mechanical disturbance during sampling rather than normal hatching since the fragility of the burbot eggs was not appreciated at that time. The main episode of hatching began approximately 32 to 37 days after fertilization. Time required to attain 50 percent hatch was not related to the dissolved oxygen environment experienced by the parents (Table 2) but relative to normoxic incubation was extended by 3 to 10 days in eggs incubated at 6 mg/L DO. One exception to this observation was eggs which had been artificially spawned from one hypoxic female on February 6. Fifty percent hatch was observed after 51 to 52 days of incubation in both normoxic and hypoxic conditions. Under normoxic incubation conditions the time required from the initiation of hatch to >90% hatch was approximately 18 days for eggs fertilized on January 26 and February 4, and 25 days for egg fertilized on February 6 (Figure 19). Prolonged incubation times due to low DO has also been observed in mountain whitefish (Seifert et al. 1974).

Embryological Development. Burbot eggs produced from normoxic and hypoxic parents on January 26 and February 6 were used to assess the effects of hypoxia during both the sexual maturation of the adult parents and during the development of the eggs from fertilization to the hatching of the larvae (Table 3). On these dates, eggs from hypoxic parents were larger than those from normoxic parents. However, a significant difference existed in the diameter of eggs spawned on the different dates. Mean egg diameters as estimated over the entire period of egg development for eggs from normoxic and hypoxic parents, were 1.23 and 1.30 mm, respectively, for the January 26 spawning and 1.14 and 1.25 mm, respectively, for the February 6 spawning. The difference in egg size observed in the February 6 spawnings was maintained throughout the period of egg development (Table 3). In eggs from the January 26 spawning, however, the size difference present during the first 2 to 3 weeks of development was eliminated during the latter stages of development. The cross-sectional area of the yolk and the oil droplet did not differ between eggs from normoxic and hypoxic parents. None of the measures of embryonic development of the eggs varied in a consistent manner in relation to the normoxic or hypoxic conditions existent during the period of egg development (P >0.05). Caution must be exercised in interpreting these results, because the development time required from fertilization to hatch was slightly increased by hypoxic treatment during egg development. It is difficult, therefore, to match the eggs from different dates to comparable stages of development for the different treatments.

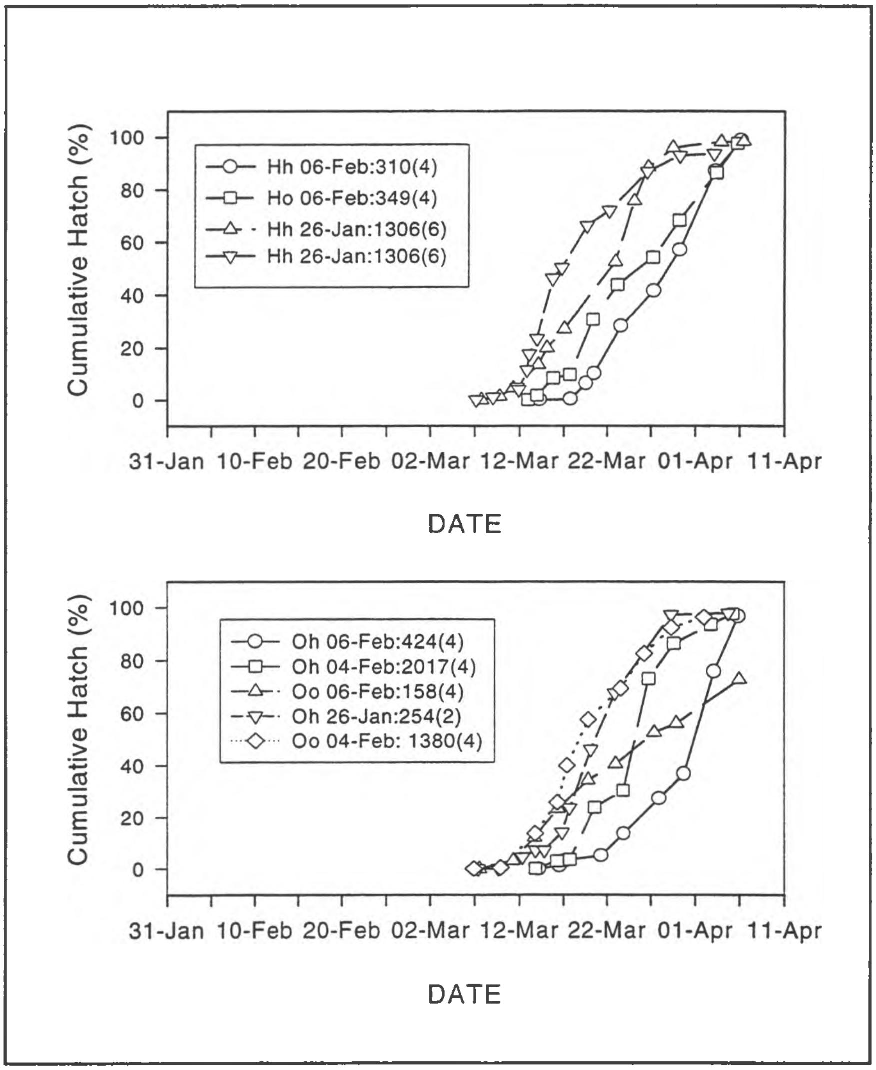

Figure 19. Embryo hatching under hypoxic and normoxic conditions. Embryos originating from parents held in to hypoxic (H) or normoxic (O) water and from hypoxic (h) or normoxic (o) incubation conditions are indicated.

The interpretation of the effects of hypoxia upon larval length, and yolk and oil droplet size (Table 4) is confounded by the differences in developmental rate of eggs incubated under normoxic and hypoxic conditions. Fifty percent hatch of the eggs from the January 26 and February 6 spawnings occurred between March 17 and 22, and March 25 and 30, respectively. Larvae measured on March 20 from the January 26 spawning represented those closest in age from fertilization to the date of fifty percent hatch while measurements on larvae from March 27 represent those closest to the date of fifty percent hatch for the February 6 spawning. In general, larvae from the January 26 spawning were similar in length and the size of the yolk and oil droplet across all adult and egg treatment groups although larvae hatched on March 13 and 20 were significantly shorter in the Cc treatment. Newly hatched larvae from the February 6 spawning were longer and had larger yolk and oil droplet areas on March 27 but not on March 20. These observations are consistent with the differences in egg sizes observed during egg development.

Table 3. Egg diameter, and cross-sectional areas of the yolk and oil droplet of burbot eggs originating from adults reared at dissolved oxygen concentrations of 13.2 mg/L, (O), or 6.0 mg/L, (H), and incubated at [DO] of 13.2, (o), or 6.0, (h), mg/L, respectively. Values presented are the mean±1 standard deviation for sample size (N). At each sampling time, treatment means with the same superscript letter are not significantly different (P<0.05) .

Spawn Date	Sample Date	Treat-ment	Egg Diameter (mm)	Yolk Area (mm^2)	Oil Droplet (mm^2)
04-Feb	09-Feb	Oo	1.03 ±0.03(5)	0.52 ±0.09(5)	0.18 ±0.02(5)
	16-Feb	Oo	1.17 ±0.11(7)	0.62 ±0.11(7)	0.14 ±0.06(6)
	19-Feb	Oo	1.14 ±0.15(10)	0.67 ±0.32(5)	0.16 ±0.05(5)
	23-Feb	Oo	1.03 ±0.09(11)	0.79 ±0.13(7)	0.14 ±0.03(7)
	27-Feb	Oo	1.12 ±0.12(15)	0.83 ±0.19(9)	0.16 ±0.05(9)
	13-Mar	Oo	1.18 ±0.16(2)	nm	0.19 ±0.04(2)
06-Feb	07-Feb	Oo	nm	nm	nm
		Oh	1.15 ±0.09(5)^{b}	0.58 ±0.19(5)^{a}	0.22 ±0.05(5)^{a}
		Ho	1.25 ±0.04(15)^{a}	0.66 ±0.15(15)^{a}	0.21 ±0.04(15)^{a}
		Hh	1.24 ±0.06(20)^{a}	0.64 ±0.14(20)^{a}	0.21 ±0.02(20)^{a}
06-Feb	09-Feb	Oo	1.16 ±0.05(10)^{b}	0.61 ±0.18(5)^{a}	0.18 ±0.05(5)$^{a\ b}$
		Oh	1.17 ±0.06(15)^{b}	0.63 ±0.20(8)^{a}	0.15 ±0.03(10)^{b}
		Ho	1.25 ±0.04(25)^{a}	0.61 ±0.13(20)^{a}	0.21 ±0.04(20)^{a}
		Hh	1.27 ±0.06(20)^{a}	0.64 ±0.15(20)^{a}	0.20 ±0.03(20)^{a}
06-Feb	14-Feb	Oo	1.15 ±0.10(11)^{a}	0.65 ±0.09(2)^{a}	0.23 ±0.08(2)^{a}
		Oh	nm	nm	nm
		Ho	1.23 ±0.02(7)^{a}	0.58 ±0.17(5)^{a}	0.17 ±0.03(5)^{a}
		Hh	nm	nm	nm
06-Feb	16-Feb	Oo	1.08 ±0.02(5)^{b}	0.48 ±0.04(5)^{a}	0.14 ±0.02(5)^{c}
		Oh	1.14 ±0.09(5)^{b}	0.49 ±0.18(5)^{a}	0.16 ±0.04(5)^{bc}
		Ho	1.24 ±0.08(10)$^{a\ b}$	0.60 ±0.14(10)^{a}	0.19 ±0.03(10)$^{a\ b}$
		Hh	1.26 ±0.20(12)^{a}	0.67 ±0.19(10)^{a}	0.21 ±0.04(10)^{a}
06-Feb	17-Feb	Oo	nm	nm	nm
		Oh	1.07 ±0.02(5)^{b}	0.70 ±0.06(5)^{a}	0.14 ±0.02(5)^{b}
		Ho	nm	nm	nm

	Hh	1.26 ±0.04(10)[a]	0.78 ±0.13(10)[a]	0.20 ±0.03(10)[a]

continued ...

Spawn Date	Sample Date	Treat-ment	Egg Diameter (mm)	Yolk Area (mm^2)	Oil Droplet (mm^2)
06-Feb	19-Feb	Oo	1.11 ±0.03(5)^{b}	0.75 ±0.09(5)^{a}	0.16 ±0.02(5)^{b}
		Oh	nm	nm	nm
		Ho	1.23 ±0.07(13)^{a}	0.84 0.12(10)^{a}	0.20 0.02(10)^{a}
		Hh	nm	nm	nm
06-Feb	23-Feb	Oo	1.13 ±0.06(9)^{b}	0.76 ±0.11(5)^{c}	0.17 ±0.07(5)^{b}
		Oh	1.15 ±0.06(15)^{b}	0.84 ±0.08(9)^{bc}	0.20 ±0.06(9)^{ab}
		Ho	1.23 ±0.09(26)^{a}	0.93 ±0.16(19)^{ab}	0.24 ±0.08(20)^{a}
		Hh	1.25 ±0.06(20)^{a}	1.02 ±0.11(20)^{a}	0.24 ±0.04(20)^{a}
06-Feb	27-Feb	Oo	nm	nm	nm
		Oh	1.15 ±0.07(10)^{b}	0.76 ±0.11(5)^{b}	0.18 ±0.05(5)^{a}
		Ho	1.23 ±0.06(20)^{a}	0.77 ±0.37(15)^{b}	0.19 ±0.06(15)^{a}
		Hh	1.26 ±0.05(22)^{a}	1.05 ±0.09(15)^{a}	0.22 ±0.05(15)^{a}
06-Feb	13-Mar	Oo	1.22 ±0.21(5)^{ab}	0.53 ±0.14(5)^{a}	0.25 ±0.08(5)^{a}
		Oh	1.14 ±0.08(7)^{b}	0.46 ±0.21(7)^{a}	0.20 ±0.08(7)^{a}
		Ho	1.30 ±0.04(16)^{a}	0.50 ±0.10(11)^{a}	0.25 ±0.08(12)^{a}
		Hh	1.26 ±0.07(16)^{a}	0.60 ±0.34(16)^{a}	0.25 ±0.10(16)^{a}
26-Jan	03-Feb	Oo	1.18 ±0.04(5)^{b}	0.65 ±0.08(5)^{b}	0.16 ±0.02(5)^{b}
		Oh	1.28 ±0.15(12)^{ab}	0.91 ±0.16(5)^{a}	0.19 ±0.03(7)^{ab}
		Ho	1.28 ±0.03(5)^{ab}	0.80 ±0.13(5)^{ab}	0.23 ±0.04(5)^{a}
		Hh	1.33 ±0.02(10)^{a}	0.73 ±0.21(10)^{ab}	0.23 ±0.05(10)^{a}
26-Jan	07-Feb	Oo	1.22 ±0.05(10)^{b}	0.77 ±0.12(10)^{a}	0.20 ±0.02(10)^{b}
		Oh	1.21 ±0.03(10)^{b}	0.75 ±0.14(10)^{a}	0.20 ±0.02(10)^{b}
		Ho	1.36 ±0.04(10)^{a}	0.82 ±0.18(10)^{a}	0.23 ±0.04(10)^{a}
		Hh	1.33 ±0.03(10)^{a}	0.84 ±0.08(10)^{a}	0.21 ±0.02(10)^{ab}
26-Jan	09-Feb	Oo	1.25 ±0.03(5)^{b}	0.90 ±0.08(5)^{a}	0.18 ±0.01(5)^{b}
		Oh	1.21 ±0.05(10)^{b}	0.92 ±0.17(6)^{a}	0.21 ±0.03(10)^{ab}
		Ho	1.34 ±0.04(5)^{a}	1.08 ±0.03(5)^{a}	0.24 ±0.05(5)^{a}
		Hh	1.36 ±0.01(5)^{a}	0.93 ±0.15(5)^{a}	0.23 ±0.02(5)^{a}
26-Jan	14-Feb	Oo	1.23 ±0.04(5)^{a}	0.98 ±0.09(5)^{a}	0.20 ±0.05(5)^{b}
		Oh	1.21 ±0.13(10)^{a}	0.98 ±0.06(5)^{a}	0.22 ±0.06(5)^{ab}
		Ho	1.33 ±0.04(5)^{a}	1.15 ±0.12(5)^{a}	0.24 ±0.02(5)^{ab}
		Hh	1.24 ±0.11(10)^{a}	1.13 ±0.07(5)^{a}	0.27 ±0.06(5)^{a}

continued ...

Spawn Date	Sample Date	Treatment	Egg Diameter (mm)	Yolk Area (mm^2)	Oil Droplet (mm^2)
26-Jan	16-Feb	Oo	1.19 ±0.04(5)[a]	0.92 ±0.04(5)[a]	0.21 ±0.03(5)[a]
		Oh	1.20 ±0.08(10)[a]	0.86 ±0.25(10)[a]	0.19 ±0.04(10)[a]
		Ho	1.22 ±0.11(10)[a]	0.93 ±0.18(10)[a]	0.18 ±0.05(10)[a]
		Hh	1.20 ±0.05(5)[a]	0.98 ±0.06(5)[a]	0.20 ±0.04(5)[a]
26-Jan	19-Feb	Oo	1.27 ±0.08(3)[a]	1.02 ±0.05(3)[a]	0.12 ±0.05(3)[a]
		Oh	nm	nm	nm
		Ho	1.34 ±0.02(5)[a]	1.16 ±0.19(5)[a]	0.19 ±0.06(5)[a]
		Hh	nm	nm	nm
26-Jan	23-Feb	Oo	1.24 ±0.04(9)[a]	1.03 ±0.09(5)[a]	0.19 ±0.04(5)[b]
		Oh	1.25 ±0.04(4)[a]	0.97 ±0.17(5)[a]	0.19 ±0.03(5)[b]
		Ho	1.32 ±0.08(8)[a]	0.75 ±0.36(10)[a]	0.16 ±0.03(10)[b]
		Hh	1.30 ±0.14(8)[a]	0.90 ±0.34(7)[a]	0.27 ±0.04(7)[a]
26-Jan	27-Feb	Oo	1.27 ±0.08(5)[a]	1.03 ±0.23(5)[a]	0.25 ±0.04(5)[b]
		Oh	1.21 ±0.07(9)[a]	1.07 ±0.10(4)[a]	0.23 ±0.05(4)[a]
		Ho	1.27 ±0.13(7)[a]	1.07 ±0.10(5)[a]	0.19 ±0.02(5)[b]
		Hh	nm	nm	nm

Table 4. Total length, and cross-sectional areas of the yolk and oil droplet of burbot larvae hatched from eggs originating from adults reared at dissolved oxygen concentrations of 13.2 mg/L, (O), or 6.0 mg/L, (H), and incubated at [DO] of 13.2, (o), or 6.0, (h), mg/L, respectively. Values presented are the mean±1 standard deviation for sample size (N). Treatment means with the same superscript letter are not significantly different ($P < 0.05$).

Spawn Date	Sample Date	Treat-ment	Total Length (mm)	Yolk Area (mm^2)	Oil Droplet (mm^2)
04-Feb	27-Feb	Oo	3.29 ±0.15(4)	0.73 ±0359(4)	0.60 ±0.43(4)
04-Feb	13-Mar	Oo	3.71 ±0.30(10)[a]	0.45 ±0.24(10)[a]	0.39 ±0.17(7)[a]
		Oh	4.04 ±0.09(6)[b]	0.56 ±0.20(6)[a]	0.22 ±0.10(2)[a]
04-Feb	20-Mar	Oo	4.29 ±1.02(10)[a]	0.49 ±0.10(10)[a]	0.25 ±0.09(10)[a]
		Oh	4.04 ±0.28(5)[a]	0.52 ±0.08(5)[a]	0.14 (1)
04-Feb	27-Mar	Oo	4.00 ±0.32(10)[a]	0.41 ±0.09(10)[a]	0.18 ±0.08(10)[a]
		Oh	4.11 ±0.14(5)[a]	0.28 ±0.05(5)[b]	0.12 ±0.02(5)[a]
06-Feb	13-Mar	Oo	3.67 (1)	0.81 (1)	0.76 (1)
		Oh	nm	nm	nm
		Ho	3.63 ±0.28(9)	0.41 ±0.21(9)	0.24 ±0.11(9)
		Hh	3.67 (1)	nm	0.15 (1)
06-Feb	20-Mar	Oo	3.94 ±0.13(5)[a]	0.55 ±0.22(5)[a b]	0.36 ±0.17(5)[a]
		Oh	3.93 ±0.13(9)[a]	0.44 ±0.16(9)[b]	0.18 ±0.04(2)[a]
		Ho	3.97 ±0.30(15)[a]	0.56 ±0.15(15)[a b]	0.31 ±0.15(15)[a]
		Hh	4.19 ±0.37(14)[a]	0.67 ±0.15(14)[a]	0.20 ±0.03(7)[a]
06-Feb	27-Mar	Oo	4.09 ±0.28(10)[a b]	0.40 ±0.06(10)[b]	0.20 ±0.04(9)[a b]
		Oh	3.95 ±0.17(10)[b]	0.40 ±0.18(10)[b]	0.16 ±0.05(10)[b]
		Ho	4.22 ±0.20(11)[a]	0.55 ±0.09(11)[a]	0.22 ±0.04(11)[a]
		Hh	4.31 ±0.35(18)[a]	0.54 ±0.17(18)[a]	0.23 ±0.05(15)[a]
26-Jan	23-Feb	Oo	3.03 (1)	nm	0.25 (1)
		Oh	3.05 ±0.33(3)[a]	0.54 (1)	0.23 ±0.02(2)[a]
		Ho	nm	nm	nm
		Hh	3.10 ±0.08(4)[a]	0.80 ±0.16(4)	0.23 ±0.04(4)[a]

continued ...

Spawn Date	Sample Date	Treat-ment	Total Length (mm)	Yolk Area (mm^2)	Oil Droplet (mm^2)
26-Jan	27-Feb	Oo	3.32 ±0.50(10)^{a}	0.62 ±0.23(10)^{b}	0.34 ±0.20(10)^{a}
		Oh	3.26 ±0.50(10)^{a}	0.49 ±0.10(10)$^{a\ b}$	0.23 ±0.04(10)^{a}
		Ho	3.34 ±0.31(5)^{a}	0.32 ±0.07(2)^{a}	0.22 ±0.06(2)^{a}
		Hh	nm	nm	nm
26-Jan	13-Mar	Oo	3.68 ±0.33(9)^{a}	0.49 ±0.18(9)$^{a\ b}$	0.21 ±0.08(9)^{a}
		Oh	4.02 ±0.50(11)^{a}	0.40 ±0.13(10)^{b}	0.19 ±0.03(10)^{a}
		Ho	4.10 ±0.50(10)^{a}	0.44 ±0.14(10)$^{a\ b}$	0.23 ±0.02(10)^{a}
		Hh	4.14 ±0.70(5)^{a}	0.59 ±0.10(5)^{a}	0.22 ±0.02(5)^{a}
26-Jan	20-Mar	Oo	4.05 ±0.23(10)^{b}	0.41 ±0.07(10)^{b}	0.17 ±0.02(10)^{a}
		Oh	4.33 ±0.15(10)^{a}	0.43 ±0.07(10)^{b}	0.19 ±0.11(10)^{a}
		Ho	4.47 ±0.29(10)^{a}	0.43 ±0.07(10)^{b}	0.15 ±0.04(10)^{a}
		Hh	4.40 ±0.16(10)^{a}	0.54 ±0.08(10)^{a}	0.21 ±0.03(10)^{a}
26-Jan	27-Mar	Oo	3.97 ±0.17(3)^{b}	0.59 ±0.11(5)^{b}	0.11 (1)
		Oh	4.42 ±0.16(10)^{a}	0.49 ±0.12(10)$^{a\ b}$	0.21 ±0.12(10)^{a}
		Ho	4.43 ±0.30(16)^{a}	0.45 ±0.15(16)^{a}	0.12 ±0.05(10)^{a}
		Hh	4.65 ±0.16(10)^{a}	0.45 ±0.04(10)^{a}	0.21 ±0.03(10)^{a}

4.0 CONCLUSIONS

The hypoxic condition used in this study (6.0 mg/L) was similar to the lowest reported levels (6.0-7.7 mg/L) upstream of the inflow of the Lesser Slave River on the upper Athabasca River (Noton and Shaw 1989). Comparison of fish exposed to hypoxic and normoxic conditions showed few consistent treatment-related differences in blood hematocrit and hemoglobin or plasma electrolyte balance and glucose. Thus, the hypoxic conditions (6 mg/L DO) used lie within the compensatory scope of homeostatic processes in burbot. The metabolic costs of this compensation remain to be established. Assessment of spawning activity suggested that the period of spawning was delayed by as much as 5 weeks in at least some burbot exposed to hypoxic conditions. Although maintaining maturing burbot under hypoxic conditions produced only minor changes in the reproductive steroids, these were consistent with the delayed spawning. There may be several reasons for the extended spawning activity. Given the strong behavioral reactions of fish to low DO (reviewed in Barton and Taylor 1996), interactions between hypoxic conditions and spawning behavior merit investigation.

Due to the difficulties we encountered in following individual spawners and their gametes, our observations about the effects of hypoxic conditions on spawning activity, embryo survival, development and hatch must be regarded as preliminary. Survival of eggs incubated from the early spawn dates were variable but the differences were unrelated to either the source of the eggs or the dissolved oxygen concentration during embryological development. Consistent with previous observations in mountain whitefish (Giles and van der Zweep 1996), the hypoxic incubation conditions did seem to extend the time required for hatch. However, indices of embryological development were unaffected by incubation conditions. Eggs produced from delayed spawnings of hypoxic fish did not survive, possibly suggesting a problem with gamete viability or fertilization.

To our knowledge, this study represents the first attempt to perform a detailed investigation of burbot reproduction. Future investigations need to consider that it is extremely difficult to spawn burbot manually and that they spawn at night. Multiple holding exposure facilities for rearing spawning adults are required to provide verification and the appropriate replication for statistical analysis. Temporal changes in reproductive processes during normal gonadal development in burbot have not been described previously. When comparable sampling times are considered physiological paramters found in the laboratory-held burbot in this study are similar to the values reported for burbot in the Peace and Athabasca drainages (Brown et al. 1996). Thus, the results reported here do provide important comparative information for the coincident field studies. (i.e. Basin-Wide Fish Survey).

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APPENDIX A

NORTHERN RIVER BASINS STUDY

SCHEDULE A - TERMS OF REFERENCE

Project: 3221-D1: OXYGEN REQUIREMENTS OF NRBS FISH: LABORATORY STUDY (BURBOT)

I. PROJECT PURPOSE

The Northern River Basins Study requires the contract laboratory to determine the effects of reduced dissolved oxygen upon gonadal development and maturation of adult burbot, *Lota lota*, at water temperature appropriate to the period of hypoxia in major rivers in the study area. The viability of the gametes from the treated fish will also be determined. The experimental period of this study will extend from September 1/94 to July 31/95.

II. BACKGROUND

Deficiencies in the dissolved oxygen [DO] requirements of several species of fish residing in the NRBS area have been identified (Barton and Taylor, 1993). These fish including goldeye, *Hiodon alosoides*, flathead chub, *Platygobio gracilis*, burbot, *Lota lota*, bull trout, *Salvelinus confluentus*, and mountain whitefish, *Prosopium williamsoni*, are of significant economic, recreational, or ecological importance within the area. Substantial declines in [DO] are anticipated during periods of ice-cover as a result of increases in biological oxygen demand [BOD] arising from the oxidation of organic materials in pulp mill effluents discharged into major the river systems. Re-aeration through surface exchange and turbulence in rapids and waterfalls is expected to satisfy the BOD during ice-free periods. Sexual development and ovulation occur during the winter period in burbot. Burbot spawning occurs under the ice. The winter habitat of this fish is not well known, but while it is likely that many move to the tributaries of the major rivers (and away from the hypoxic water). However, some populations probably reside in the major river channels throughout all or part of the period of ice-cover. The temporal changes in levels of reproductive hormones during normal sexual development of burbot are largely unknown and the adverse effects of low oxygen tensions upon this process and subsequent viability of their gametes have not been investigated.

The goal of the proposed study is to define the temporal changes in reproductive hormones, identify changes in blood electrolytes, hemoglobin, hematocrit, and blood oxygen content, and evaluate the viability of the eggs and sperm for this species during the period of sexual development under normoxic and hypoxic conditions. The results will be used to produce bioindicators of reproductive performance as a tool for long-term monitoring of the levels of stress experienced by spawning fish in the NRB Study Area.

This project is one step towards the larger goal to provide criteria for assessing the impact of reduced levels of dissolved oxygen upon the survival and biological state of selected fish species residing in the NRB Study area. The biological responses to be evaluated will be the processes of gonadal development and maturation of adult burbot, *Lota lota*, measured at environmentally realistic water temperatures (2-3°C). The study will focus on those levels of dissolved oxygen (approximately 6.0 mg/l) present during the period of ice-cover when hypoxic conditions are most severe.

The results of the study will be incorporated into a report relating the severity of response to the hypoxic stress for this species and providing recommendations for the application of specific biological responses to long-term monitoring of the levels of stress experienced by these fish in the NRB Study area.

Adult burbot will be collected from the Manitoba Interlake region and the Winnipeg River, respectively. After conditioning to laboratory facilities the fish will be exposed to hypoxic (O_2 = 6 mg/l) and normoxic (O_2 > 13 mg/l) conditions for approximately seven months. During this period they will be sampled for plasma hormone titre and electrolytes and whole blood hemoglobin and oxygen content. After complete sexual maturation the fish will be spawned and the effects of hypoxia upon gamete viability and early development will be determined. The results will be interpreted with respect to the anticipated impacts of hypoxia upon these fish in major rivers in the NRB Study Area.

III. GENERAL REQUIREMENTS

1. The contractor is required to obtain adult male and female burbot from wild populations in Manitoba and rear these fish at a water temperature and photo period appropriate to their natural environment.

    a. The chemical characteristics of the incubation water should be comparable to those occurring in the major rivers of the Study Area: pH, 7.8-8.4; alkalinity, 10-110 mg/l as $CaCO_3$; hardness, 85-145 mg/l as $CaCO_3$; TDS, 90-150 mg/l; and Ca, Mg, Na, K, and Cl, 23-40, 7-11, 0.6-7.0, 0.2-2.0, and 0.3-7.0 mg/l, respectively. Concentrations of copper, cadmium, zinc, arsenic, cobalt, chromium, manganese, lead, and selenium will be <1 µg/l and free chlorine will be <3 µg/l in the test water to avoid interactive toxic effects in the experimental treatments.

    b. The burbot will be collected in October when water temperatures are ≤6°C and will be reared in the laboratory with a temperature regime which declines to 3°C by November 1. Thereafter the fish will be maintained at 3.0 ±0.2°C.

2. The contractor is required to assess the impact of reduced dissolved oxygen levels upon gonadal development, maturation and gamete viability of adult burbot.

   a. During the period of November 30, 1994 to April 15, 1995 (or until spawning) adult burbot of both sexes will be reared in water containing ≥12.5 and 6 mg/l (± 10% of nominal) of dissolved oxygen. At 5 week intervals throughout this period blood will be extracted from 5 - 10 fish of each species, sex and oxygen treatment. Subsamples will be taken for hematology and the remaining plasma will be separated and stored at -80°C for future analysis of reproductive hormones and electrolytes.

   b. Upon completion of gonadal maturation individual pairs of fish will be mated and their fertilized eggs will be incubated in separate incubators. Since burbot spawn before ice-out, their eggs will be incubated at 3°C in water containing 6 and 12.5 mg/l of dissolved oxygen. Sperm motility of the species will be assessed at the time of sexual maturation. The survival and development of the eggs will be monitored. Success of hatching and physical abnormalities will be assessed.

   c. The plasma levels of hormones associated with sexual development and maturation; Gonadotrophin II, 17ß-Estrodiol, 11-ketotestosterone, and testosterone will be measured in the plasma samples. The concentrations of sodium, potassium, and calcium will be determined on these same samples. Should the plasma volume be inadequate for all analyses the order of priority for analysis will be hormones > calcium > sodium and potassium.

IV. REPORTING REQUIREMENTS

1. Submit a brief progress report to the Project Liaison Officer by January 15, 1995 and a summary progress report by March 31, 1995.

2. Submit ten copies of the Draft Report along with an electronic copy to the Project Liaison Officer by July 31, 1995. The draft report is to follow the Northern River Basin Style Guide.

3. Three weeks after the receipt of review comments on the draft report, the Contractor is to provide the Project Liaison Officer with two unbound, camera ready copies and ten cerlox bound copies of the final report along with an electronic version.

   The final report is to include the following: an acknowledgement section that indicates any local involvement in the project, Report Summary, Table of Contents, List of Tables, List of Figures and an Appendix with the Terms of Reference for this project.

Text for the report should be set up in the following format:

a. Times Roman 12 point (Pro) or Times New Roman (WPWIN60) font.
b. Margins; are 1" at top and bottom, 7/8" on left and right.
c. Headings; in the report body are labelled with hierarchical decimal Arabic numbers.
d. Text; is presented with full justification; that is, the text aligns on both left and right margins.
e. Page numbers; are Arabic numerals for the body of the report, centred at the bottom of each page and bold.

If photographs are to be included in the report text they should be high contrast black and white.

- All tables and figures in the report should be clearly reproducible by a black and white photocopier.

- Along with copies of the final report, the Contractor is to supply an electronic version of the report in Word Perfect 5.1 or Word Perfect for Windows Version 6.0 format.

- Electronic copies of tables, figures and data appendices in the report are also to be submitted to the Project Liaison Officer along with the final report. These should be submitted in a spreadsheet (Quattro Pro preferred, but also Excel or Lotus) or database (dBase IV) format. Where appropriate, data in tables, figures and appendices should be geo-referenced.

4. All figures and maps are to be delivered in both hard copy (paper) and digital formats. Acceptable formats include: DXF, uncompressed E∅∅, VEC/VEH, Atlas and ISIF. All digital maps must be properly geo-referenced.

5. All sampling locations presented in report and electronic format should be geo-referenced. This is to include decimal latitudes and longitudes (to six decimal places) and UTM coordinates. The first field for decimal latitudes / longitudes should be latitudes (10 spaces wide). The second field should be longitude (11 spaces wide).

6. Six to ten 35 mm slides that can be used at public meetings to summarize the project, methods and key findings. The presentation package of 35 mm slides is to comprise of one original and four duplicates of each slide.

7. The report is to include all the results. In addition to generally accepted scientific reporting standards the draft report will include:

a. specimen handling, processing and analytical methods, quality assurance/quality control measures.

b. a description of the methods and water treatment systems employed in the study.

c. an analysis of the sublethal effects of reduced levels of dissolved oxygen upon gonadal development and maturation, and gamete viability of burbot and goldeye.

d. a brief interpretation of the meaning of the results with respect to the sensitivity of adult burbot and goldeye to dissolved oxygen levels anticipated in the study area.

8. The raw data relating to water system operation, daily dissolved oxygen measurements, and biological and biochemical measurements will be maintained in a data-base retained by the laboratory but will be made available to the Northern River Basin Study upon request.

V. INTELLECTUAL PROPERTY

Upon completion or termination of this project, all data, documents, and materials which are acquired or produced under this project shall become the sole property of the Northern River Basins Study.

VI. PROJECT MANAGEMENT PLAN -Fisheries and Oceans Canada - Freshwater Institute/Winnipeg physiology laboratory

1. Adult burbot will be collected from rivers in south-central Manitoba in October 1994. All permits for the collection and transport of these fish will be obtained by the laboratory and regulations concerning the disposition of the fish will be enforced.

2. The Northern Rivers Study Office will be informed at the earliest possible date of any impediments to the execution of this investigation such as mortality of the fish or failure of the culture systems as nonviability of the gametea.

3. The project will cover the period September 94 to July 95, with investigations split into two parts. They cover the periods September 94 to March 31, 1995 and, April 95 to July 31, 1995. This project costs will include the salary of technical assistants, laboratory and analytical costs and expenses incurred in producing the interim and final reports to the Northern River Basins Study as specified in III. REPORTING REQUIREMENTS, above.

   The Contractor agrees to provide expert scientific advice at no additional cost.

VII. CONTRACT ADMINISTRATION

The Project Liaison Officer (Component Coordinator) for this project is:

Ken Crutchfield
Associate Science Director
Northern River Basins Study
690 Standard Life Centre
10405 - Jasper Avenue
Edmonton, Alberta T5J 3N4
Phone: 403 - 427 - 1742
Facsimile: 403 0 422 - 3055

Please contact the Component Coordinator on administrative matters.

This project has been proposed by the Food Chain Component of the NRBS.
The Component Leader is:

Mr. Tom Mill
Manager, Natural Resource Planning Division
Research and Strategic Services
Alberta Environmental Protection
9th Flr. Oxbridge Place
9915 - 108 Street
Edmonton, Alberta T5K 2G8
Phone: 403 - 427 - 8775
Facsimile: 403 - 422- 4190

Please contact the Component Leader on issues related to science.

VIII. LITERATURE CITED

Barton, B.A., and B.R. Taylor. February 1994. Dissolved oxygen requirements for fishes of the Northern River Basins. Report to Northern River Basins Study by Environmental Associates, Calgary, Alberta. Northern River Basins Study Report # 29, 104 pp+append.

APPENDIX B

Table 5. Exposure conditions, fish tag #, sex, sample time after begining exposure, blood hematiocrit (Hct), blood hemoglobin (Hb), plasma testosterone (Test), plasma 17ß-estradiol (17ß-E2), plasma 11-ketotestosterone (11Ktest), plasma glucose (Glu), plasma calcium (Ca), plasma magnesium (Mg), plasma potassium (K), and plasma sodium (Na) in experimental burbot.

Treatment	Fish Tag #	SEX	Sample Time (day)	Hct (%)	Hb (g/dL)	Test (ng/mL)	17ß-E2 (ng/mL)	11Ktest (ng/mL)	Glu (mmol/L)	Ca (mmol/L)	Mg (mmol/L)	K (mmol/L)	Na (mmol/L)
Normoxic	C-2004	F	1	27.5	5.49	25.03	6.05		4.86	6.18	0.74	1.60	165
Normoxic	C-2010	F	1	24.0	3.34	7.78	9.83		4.06	5.82	0.75	0.51	150
Normoxic	C-2020	F	1	21.5	4.85	11.17	7.14		10.14	6.01	0.79	1.49	144
Normoxic	C-2027	F	1	30.0	7.17	0.58	0.01		12.28	3.18	0.66	1.38	150
Normoxic	C-2032	F	1	25.5	4.50	11.98	3.96		8.83	9.22	0.93	0.54	139
Normoxic	C-2038	F	1	20.0	4.39	3.73	4.09		4.17	4.91	0.88	1.69	150
Normoxic	C-2049	F	1	19.5	4.28	17.39	12.41		5.87	5.45	0.67	1.40	147
Normoxic	C-2056	F	1	20.0	3.70	9.78	7.21		6.64	5.50	0.87	1.49	142
Normoxic	C-2065	F	1			6.46	7.05						
Normoxic	C-2071	F	1	23.5	4.74	7.86	4.50		4.27	6.16	1.04	2.30	149
Normoxic	C-2079	F	1	20.5	3.15	2.55	9.63		13.30	7.36	0.83	1.87	133
Normoxic	C-2080	F	1	23.5	5.07	29.53	6.28		4.00	6.22	0.81	1.76	155
Normoxic	C-2098	F	1	25.5	3.01								
Normoxic	C-2012	M	1	22.5	4.06	13.26		12.54	6.26	3.19	0.73	1.82	149
Normoxic	C-2013	M	1	30.5	6.09	34.75		54.44	6.20	7.33	1.06	0.79	153
Normoxic	C-2015	M	1	23.0	5.02	17.42		21.25	4.24	3.18	0.72	0.85	158
Normoxic	C-2042	M	1	27.0	3.61	14.25		6.35	3.50	3.18	0.71	1.46	148
Normoxic	C-2051	M	1	25.5	3.67	18.90		17.58	5.97	3.46	0.68	1.49	142
Normoxic	C-2055	M	1	26.5	7.11	61.58		16.53	3.64	2.98	0.60	1.48	162
Normoxic	C-2069	M	1	23.5	4.33	15.38		13.33	3.98	3.22	0.81	1.02	149
Normoxic	C-2088	M	1	21.0	0.86	21.12		18.89	8.72	3.00	0.60	1.17	170
Normoxic	G-957	F	1	24.5	5.65	3.75	4.15		4.92				
Normoxic	G-959	F	1	16.0	2.24	11.75	5.09		24.28	8.65	0.91	1.74	101
Normoxic	G-961	F	1	18.0	2.02	12.31	9.39		3.75	5.50	0.87	1.35	147
Normoxic	G-963	F	1	20.0	2.13	8.82	5.36		6.77	6.31	0.90	1.90	142
Normoxic	G-976	F	1	23.0	2.90	25.51	6.82		4.32	6.72	0.81	1.68	156
Normoxic	G-983	F	1	28.0	5.29	10.43	9.90		7.84	6.69	0.77	0.71	165
Normoxic	G-985	F	1	16.5	3.12	0.30	0.01		32.75	5.78	1.41	1.42	118
Normoxic	G-987	F	1	25.0	4.22	5.37	9.24		16.60	5.92	0.76	1.89	163
Normoxic	G-989	F	1	11.0	0.78	29.43	7.39		6.23	7.77	0.82	1.21	162
Normoxic	G-993	F	1	9.0	0.92	13.06	5.01		2.72	4.36	0.65	2.20	155
Normoxic	G-955	M	1	17.0	2.46	9.22		3.44	6.68	2.87	0.65	1.25	134
Normoxic	G-965	M	1	20.0	4.39	21.40		1.42	3.81	2.99	0.60	1.43	147
Normoxic	G-967	M	1	27.5	6.39	15.19		17.74	2.81				
Normoxic	G-973	M	1	19.5	4.22	43.48		55.62	4.25	3.33	0.71	1.69	155
Normoxic	G-974	M	1	27.0	5.73	17.74		6.26	6.07	2.91	0.52	1.40	
Normoxic	G-975	M	1	24.0	5.40	22.69		14.64	7.11	2.97	0.55	2.04	152
Normoxic	G-977	M	1	11.0	2.18	13.71		12.47	9.53	3.00	0.68	1.72	142
Normoxic	G-979	M	1	28.5	4.44	17.38		13.70	4.73	3.07	0.54	0.20	130
Normoxic	G-981	M	1	29.0	4.06	29.41		59.50	4.44	3.34	0.61	0.30	145
Normoxic	G-991	M	1	22.0	3.81	21.78		20.93	5.52	3.31	0.57	0.92	172
Hypoxic	C-2006	F	1	23.0	5.21	26.23	12.25		4.34	5.96	0.78	1.69	154
Hypoxic	C-2019	F	1	21.0	3.20	10.52	3.56		5.07	6.33	0.90	1.89	152
Hypoxic	C-2030	F	1	22.0		8.45	8.90		2.85	4.26	0.91	1.58	141
Hypoxic	C-2036	F	1	24.5	4.74	6.59	4.73		2.16	3.69	0.75	1.63	141
Hypoxic	C-2046	F	1	26.0	5.51	12.95	7.79		4.52	5.74	0.69	1.88	152

Treatment	Fish Tag #	SEX	Sample Time (day)	Hct (%)	Hb (g/dL)	Test (ng/mL)	17ß-E2 (ng/mL)	11Ktest (ng/mL)	Glu (mmol/L)	Ca (mmol/L)	Mg (mmol/L)	K (mmol/L)	Na (mmol/L)
Normoxic	C-2004	F	1	27.5	5.49	25.03	6.05		4.86	6.18	0.74	1.60	165
Normoxic	C-2010	F	1	24.0	3.34	7.78	9.83		4.06	5.82	0.75	0.51	150
Hypoxic	C-2053	F	1	29.5	5.38	6.66	10.43		4.57	7.75	0.95	1.80	159
Hypoxic	C-2058	F	1	27.5	5.32	0.20	0.01		7.15	3.97	0.75	0.44	169
Hypoxic	C-2081	F	1	17.0	2.68	2.33	8.27		25.30	6.15	0.76	1.56	112
Hypoxic	C-2085	F	1	13.5	2.65	24.40	2.81		10.69	6.10	0.57	1.02	108
Hypoxic	C-2087	F	1	18.0	1.94	17.46	4.93		9.18	8.91	1.08	1.25	145
Hypoxic	C-2003	M	1	24.0	5.68	0.09		0.50					
Hypoxic	C-2017	M	1	21.5	4.91	12.76		2.41	4.73	3.49	0.70	1.70	162
Hypoxic	C-2018	M	1	12.0	2.54	29.46		17.00	10.87	3.64	0.62	1.90	134
Hypoxic	C-2022	M	1	13.0	0.75	15.83		8.67	1.85	1.98	0.37	0.85	112
Hypoxic	C-2039	M	1	28.5	7.11	47.42		36.63	3.11	3.28	0.74	1.71	142
Hypoxic	C-2048	M	1	23.0	5.10	14.49		9.51	4.86	3.25	0.69	0.76	147
Hypoxic	C-2052	M	1	26.5	4.06	26.33		17.78	3.86	3.10	0.56	1.16	173
Hypoxic	C-2068	M	1	19.0	3.50	57.26		45.91	4.90	3.06	0.57	1.25	158
Hypoxic	C-2077	M	1	23.0	5.27	21.69		15.86	3.03	2.99	0.58	1.60	169
Hypoxic	G-953	F	1	19.0	3.26	12.74	3.56		7.86	9.70	1.07	1.15	131
Hypoxic	G-964	F	1	26.5	3.42	3.27	5.12		4.00	3.33	0.52	4.64	110
Hypoxic	G-966	F	1	22.0	4.85	10.84	2.16		6.64	8.20	0.90	1.76	130
Hypoxic	G-970	F	1	29.5	6.20	9.32	13.53		4.69				
Hypoxic	G-971	F	1	29.0	6.31	24.23	7.75		2.43	5.52	0.75	1.95	155
Hypoxic	G-980	F	1	24.0	7.06	18.35	10.29		4.22	6.64	0.83	0.85	166
Hypoxic	G-986	F	1	25.0	4.94	16.34	6.47		6.36	6.98	0.79	1.55	165
Hypoxic	G-990	F	1	24.0	4.52	21.33	7.56		3.44	5.00	0.65	1.02	179
Hypoxic	G-956	M	1	25.0	3.84	14.33		16.69	4.94	2.93	0.74	0.86	146
Hypoxic	G-958	M	1	31.0	6.78	5.16		1.71	3.37	2.87	0.74	1.69	144
Hypoxic	G-960	M	1	21.5	1.99	8.93		6.30	7.25	3.37	0.71	2.74	131
Hypoxic	G-962	M	1	31.5	6.20	32.34		24.41	6.49	3.19	0.70	1.59	150
Hypoxic	G-968	M	1	27.5	5.68	20.81		7.85					
Hypoxic	G-969	M	1	29.0	6.26	34.31		17.85	7.00	3.69	0.72	1.76	156
Hypoxic	G-972	M	1	24.5	5.27	22.17		13.07	5.07	3.53	0.73	1.94	155
Hypoxic	G-978	M	1	25.0	4.55	19.31		13.07	6.58	3.41	0.76	1.45	150
Hypoxic	G-982	M	1	31.0	4.96	0.16		0.50	3.80	3.33	0.71	0.80	139
Hypoxic	G-984	M	1	23.5	5.29	32.14			5.34	7.40	1.22	1.09	150
Hypoxic	G-988	M	1	23.0	2.73	13.23		14.28	8.32	3.26	0.63	1.48	175
Hypoxic	G-992	M	1	25.5	7.19	11.29		3.15	3.05	3.06	0.54	1.40	170
Normoxic	C-2004	F	30	22.0	4.39	56.82	2.41		4.11	5.21	1.12	2.92	115
Normoxic	C-2010	F	30		4.99	3.08	15.13		4.60	4.78	0.75	2.59	94
Normoxic	C-2020	F	30	21.5	4.63	33.05	4.62		5.18	4.38	0.83	2.27	112
Normoxic	C-2027	F	30	27.5	5.40	0.10			13.22	2.06	0.49	1.65	126
Normoxic	C-2032	F	30	22.5	1.80	21.30	15.13		6.17	6.27	1.00	2.01	108
Normoxic	C-2038	F	30	21.5	3.89	3.87	16.45		4.13	4.56	1.01	5.32	141
Normoxic	C-2049	F	30	21.0	5.02	34.72	5.59		4.99	4.81	0.86	2.76	116
Normoxic	C-2056	F	30	19.0	3.37	20.07	4.15		4.02	5.98	1.21	2.81	138
Normoxic	C-2065	F	30	24.5	5.07	36.45	13.70		3.14	3.75	0.89	3.43	126
Normoxic	C-2071	F	30	25.5	5.49	32.99	4.46		4.80	5.12	1.10	9.74	88
Normoxic	C-2079	F	30	20.0	3.84	17.77	4.73		7.01	8.36	1.25	2.70	129
Normoxic	C-2080	F	30	27.0	6.26	34.66	2.53		8.28	7.53	1.30	2.83	138
Normoxic	C-2098	F	30	23.0	4.69	39.27	0.16		7.07	3.99	0.83	3.39	114
Normoxic	C-2012	M	30	18.0	4.08	30.49		35.99	3.27	2.48	0.63	3.06	121
Normoxic	C-2013	M	30	30.5	5.40	35.34		53.45	5.95	3.27	0.76	3.25	129
Normoxic	C-2015	M	30	25.0	4.25	33.04		65.19	4.56	2.86	0.66	2.73	119

Treatment	Fish Tag #	SEX	Sample Time (day)	Hct (%)	Hb (g/dL)	Test (ng/mL)	17ß-E2 (ng/mL)	11Ktest (ng/mL)	Glu (mmol/L)	Ca (mmol/L)	Mg (mmol/L)	K (mmol/L)	Na (mmol/L)
Normoxic	C-2004	F	1	27.5	5.49	25.03	6.05		4.86	6.18	0.74	1.60	165
Normoxic	C-2010	F	1	24.0	3.34	7.78	9.83		4.06	5.82	0.75	0.51	150
Normoxic	C-2042	M	30	29.5	5.35	27.99		43.76	5.51	3.30	0.76	2.91	146
Normoxic	C-2051	M	30	29.0	5.46	24.96		46.59	5.48	3.31	0.82	2.52	122
Normoxic	C-2069	M	30	29.0	1.61	36.35		37.49	3.87	3.56	0.87	3.16	131
Normoxic	C-2088	M	30	26.0	4.52	31.74		52.03	5.81	3.38	0.78	5.44	125
Hypoxic	C-2006	F	30	22.5	0.72	42.51	4.10		4.09	4.32	0.83	1.85	139
Hypoxic	C-2019	F	30	25.0	4.80	17.92	3.70		7.01	5.35	1.03	2.79	122
Hypoxic	C-2030	F	30	16.0	3.15	22.51	23.50		4.96	3.58	0.79	1.90	131
Hypoxic	C-2036	F	30	18.5	4.03	3.85	3.54		4.99	1.96	0.51	1.64	60
Hypoxic	C-2046	F	30	29.5	1.96	40.76	3.15		5.49	6.48	0.96	2.30	133
Hypoxic	C-2053	F	30	31.5	5.51	20.54	4.00		5.02	9.69	1.32	2.27	150
Hypoxic	C-2058	F	30	23.5	4.50	0.50			5.10	2.57	0.82	1.59	137
Hypoxic	C-2085	F	30	14.5	2.49	26.20	1.97		6.13	6.58	1.08	3.04	119
Hypoxic	C-2087	F	30	18.0	2.98	20.61	3.94		15.52	8.67	1.11	2.24	108
Hypoxic	C-2003	M	30	30.5	4.61	0.86		0.50	5.85	3.30	0.89	2.72	159
Hypoxic	C-2017	M	30	27.0	5.71	34.27		22.97	4.28	2.60	0.76	2.55	150
Hypoxic	C-2018	M	30	15.5	2.35	48.80		31.51	6.17	2.45	0.56	2.18	110
Hypoxic	C-2022	M	30	15.5	3.26	13.25		7.75	4.78	2.62	0.77	3.35	139
Hypoxic	C-2039	M	30	32.0	5.40	54.03		35.38	5.89	2.68	0.67	2.64	125
Hypoxic	C-2048	M	30	25.0	4.96	20.30		21.43	5.06	1.95	0.59	2.00	86
Hypoxic	C-2052	M	30	32.5	1.44	33.14		25.16	4.86	2.63	0.70	3.22	142
Hypoxic	C-2068	M	30	30.0	2.90	28.60		16.88	5.55	2.92	0.77	3.89	133
Hypoxic	C-2077	M	30	30.0	4.96	38.12		31.27	5.06	2.86	0.81	2.92	149
Normoxic	G-961	F	51	19.0	2.87	48.64	1.57		4.50	4.28	1.08	2.89	128
Normoxic	G-976	F	51	21.0	3.80	54.06	3.43		5.02	4.50	1.00	2.80	114
Normoxic	G-963	F	51	18.5	3.28	35.23	7.74		4.98	3.54	0.90	3.44	115
Normoxic	G-989	F	51	11.5	1.80	58.34	2.07		4.58	3.71	0.99	2.78	144
Normoxic	G-993	F	51	18.5	5.17	42.99	3.41		3.93	3.55	0.99	3.39	152
Normoxic	G-955	M	51	12.5	1.97	37.51		35.60	2.66	2.87	0.78	4.07	130
Normoxic	G-967	M	51	29.0	6.07	37.95		77.56	11.03	2.72	0.80	3.33	137
Normoxic	G-973	M	51	26.5	5.14	55.66		107.94	5.63	2.39	0.71	3.03	124
Normoxic	G-974	M	51	33.5	7.48	28.35		21.33	5.02	2.22	0.67	2.81	110
Normoxic	G-975	M	51	23.0	4.66	33.49		65.48	4.52	2.59	0.87	3.74	148
Normoxic	G-977	M	51	13.5	2.49	31.38		53.47	4.44	2.39	0.79	5.72	124
Normoxic	G-979	M	51	27.5	5.24	34.80		56.48	3.51	1.92	0.60	2.42	129
Normoxic	G-981	M	51	30.5	6.79	37.01		48.38	3.31	2.29	0.73	2.19	155
Normoxic	G-991	M	51	26.0	5.45	33.14		36.82	5.63	2.70	0.77	2.76	140
Hypoxic	G-953	F	51	27.0	5.45	43.43	4.07		6.49	5.89	0.86	1.54	105
Hypoxic	G-970	F	51	26.0	5.55	47.56	2.47		8.25	4.38	0.90	2.10	104
Hypoxic	G-964	F	51	27.5	5.34	3.68	4.20		3.27	3.01	0.80	1.80	109
Hypoxic	G-971	F	51	24.5	5.69	34.62	0.56		4.78	3.41	0.91	3.08	139
Hypoxic	G-966	F	51	24.0	5.34	49.08	3.56		6.13	10.37	1.58	3.12	133
Hypoxic	G-980	F	51	25.5	4.97	26.78	2.30		6.68	4.87	1.09	2.50	129
Hypoxic	G-986	F	51	29.5	6.07	34.07	2.96		5.61	5.44	1.29	2.48	145
Hypoxic	G-990	F	51	28.5	5.45	35.39	4.34		3.45	2.74	0.84	2.66	131
Hypoxic	G-956	M	51	9.0	1.83	25.97		32.42	3.87	3.83	0.92	2.53	137
Hypoxic	G-968	M	51	30.5	6.07	19.21		27.04	5.85	3.45	0.92	2.45	140
Hypoxic	G-958	M	51	38.0	7.37	39.76		47.52	3.79	2.60	0.85	2.03	112
Hypoxic	G-969	M	51	25.5	5.76	40.27		90.80	4.26	2.80	0.77	4.16	150
Hypoxic	G-960	M	51	25.5	5.28	45.01		28.16	8.57	3.37	0.85	3.06	129
Hypoxic	G-972	M	51	35.0	7.34	63.30		96.10	3.80	5.07	1.13	3.06	149

Treatment	Fish Tag #	SEX	Sample Time (day)	Hct (%)	Hb (g/dL)	Test (ng/mL)	17ß-E2 (ng/mL)	11Ktest (ng/mL)	Glu (mmol/L)	Ca (mmol/L)	Mg (mmol/L)	K (mmol/L)	Na (mmol/L)
Normoxic	C-2004	F	1	27.5	5.49	25.03	6.05		4.86	6.18	0.74	1.60	165
Normoxic	C-2010	F	1	24.0	3.34	7.78	9.83		4.06	5.82	0.75	0.51	150
Hypoxic	G-962	M	51	34.5	8.20	50.44		104.58	5.43	3.34	0.94	2.79	148
Hypoxic	G-978	M	51	28.0	5.21	22.81		20.03	5.89	2.90	0.82	2.32	129
Hypoxic	G-982	M	51	25.0	4.83	0.16		0.50	2.75	2.62	0.82	3.47	146
Hypoxic	G-984	M	51	27.0	5.69	42.10	0.32		5.15	3.71	0.92	3.57	135
Hypoxic	G-988	M	51	28.5	6.20	56.66		61.33	5.30	2.88	0.79	2.60	130
Hypoxic	G-992	M	51	35.5	7.20	12.31		5.92	4.80	3.31	0.79	2.52	128
Normoxic	C-2004	F	71	23.5	4.28	51.17	1.26		4.21	2.72	0.82	2.32	132
Normoxic	C-2010	F	71	14.0	2.59	27.99	0.95		3.49	4.42	0.88	2.37	136
Normoxic	C-2020	F	71	16.0	3.21	16.77	0.56		5.93	3.54	0.80	2.13	120
Normoxic	C-2027	F	71	28.0	5.76	0.19			10.79	3.95	1.16	2.56	147
Normoxic	C-2032	F	71	24.0	4.97	14.22	1.88		8.13	3.95	0.94	2.69	138
Normoxic	C-2038	F	71	17.5	3.04	35.79	5.12		4.03	2.05	0.78	3.13	109
Normoxic	C-2049	F	71	22.5	5.17	21.71	1.18		4.54	4.33	0.93	2.77	138
Normoxic	C-2056	F	71	15.5	2.80	16.29	0.25		4.09	3.55	0.94	2.66	136
Normoxic	C-2065	F	71	24.5	3.80	0.14	0.05		2.72	3.94	0.97	2.51	147
Normoxic	C-2071	F	71	25.0	4.11	21.11	4.37		6.28	4.54	1.02	2.59	135
Normoxic	C-2079	F	71	16.0	2.90	13.46	0.19		8.39	3.51	0.84	2.82	132
Normoxic	C-2080	F	71	28.0	5.72	38.45	0.29		8.91	5.05	0.97	2.42	134
Normoxic	C-2012	M	71	18.0	3.69	30.82		95.25	6.08	3.05	0.74	1.89	122
Normoxic	C-2013	M	71	23.5	4.76	30.13		58.99	5.63	3.63	0.82	2.50	141
Normoxic	C-2015	M	71	27.5	5.00	18.90		136.58	5.09	2.69	0.69	2.66	125
Normoxic	C-2042	M	71	27.0	4.79	29.65		31.21	5.71	2.12	0.77	2.32	145
Normoxic	C-2051	M	71	24.5	4.55	17.26		132.71	5.03	2.03	0.65	3.20	121
Normoxic	C-2055	M	71	23.5	4.83	25.22		82.98	2.67	3.60	0.83	2.70	135
Normoxic	C-2069	M	71	32.0	5.41	25.19		62.79	4.72	2.62	0.66	2.14	94
Normoxic	C-2088	M	71	25.5	4.42	57.14		28.45	4.93	2.13	0.71	2.22	119
Hypoxic	C-2006	F	71	28.0	5.59	88.93	1.22		3.56	4.27	0.85	2.31	143
Hypoxic	C-2019	F	71	17.5	3.66	13.62	0.41		5.61	4.20	0.89	1.99	124
Hypoxic	C-2030	F	71	14.5	2.90	2.53	0.09		6.28	3.98	0.93	1.63	147
Hypoxic	C-2036	F	71	14.0	2.97	23.28	0.25		1.88	2.80	0.73	2.20	134
Hypoxic	C-2046	F	71	25.5	6.31	0.76	0.30		7.74	6.13	1.06	2.19	134
Hypoxic	C-2053	F	71	20.5	5.52	0.33	0.35		6.65	6.90	1.08	2.15	135
Hypoxic	C-2085	F	71	15.0	3.00	0.41	0.04		3.90	5.09	0.93	2.39	131
Hypoxic	C-2087	F	71	17.5	3.42	35.07	0.34		9.99				
Hypoxic	C-2003	M	71	27.0	5.38	0.19		0.50	3.82	3.09	0.94	2.71	134
Hypoxic	C-2017	M	71	27.0	5.31	43.78		71.91	4.17	2.95	0.85	2.14	138
Hypoxic	C-2018	M	71	17.5	2.80	26.09		91.28	5.61	2.14	0.67	2.10	135
Hypoxic	C-2022	M	71	18.5	4.04	21.18		14.27	4.01	3.45	0.93	2.59	142
Hypoxic	C-2039	M	71	31.0	4.42	35.30		106.37	4.72	3.17	0.95	2.50	135
Hypoxic	C-2048	M	71	20.0	4.76	53.67		37.65	5.19	3.07	0.86	2.69	143
Hypoxic	C-2052	M	71	29.0	6.10	35.74		34.07	5.40	2.89	0.75	2.33	115
Hypoxic	C-2068	M	71	29.5	6.00	16.80		11.00	3.15	3.12	0.96	3.38	162
Hypoxic	C-2077	M	71	30.0	6.62	1.83		0.60	5.54	2.93	0.86	2.19	116
Normoxic	G-961	F	86	14.5	2.80	0.31	0.17		4.15	4.14	1.06	2.93	157
Normoxic	G-963	F	86	18.0	3.59	1.33	0.16		5.15	4.38	1.01	2.85	142
Normoxic	G-976	F	86	16.0	3.56	0.46	0.41		3.85	4.32	1.07	2.33	147
Normoxic	G-983	F	86	28.0	4.48	0.31	0.03		3.22	4.16	1.01	2.31	146
Normoxic	G-989	F	86	14.5	2.45	0.32	0.03		2.81	3.93	0.97	2.95	143
Normoxic	G-993	F	86	36.0	6.34	0.26	0.07		4.56	3.32	0.95	2.68	125
Normoxic	G-955	M	86	12.0	2.45	0.40		17.12	5.17	3.04	0.83	2.81	120

Treatment	Fish Tag #	SEX	Sample Time (day)	Hct (%)	Hb (g/dL)	Test (ng/mL)	17ß-E2 (ng/mL)	11Ktest (ng/mL)	Glu (mmol/L)	Ca (mmol/L)	Mg (mmol/L)	K (mmol/L)	Na (mmol/L)
Normoxic	C-2004	F	1	27.5	5.49	25.03	6.05		4.86	6.18	0.74	1.60	165
Normoxic	C-2010	F	1	24.0	3.34	7.78	9.83		4.06	5.82	0.75	0.51	150
Normoxic	G-967	M	86	22.5	4.00	1.61		7.15	3.75	3.16	0.83	2.58	140
Normoxic	G-973	M	86	29.0	5.86	10.37		25.29	5.86	2.96	0.79	2.66	141
Normoxic	G-974	M	86	32.0	6.72	1.65		3.93	6.00	2.86	0.79	2.49	151
Normoxic	G-975	M	86	24.5	4.48	0.06		0.50	2.66	2.73	0.91	2.88	158
Normoxic	G-977	M	86	17.0	3.11	17.62		26.51	5.39	2.80	0.81	2.86	147
Normoxic	G-979	M	86	24.5	4.79	4.98		6.61	4.02	3.44	0.82	2.53	161
Normoxic	G-981	M	86	25.5	5.14	0.73		0.50	5.34	2.82	0.68	2.49	134
Normoxic	G-991	M	86	25.5	4.66	5.05		8.25	7.13	3.01	0.77	2.37	130
Hypoxic	G-953	F	86	23.5	4.45	56.68	0.33		4.81	4.22	0.86	2.19	140
Hypoxic	G-964	F	86	24.0	4.38	5.88	8.68		3.81	2.66	0.87	2.21	126
Hypoxic	G-966	F	86	13.5	2.66	0.21	0.09		4.11	5.86	1.07	2.64	150
Hypoxic	G-970	F	86	28.5	5.31	0.36	0.73		4.66	3.31	0.90	1.78	141
Hypoxic	G-971	F	86	27.0	5.38	0.25	0.21		3.32	2.82	0.87	2.67	148
Hypoxic	G-980	F	86	22.0	4.24	0.17	0.08		4.51	2.39	0.64	2.61	136
Hypoxic	G-986	F	86	31.0	6.62	55.67	4.38		6.36	3.04	1.07	2.57	142
Hypoxic	G-990	F	86	30.0	6.03	0.78	0.25		8.04	2.75	0.77	2.32	144
Hypoxic	G-958	M	86	36.0	7.13	0.95		5.90	2.77	2.43	0.92	2.74	142
Hypoxic	G-960	M	86	28.0	5.17	24.47		26.89	11.68	2.60	0.78	2.56	143
Hypoxic	G-962	M	86	29.0	5.79	0.09		0.50	3.09	2.51	0.83	3.64	161
Hypoxic	G-968	M	86	22.0	4.42	29.68		57.14	6.64	2.53	0.84	2.09	137
Hypoxic	G-972	M	86	31.5	6.27	1.21		0.50	3.79	2.50	0.85	2.89	139
Hypoxic	G-978	M	86	28.5	5.45	44.57		54.99	4.81	2.43	0.74	2.23	138
Hypoxic	G-982	M	86	24.5	4.31	0.04		0.50	2.58	2.34	0.70	2.72	141
Hypoxic	G-988	M	86	24.5	4.93	6.68		7.65	4.15	2.24	0.71	2.50	147
Hypoxic	G-992	M	86	38.5	7.96	16.39		16.69	4.45	2.35	0.80	2.00	124
Normoxic	C-2010	F	107	13.0	3.04	0.15	0.24		3.03	3.51	0.80	2.11	162
Normoxic	C-2027	F	107	26.0	4.17	0.12			3.16	3.34	1.08	3.35	156
Normoxic	C-2032	F	107	28.0	5.31	0.04	0.05		3.01	3.18	0.99	1.85	129
Normoxic	C-2038	F	107	22.0	3.97	0.05	0.10		3.03	2.48	0.83	2.62	124
Normoxic	C-2049	F	107	27.0	4.35	0.11	0.15		5.35	3.01	0.86	2.07	133
Normoxic	C-2056	F	107	26.5	5.69	0.06	0.10		3.14	3.30	1.12	2.63	134
Normoxic	C-2065	F	107	28.0	7.51	0.03	0.04		3.33	2.77	0.80	2.93	144
Normoxic	C-2071	F	107	22.0	5.03	0.13	0.05		3.45	2.84	0.82	2.00	128
Normoxic	C-2079	F	107	21.5	4.45	0.08	0.20		3.89	3.30	1.07	2.94	136
Normoxic	C-2080	F	107	27.0	5.69	0.02	0.10		4.14	2.96	0.74	2.19	126
Normoxic	C-2012	M	107	17.5	3.73	4.17		1.09	2.32	2.12	0.81	2.29	138
Normoxic	C-2013	M	107					0.50	4.25	2.29	0.72	2.33	136
Normoxic	C-2015	M	107	24.0	5.17	0.37		4.57	2.95	2.08	0.77	2.37	119
Normoxic	C-2042	M	107	22.0	4.59	0.06		0.50	3.10	1.85	0.75	2.40	131
Normoxic	C-2051	M	107	21.5	5.89				2.70	2.15	0.85	2.17	128
Normoxic	C-2055	M	107	24.5	5.10	0.13		0.50	2.87	2.46	0.88	1.16	142
Normoxic	C-2069	M	107	24.0	5.14	0.11		0.50	2.72	2.64	0.89	2.57	140
Normoxic	C-2088	M	107		5.21	2.14		0.50	3.35	1.96	0.60	1.20	132
Hypoxic	C-2019	F	107	11.5	2.42	0.07	0.05		3.41	2.35	0.82	2.54	136
Hypoxic	C-2030	F	107	5.0	1.08	2.96	0.25		2.32	2.54	0.84	2.74	134
Hypoxic	C-2036	F	107	7.5	1.32	0.08	0.05		1.60	1.98	0.66	1.90	131
Hypoxic	C-2046	F	107	29.5	6.41	0.06	0.11		4.19	3.19	0.86	1.96	113
Hypoxic	C-2085	F	107	13.5	2.70	0.11	0.04		4.73	1.86	0.69	2.21	126
Hypoxic	C-2087	F	107	17.0	3.25	0.29	0.07		29.78	2.65	0.68	2.33	117
Hypoxic	C-2003	M	107	27.0	5.34	0.10		0.50	3.22	1.81	0.81	3.22	145

Treatment	Fish Tag #	SEX	Sample Time (day)	Hct (%)	Hb (g/dL)	Test (ng/mL)	17ß-E2 (ng/mL)	11Ktest (ng/mL)	Glu (mmol/L)	Ca (mmol/L)	Mg (mmol/L)	K (mmol/L)	Na (mmol/L)
Normoxic	C-2004	F	1	27.5	5.49	25.03	6.05		4.86	6.18	0.74	1.60	165
Normoxic	C-2010	F	1	24.0	3.34	7.78	9.83		4.06	5.82	0.75	0.51	150
Hypoxic	C-2017	M	107	32.3	6.58	0.59		0.50	2.53	2.26	0.84	2.04	141
Hypoxic	C-2018	M	107	20.0	4.17	1.09		0.50	4.12	1.80	0.76	2.34	143
Hypoxic	C-2022	M	107	19.5	4.04	62.65		49.14	3.26	1.88	0.85	2.63	131
Hypoxic	C-2039	M	107	26.5	5.83	0.05		0.50		3.29	0.80	1.82	137
Hypoxic	C-2048	M	107	16.5	3.04	0.08		0.50	3.08	3.04	0.87	2.61	134
Hypoxic	C-2052	M	107	26.0	5.83	5.19		0.50	2.30	1.95	0.68	1.99	124
Hypoxic	C-2068	M	107	30.0	5.21	34.51		15.77	4.20	1.86	0.75	1.70	125
Hypoxic	C-2077	M	107	31.0	6.79	0.14		0.50	7.34	1.98	0.82	2.31	134
Normoxic	C-2004	F	121			1.02	0.07		2.60	3.70	1.10	1.17	126
Normoxic	C-2010	F	121			0.81	0.03		3.06	2.71	0.79	1.15	134
Normoxic	C-2020	F	121			0.87	0.01		6.23	3.03	0.93	1.60	116
Normoxic	C-2027	F	121			0.13	0.01		7.62	3.55	1.00	0.65	113
Normoxic	C-2032	F	121			0.18	0.01		2.89	4.09	1.04	1.26	129
Normoxic	C-2038	F	121			0.86	0.04		4.31	2.69	0.94	1.82	113
Normoxic	C-2049	F	121			0.26	0.08		3.75	3.42	0.92	0.57	128
Normoxic	C-2056	F	121			0.17	0.03		3.09	3.16	1.09	0.89	137
Normoxic	C-2065	F	121			0.17	0.02		3.23	3.45	0.83	1.37	132
Normoxic	C-2071	F	121			0.15	0.01		2.28	3.35	0.83	0.87	113
Normoxic	C-2079	F	121			0.86	0.12		3.87	3.41	1.03	1.48	124
Normoxic	C-2080	F	121			0.65	0.04		4.04	2.97	0.86	0.48	115
Normoxic	C-2012	M	121			0.71		3.15	3.77	2.13	0.66	0.52	136
Normoxic	C-2013	M	121			0.20		0.50	2.47	2.74	0.72	1.41	112
Normoxic	C-2015	M	121			0.26		1.58	2.81	2.98	0.94	0.72	136
Normoxic	C-2042	M	121			0.61		0.50	2.00	2.01	0.69	1.12	95
Normoxic	C-2051	M	121			0.33		0.50	3.38	2.72	0.87	1.24	122
Normoxic	C-2055	M	121			0.88		0.50	2.00	3.19	0.93	1.60	137
Normoxic	C-2069	M	121			0.14		0.50	4.06	2.98	0.87	1.53	123
Normoxic	C-2088	M	121			1.06		0.50	2.09	2.38	0.73	1.06	106
Hypoxic	C-2006	F	121			0.73	0.07		1.83	3.80	1.05	1.18	115
Hypoxic	C-2030	F	121			4.45	0.63		2.18	2.45	0.84	2.00	113
Hypoxic	C-2036	F	121			0.03	0.05		4.66	2.08	0.58	1.15	101
Hypoxic	C-2046	F	121			0.86	0.07		3.51	2.98	0.98	1.17	84
Hypoxic	C-2053	F	121			0.82	0.03		2.68	3.65	1.17	0.92	132
Hypoxic	C-2058	F	121			0.20			2.72	2.32	0.94	0.90	102
Hypoxic	C-2085	F	121			0.89	0.04		2.47	3.63	1.05	2.31	133
Hypoxic	C-2003	M	121			0.67		0.50	2.83	2.99	1.24	1.89	132
Hypoxic	C-2017	M	121			0.16		0.50	1.76	2.55	1.19	0.80	134
Hypoxic	C-2018	M	121			0.30		0.89	3.29	2.18	0.90	2.16	121
Hypoxic	C-2022	M	121					67.14	3.26	2.75	1.06	1.29	126
Hypoxic	C-2039	M	121			1.02		0.50	5.29	3.10	1.28	0.58	139
Hypoxic	C-2048	M	121			0.02		0.50	1.45	1.87	0.70	1.76	139
Hypoxic	C-2052	M	121			2.36		0.74	2.32	1.74	0.72	0.79	69
Hypoxic	C-2068	M	121			34.67		16.85	3.47	2.66	1.14	1.34	134
Hypoxic	C-2077	M	121			0.81		0.73	5.94	3.08	1.25	0.77	126
Normoxic	G-961	F	128			0.05	0.02		3.43	3.38	0.94	2.54	137
Normoxic	G-963	F	128			1.56	0.02		3.43	3.72	1.02	2.47	146
Normoxic	G-976	F	128			0.07	0.08		2.65	3.51	1.00	1.92	103
Normoxic	G-983	F	128			0.05	0.02		3.09	2.93	0.76	1.88	130
Normoxic	G-989	F	128			0.07	0.01		2.07	3.06	0.95	2.24	135
Normoxic	G-993	F	128			0.07	0.02		3.80	3.12	0.89	1.75	134

Treatment	Fish Tag #	SEX	Sample Time (day)	Hct (%)	Hb (g/dL)	Test (ng/mL)	17ß-E2 (ng/mL)	11Ktest (ng/mL)	Glu (mmol/L)	Ca (mmol/L)	Mg (mmol/L)	K (mmol/L)	Na (mmol/L)
Normoxic	C-2004	F	1	27.5	5.49	25.03	6.05		4.86	6.18	0.74	1.60	165
Normoxic	C-2010	F	1	24.0	3.34	7.78	9.83		4.06	5.82	0.75	0.51	150
Normoxic	G-955	M	128			0.04		0.50	5.21	2.92	0.95	2.81	141
Normoxic	G-967	M	128			0.06		0.50	3.06	3.05	0.86	1.72	125
Normoxic	G-973	M	128			0.15		0.50	3.09	2.93	0.92	1.53	144
Normoxic	G-974	M	128			0.05		0.50	3.27	3.01	0.84	1.46	135
Normoxic	G-975	M	128			0.05		0.50	3.96	2.97	0.93	2.33	140
Normoxic	G-977	M	128			0.47		0.50	2.99	2.57	0.76	2.42	143
Normoxic	G-979	M	128			0.03		0.50	4.36	3.12	0.81	2.68	142
Normoxic	G-981	M	128			0.05		0.50	2.97	2.76	0.76	1.57	119
Normoxic	G-991	M	128			0.13		4.35	4.61	2.62	0.76	1.55	133
Hypoxic	G-953	F	128			0.20	0.02		3.55	3.37	0.91	0.76	139
Hypoxic	G-964	F	128			13.47	3.41		3.92	3.01	1.03	0.97	141
Hypoxic	G-966	F	128			0.15	0.04		3.13	2.67	0.77	1.04	131
Hypoxic	G-970	F	128			0.19	0.09		7.96	2.79	0.90	0.96	135
Hypoxic	G-971	F	128			0.17	0.05		3.04	2.18	0.80	0.53	144
Hypoxic	G-980	F	128			0.06	0.09		3.34	2.85	0.85	1.63	143
Hypoxic	G-986	F	128			0.11	0.04			3.50	1.32	0.54	145
Hypoxic	G-990	F	128			0.11	0.15		3.53	2.49	0.89	0.92	148
Hypoxic	G-960	M	128			0.31		0.50	1.77	2.59	0.96	0.48	135
Hypoxic	G-962	M	128			4.47		0.86	4.19	3.10	1.11	0.66	150
Hypoxic	G-968	M	128			0.53		0.50	4.51	2.81	0.88	1.28	144
Hypoxic	G-969	M	128			0.08		0.50	7.59	3.72	0.87	2.82	147
Hypoxic	G-972	M	128			0.19		0.50	2.89	2.34	0.85	0.62	144
Hypoxic	G-978	M	128			0.40		0.50	5.89	2.75	1.17	0.27	139
Hypoxic	G-982	M	128			0.12		0.50	3.64	2.69	0.87	0.84	148
Hypoxic	G-984	M	128			0.07		0.50	5.81	2.74	0.80	1.74	142
Hypoxic	G-988	M	128			0.11		0.50	4.20	3.08	0.81	2.33	129
Hypoxic	G-992	M	128			0.26		49.59	4.45	2.75	0.77	1.15	119

Table 6. Fish tag #, treatment, tank compartment, sex, length, weight, gonad weight, stomach weight, intestine weight, liver weight, liver somatic index (LSI) and condition factor of experimental burbot after spawning.

Fish Tag #	Treatment	Compartment	Sex	Length (mm)	Weight (g)	Gonad Weight (g)	Stomach Weight (g)	Intestine Weight (g)	Liver Weight (g)	LSI (%)	Condition Factor
C-2087	Hypoxic	Back	F								
C-2030	Hypoxic	Back	F	480	442	6.3	28.5	9.2	16.5	3.92	0.400
C-2036	Hypoxic	Back	F	563	1000	22.0	45.5	15.5	16.8	1.75	0.560
C-2019	Hypoxic	Back	F								
C-2006	Hypoxic	Back	F	481	680	8.9	35.9	11.8	16.1	2.46	0.611
C-2053	Hypoxic	Back	F	578	820	14.2	41.3	15.0	26.5	3.40	0.425
C-2046	Hypoxic	Back	F	620	521	9.6	36.9	11.9	19.7	4.01	0.219
C-2085	Hypoxic	Back	F	491	580	9.8	37.2	11.6	29.1	5.37	0.490
C-2081	Hypoxic	Back	F								
C-2058	Hypoxic	Back	F	450	580	1.7	21.2	11.1	36.3	6.69	0.636
C-2048	Hypoxic	Back	M	498	540	19.6	27.7	10.0	12.0	2.36	0.437
C-2052	Hypoxic	Back	M	547	700	52.1	38.9	14.8	29.4	4.75	0.427
C-2003	Hypoxic	Back	M	541	740	0.5	42.0	10.6	12.0	1.65	0.467
C-2068	Hypoxic	Back	M	575	1100	86.4	51.9	12.8	33.4	3.41	0.578
C-2018	Hypoxic	Back	M	422	400	29.0	20.0	7.3	21.2	6.05	0.532
C-2039	Hypoxic	Back	M	483	640	29.8	28.3	11.4	18.3	3.10	0.568
C-2017	Hypoxic	Back	M	688	1500	59.6	70.7	21.0	43.9	3.15	0.460
C-2077	Hypoxic	Back	M	680	1400	20.6	59.5	16.4	34.1	2.54	0.445
C-2022	Hypoxic	Back	M	550	820	63.7	23.9	12.2	11.1	1.49	0.492
G-986	Hypoxic	Front	F	595	940	15.4	57.9	13.7	22.7	2.51	0.446
G-966	Hypoxic	Front	F	588	1120	18.2	60.0	18.5	44.9	4.24	0.551
G-980	Hypoxic	Front	F	423	460	13.6	27.9	10.1	14.2	3.28	0.608
G-990	Hypoxic	Front	F	537	700	10.7	47.9	11.5	16.7	2.48	0.452
G-964	Hypoxic	Front	F	643	1560	122.1	124.2	39.4	22.2	1.57	0.586
G-970	Hypoxic	Front	F	515	620	8.6	33.1	9.8	27.0	4.62	0.454
G-971	Hypoxic	Front	F	628	1200	9.1	58.6	13.7	26.1	2.24	0.484
G-953	Hypoxic	Front	F	505	720	12.6	42.2	11.6	47.5	7.20	0.559
G-992	Hypoxic	Front	M	668	1680	208.6	73.1	14.4	21.6	1.49	0.563
G-958	Hypoxic	Front	M	651	1220	39.4	65.9	12.6	25.0	2.16	0.442
G-968	Hypoxic	Front	M	413	440	24.5	23.2	6.0	14.0	3.49	0.624
G-982	Hypoxic	Front	M	455	420	0.3	24.2	5.5	21.5	5.40	0.446
G-956	Hypoxic	Front	M								
G-978	Hypoxic	Front	M	525	980	38.9	40.2	14.6	31.3	3.44	0.677
G-988	Hypoxic	Front	M	491	760	80.3	43.2	11.3	37.7	5.86	0.641
G-962	Hypoxic	Front	M	530	860	57.3	29.2	8.2	24.6	3.16	0.577
G-972	Hypoxic	Front	M	592	1100	50.1	41.4	10.3	48.2	4.81	0.530
G-969	Hypoxic	Front	M	507	660	9.0	29.5	7.5	29.2	4.69	0.506
G-960	Hypoxic	Front	M	507	680	25.6	30.8	8.2	35.0	5.64	0.522
G-984	Hypoxic	Front	M	392	320	5.5	15.7	5.1	9.7	3.17	0.531
C-2080	Normoxic	Back	F	578	1060	10.6	47.3	12.3	33.1	3.25	0.549
C-2079	Normoxic	Back	F	439	480	8.9	24.8	7.2	9.5	2.05	0.567
C-2098	Normoxic	Back	F								

Fish Tag #	Treatment	Compartment	Sex	Length (mm)	Weight (g)	Gonad Weight (g)	Stomach Weight (g)	Intestine Weight (g)	Liver Weight (g)	LSI (%)	Condition Factor
C-2087	Hypoxic	Back	F								
C-2056	Normoxic	Back	F	598	940	13.4	96.6	42.7	18.7	2.06	0.440
C-2071	Normoxic	Back	F	550	800	14.9	46.8	13.0	19.7	2.57	0.481
C-2049	Normoxic	Back	F	517	540	9.4	38.5	10.3	15.4	2.99	0.391
C-2065	Normoxic	Back	F	648	1480	23.1	64.6	17.1	39.1	2.76	0.544
C-2020	Normoxic	Back	F	539	800	14.7	45.6	12.3	23.5	3.09	0.511
C-2027	Normoxic	Back	F	565	1000	5.8	49.7	12.3	42.7	4.49	0.554
C-2038	Normoxic	Back	F	697	1260	28.4	75.0	18.3	24.4	2.02	0.372
C-2010	Normoxic	Back	F	429	460	6.7	23.6	8.0	15.0	3.41	0.583
C-2032	Normoxic	Back	F	390	260	3.9	18.1	5.9	5.2	2.06	0.438
C-2004	Normoxic	Back	F	615	1220	13.3	53.0	15.1	63.7	5.57	0.524
C-2042	Normoxic	Back	M	510	720	9.4	34.6	10.3	26.7	3.90	0.543
C-2088	Normoxic	Back	M	490	700	42.8	36.0	9.1	35.1	5.64	0.595
C-2015	Normoxic	Back	M	485	700	36.8	31.3	8.9	28.6	4.51	0.613
C-2013	Normoxic	Back	M	378	280	2.5	15.7	4.9	11.4	4.28	0.518
C-2069	Normoxic	Back	M	502	680	34.1	36.1	10.0	11.4	1.80	0.537
C-2012	Normoxic	Back	M	450	500	28.1	22.5	7.4	19.2	4.24	0.548
C-2055	Normoxic	Back	M	415	420	17.5	20.8	5.7	18.5	4.82	0.587
C-2051	Normoxic	Back	M	454	560	16.2	22.1	7.8	19.5	3.72	0.598
G-985	Normoxic	Front	F								
G-993	Normoxic	Front	F	628	1040	16.3	54.0	17.1	21.7	2.17	0.420
G-987	Normoxic	Front	F								
G-957	Normoxic	Front	F								
G-959	Normoxic	Front	F								
G-983	Normoxic	Front	F	445	480	15.6	23.3	10.1	18.4	4.12	0.545
G-976	Normoxic	Front	F	556	880	14.9	55.9	12.4	33.2	3.99	0.512
G-961	Normoxic	Front	F	637	800	21.7	71.5	22.9	59.9	8.34	0.309
G-989	Normoxic	Front	F	519	1400	13.4	50.4	14.3	35.4	2.62	1.001
G-963	Normoxic	Front	F	543	740	13.2	40.9	14.3	17.4	2.45	0.462
G-977	Normoxic	Front	M	500	780	32.7	39.1	16.5	37.5	5.28	0.624
G-967	Normoxic	Front	M	501	640	7.6	29.9	9.3	19.4	3.16	0.509
G-955	Normoxic	Front	M	469	480	9.0	22.1	5.8	20.7	4.61	0.465
G-981	Normoxic	Front	M	407	420	3.8	20.5	6.6	30.1	7.80	0.623
G-965	Normoxic	Front	M								
G-975	Normoxic	Front	M	499	660	16.6	27.3	6.6	16.2	2.57	0.531
G-979	Normoxic	Front	M	400	380	5.7	20.2	6.0	17.0	4.74	0.594
G-973	Normoxic	Front	M	502	720	18.9	30.9	8.7	35.9	5.40	0.569
G-974	Normoxic	Front	M	530	700	11.4	39.5	9.7	25.8	3.89	0.470
G-991	Normoxic	Front	M	515	740	29.3	34.3	10.7	34.4	5.09	0.542

Table 7. Egg diameter and cross-sectional areas of the yolk and oil droplet of burbot eggs originating from adults reared in normoxic (O) and hypoxic (H) water and incubated under normoxic (o) and hypoxic (h) condtions.

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
03-Feb	2	T6-2	Oo	26-Jan	1.226	0.141	0.637	0.778
03-Feb	3	T6-2	Oo	26-Jan	1.189	0.174	0.769	0.943
03-Feb	4	T6-2	Oo	26-Jan	1.215	0.179	0.650	0.829
03-Feb	5	T6-2	Oo	26-Jan	1.136	0.156	0.638	0.794
03-Feb	1	T6-3	Ho	26-Jan	1.129	0.213	0.655	0.868
03-Feb	2	T6-3	Ho	26-Jan	1.278	0.240	0.995	1.235
03-Feb	3	T6-3	Ho	26-Jan	1.316	0.184	0.833	1.017
03-Feb	4	T6-3	Ho	26-Jan	1.377	0.297	0.764	1.061
03-Feb	5	T6-3	Ho	26-Jan	1.318	0.215	0.726	0.941
03-Feb	1	T5-2	Oh	26-Jan	1.318	0.164	0.980	1.144
03-Feb	2	T5-2	Oh	26-Jan	1.361	0.217		
03-Feb	3	T5-2	Oh	26-Jan	1.286	0.200		
03-Feb	4	T5-2	Oh	26-Jan	1.318	0.223	1.093	1.316
03-Feb	5	T5-2	Oh	26-Jan	1.295	0.223	0.975	1.198
03-Feb	1	T5-3	Hh	26-Jan	1.294	0.259	0.695	0.954
03-Feb	2	T5-3	Hh	26-Jan	1.316	0.211	0.416	0.627
03-Feb	3	T5-3	Hh	26-Jan	1.324	0.192	0.926	1.118
03-Feb	4	T5-3	Hh	26-Jan	1.315	0.264	0.354	0.618
03-Feb	5	T5-3	Hh	26-Jan	1.336	0.174	0.774	0.948
03-Feb	1	T3-2	Oh	26-Jan	1.689	.	.	
03-Feb	2	T3-2	Oh	26-Jan	1.118	.	.	
03-Feb	3	T3-2	Oh	26-Jan	1.176	.	.	
03-Feb	4	T3-2	Oh	26-Jan	1.190	.	.	
03-Feb	5	T3-2	Oh	26-Jan	1.232	.	.	
03-Feb	6	T3-2	Oh	26-Jan	1.191	0.159	0.661	0.820
03-Feb	7	T3-2	Oh	26-Jan	1.163	0.151	0.850	1.001
03-Feb	1	T3-3	Hh	26-Jan	1.305	0.208	0.975	1.183
03-Feb	2	T3-3	Hh	26-Jan	1.324	0.249	0.676	0.925
03-Feb	3	T3-3	Hh	26-Jan	1.312	0.213	0.814	1.027
03-Feb	4	T3-3	Hh	26-Jan	1.348	0.340	0.746	1.086
03-Feb	5	T3-3	Hh	26-Jan	1.378	0.215	0.931	1.146
07-Feb	1	T2-2	Oo	26-Jan	1.171	0.201	0.821	1.022
07-Feb	2	T2-2	Oo	26-Jan	1.175	0.202	0.706	0.908
07-Feb	3	T2-2	Oo	26-Jan	1.204	0.203	0.860	1.063
07-Feb	4	T2-2	Oo	26-Jan	1.280	0.175	0.621	0.796
07-Feb	5	T2-2	Oo	26-Jan	1.225	0.186	0.900	1.086
07-Feb	1	T2-3	Ho	26-Jan	1.350	0.237	0.846	1.083
07-Feb	2	T2-3	Ho	26-Jan	1.450	0.195	0.461	0.656
07-Feb	3	T2-3	Ho	26-Jan	1.361	0.213	0.753	0.966
07-Feb	4	T2-3	Ho	26-Jan	1.331	0.193	0.839	1.032
07-Feb	5	T2-3	Ho	26-Jan	1.334	0.225	0.811	1.036
07-Feb	1	T2-19	Ho	06-Feb	1.248	0.203	0.956	1.159
07-Feb	2	T2-19	Ho	06-Feb	1.272	0.214	0.775	0.989
07-Feb	3	T2-19	Ho	06-Feb	1.277	0.182	0.673	0.855
07-Feb	4	T2-19	Ho	06-Feb	1.250	0.178	0.607	0.785
07-Feb	5	T2-19	Ho	06-Feb	1.253	0.192	0.427	0.619
07-Feb	1	T3-2	Oh	26-Jan	1.234	0.234	0.887	1.121

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
07-Feb	2	T3-2	Oh	26-Jan	1.245	0.190	0.759	0.949
07-Feb	3	T3-2	Oh	26-Jan	1.240	0.176	0.916	1.092
07-Feb	4	T3-2	Oh	26-Jan	1.235	0.184	0.876	1.060
07-Feb	5	T3-2	Oh	26-Jan	1.216	0.158	0.695	0.853
07-Feb	1	T3-4	Hh	26-Jan	1.341	0.242	0.935	1.177
07-Feb	2	T3-4	Hh	26-Jan	1.353	0.183	0.885	1.068
07-Feb	3	T3-4	Hh	26-Jan	1.328	0.234	0.713	0.947
07-Feb	4	T3-4	Hh	26-Jan	1.295	0.215	0.918	1.133
07-Feb	5	T3-4	Hh	26-Jan	1.301	0.195	0.915	1.110
07-Feb	1	T3-16	Hh	06-Feb	1.258	0.188	0.672	0.860
07-Feb	2	T3-16	Hh	06-Feb	1.330	0.216	0.710	0.926
07-Feb	3	T3-16	Hh	06-Feb	1.206	0.220	0.577	0.797
07-Feb	4	T3-16	Hh	06-Feb	1.284	0.230	0.611	0.841
07-Feb	5	T3-16	Hh	06-Feb	1.380	0.203	0.751	0.954
07-Feb	1	T3-18	Hh	06-Feb	1.297	0.164	0.731	0.895
07-Feb	2	T3-18	Hh	06-Feb	1.290	0.217	0.857	1.074
07-Feb	3	T3-18	Hh	06-Feb	1.278	0.246	0.896	1.142
07-Feb	4	T3-18	Hh	06-Feb	1.267	0.230	0.720	0.950
07-Feb	5	T3-18	Hh	06-Feb	1.216	0.167	0.584	0.751
07-Feb	1	T3-19	Oh	06-Feb	0.988	0.143	0.319	0.462
07-Feb	2	T3-19	Oh	06-Feb	1.202	0.233	0.512	0.745
07-Feb	3	T3-19	Oh	06-Feb	1.191	0.241	0.584	0.825
07-Feb	4	T3-19	Oh	06-Feb	1.188	0.197	0.825	1.022
07-Feb	5	T3-19	Oh	06-Feb	1.183	0.274	0.646	0.920
07-Feb	1	T5-2	Oh	26-Jan	1.171	0.219	0.519	0.738
07-Feb	2	T5-2	Oh	26-Jan	1.226	0.187	0.802	0.989
07-Feb	3	T5-2	Oh	26-Jan	1.167	0.211	0.557	0.768
07-Feb	4	T5-2	Oh	26-Jan	1.202	0.200	0.830	1.030
07-Feb	5	T5-2	Oh	26-Jan	1.191	0.213	0.636	0.849
07-Feb	1	T5-4	Hh	26-Jan	1.331	0.209	0.866	1.075
07-Feb	2	T5-4	Hh	26-Jan	1.381	0.199	0.808	1.007
07-Feb	3	T5-4	Hh	26-Jan	1.311	0.203	0.725	0.928
07-Feb	4	T5-4	Hh	26-Jan	1.337	0.217	0.822	1.039
07-Feb	5	T5-4	Hh	26-Jan	1.357	0.215	0.822	1.037
07-Feb	1	T5-16	Hh	06-Feb	1.247	0.208	0.506	0.714
07-Feb	2	T5-16	Hh	06-Feb	1.189	0.188	0.550	0.738
07-Feb	3	T5-16	Hh	06-Feb	1.152	0.224	0.686	0.910
07-Feb	4	T5-16	Hh	06-Feb	1.176	0.232	0.811	1.043
07-Feb	5	T5-16	Hh	06-Feb	1.157	0.230	0.485	0.715
07-Feb	1	T5-18	Hh	06-Feb	1.166	0.186	0.625	0.811
07-Feb	2	T5-18	Hh	06-Feb	1.263	0.193	0.467	0.660
07-Feb	3	T5-18	Hh	06-Feb	1.244	0.193	0.531	0.724
07-Feb	4	T5-18	Hh	06-Feb	1.238	0.190	0.346	0.536
07-Feb	5	T5-18	Hh	06-Feb	1.230	0.216	0.594	0.810
07-Feb	1	T6-2	Oo	26-Jan	1.222	0.217	0.717	0.934
07-Feb	2	T6-2	Oo	26-Jan	1.225	0.165	0.909	1.074
07-Feb	3	T6-2	Oo	26-Jan	1.205	0.217	0.859	1.076
07-Feb	4	T6-2	Oo	26-Jan	1.195	0.190	0.781	0.971
07-Feb	5	T6-2	Oo	26-Jan	1.324	0.249	0.553	0.802
07-Feb	1	T6-3	Ho	26-Jan	1.342	0.186	0.764	0.950
07-Feb	2	T6-3	Ho	26-Jan	1.382	0.259	1.070	1.329

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
07-Feb	3	T6-3	Ho	26-Jan	1.351	0.201	0.680	0.881
07-Feb	4	T6-3	Ho	26-Jan	1.334	0.244	0.977	1.221
07-Feb	5	T6-3	Ho	26-Jan	1.358	0.330	1.015	1.345
07-Feb	1	T6-16	Ho	06-Feb	1.198	0.222	0.455	0.677
07-Feb	2	T6-16	Ho	06-Feb	1.293	0.204	0.736	0.940
07-Feb	3	T6-16	Ho	06-Feb	1.170	0.200	0.777	0.977
07-Feb	4	T6-16	Ho	06-Feb	1.188	0.300	0.662	0.962
07-Feb	5	T6-16	Ho	06-Feb	1.252	0.204	0.896	1.100
07-Feb	1	T6-18	Ho	06-Feb	1.319	0.312	0.661	0.973
07-Feb	2	T6-18	Ho	06-Feb	1.278	0.177	0.626	0.803
07-Feb	3	T6-18	Ho	06-Feb	1.256	0.205	0.620	0.825
07-Feb	4	T6-18	Ho	06-Feb	1.247	0.189	0.449	0.638
07-Feb	5	T6-18	Ho	06-Feb	1.302	0.196	0.578	0.774
09-Feb	1	T2-16	Oo	04-Feb	1.012	0.169	0.402	0.571
09-Feb	2	T2-16	Oo	04-Feb	1.036	0.153	0.442	0.595
09-Feb	3	T2-16	Oo	04-Feb	1.074	0.178	0.584	0.762
09-Feb	4	T2-16	Oo	04-Feb	1.034	0.179	0.571	0.750
09-Feb	5	T2-16	Oo	04-Feb	1.007	0.202	0.595	0.797
09-Feb	1	T2-18	Ho	06-Feb	1.260	0.177	0.520	0.697
09-Feb	2	T2-18	Ho	06-Feb	1.219	0.257	0.511	0.768
09-Feb	3	T2-18	Ho	06-Feb	1.251	0.248	0.609	0.857
09-Feb	4	T2-18	Ho	06-Feb	1.192	0.189	0.600	0.789
09-Feb	5	T2-18	Ho	06-Feb	1.182	0.224	0.400	0.624
09-Feb	1	T2-19	Ho	06-Feb	1.273	0.191	0.597	0.788
09-Feb	2	T2-19	Ho	06-Feb	1.239	0.169	0.495	0.664
09-Feb	3	T2-19	Ho	06-Feb	1.267	0.257	0.477	0.734
09-Feb	4	T2-19	Ho	06-Feb	1.267	0.300	0.681	0.981
09-Feb	5	T2-19	Ho	06-Feb	1.279	0.164	0.418	0.582
09-Feb	1	T5-2	Oh	26-Jan	1.239	0.196	1.054	1.250
09-Feb	2	T5-2	Oh	26-Jan	1.165	0.220	0.851	1.071
09-Feb	3	T5-2	Oh	26-Jan	1.214	0.191	1.033	1.224
09-Feb	4	T5-2	Oh	26-Jan	1.206	0.238	0.995	1.233
09-Feb	5	T5-2	Oh	26-Jan	1.293	0.273	0.969	1.242
10-Feb	1	T5-3	Hh	26-Jan	1.455	0.266	1.333	1.599
10-Feb	2	T5-3	Hh	26-Jan	1.382	0.303	1.137	1.440
10-Feb	3	T5-3	Hh	26-Jan	1.295	0.176	1.033	1.209
10-Feb	4	T5-3	Hh	26-Jan	1.321	0.216	0.947	1.163
10-Feb	5	T5-3	Hh	26-Jan	1.309	0.189	0.997	1.186
09-Feb	1	T5-16	Hh	06-Feb	1.222	0.170	0.572	0.742
09-Feb	2	T5-16	Hh	06-Feb	1.285	0.189	0.574	0.763
09-Feb	3	T5-16	Hh	06-Feb	1.246	0.183	0.652	0.835
09-Feb	4	T5-16	Hh	06-Feb	1.230	0.214	0.727	0.941
09-Feb	5	T5-16	Hh	06-Feb	1.266	0.214	0.939	1.153
09-Feb	1	T5-18	Hh	06-Feb	1.304	0.183	0.663	0.846
09-Feb	2	T5-18	Hh	06-Feb	1.401	0.196	0.814	1.010
09-Feb	3	T5-18	Hh	06-Feb	1.283	0.214	0.620	0.834
09-Feb	4	T5-18	Hh	06-Feb	1.294	0.195	0.748	0.943
09-Feb	5	T5-18	Hh	06-Feb	1.316	0.163	0.898	1.061
09-Feb	1	T5-19	Oh	06-Feb	1.234	0.165	1.004	1.169
09-Feb	2	T5-19	Oh	06-Feb	1.064	0.139	0.486	0.625
09-Feb	3	T5-19	Oh	06-Feb	1.193	0.187		

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
09-Feb	4	T5-19	Oh	06-Feb	1.258	0.229		
09-Feb	5	T5-19	Oh	06-Feb	1.064	0.130	0.636	0.766
09-Feb	1	T3-2	Oh	26-Jan	1.274	0.237	0.610	0.847
09-Feb	2	T3-2	Oh	26-Jan	1.180	0.149	.	.
09-Feb	3	T3-2	Oh	26-Jan	1.237	0.208	.	.
09-Feb	4	T3-2	Oh	26-Jan	1.148	0.185	.	.
09-Feb	5	T3-2	Oh	26-Jan	1.173	0.221	.	.
09-Feb	1	T3-3	Hh	26-Jan	1.369	0.255	0.870	1.125
09-Feb	2	T3-3	Hh	26-Jan	1.344	0.212	0.691	0.903
09-Feb	3	T3-3	Hh	26-Jan	1.351	0.218	0.966	1.184
09-Feb	4	T3-3	Hh	26-Jan	1.366	0.215	1.075	1.290
09-Feb	5	T3-3	Hh	26-Jan	1.366	0.236	1.034	1.270
09-Feb	1	T3-16	Hh	06-Feb	1.183	0.234	0.574	0.808
09-Feb	2	T3-16	Hh	06-Feb	1.179	0.230	0.652	0.882
09-Feb	3	T3-16	Hh	06-Feb	1.212	0.247	0.478	0.725
09-Feb	4	T3-16	Hh	06-Feb	1.187	0.221	0.607	0.828
09-Feb	5	T3-16	Hh	06-Feb	1.234	0.184	0.659	0.843
09-Feb	1	T3-18	Hh	06-Feb	1.311	0.189	0.609	0.798
09-Feb	2	T3-18	Hh	06-Feb	1.330	0.190	0.725	0.915
09-Feb	3	T3-18	Hh	06-Feb	1.295	0.284	0.571	0.855
09-Feb	4	T3-18	Hh	06-Feb	1.231	0.212	0.311	0.523
09-Feb	5	T3-18	Hh	06-Feb	1.299	0.181	0.424	0.605
09-Feb	1	T3-19	Oh	06-Feb	1.124	0.132	0.500	0.632
09-Feb	2	T3-19	Oh	06-Feb	1.170	0.146	0.567	0.713
09-Feb	3	T3-19	Oh	06-Feb	1.228	0.159	0.844	1.003
09-Feb	4	T3-19	Oh	06-Feb	1.125	0.132	0.605	0.737
09-Feb	5	T3-19	Oh	06-Feb	1.145	0.123	0.412	0.535
09-Feb	6	T3-19	Oh	06-Feb	1.179	.	.	.
09-Feb	7	T3-19	Oh	06-Feb	1.235	.	.	.
09-Feb	8	T3-19	Oh	06-Feb	1.240	.	.	.
09-Feb	9	T3-19	Oh	06-Feb	1.177	.	.	.
09-Feb	10	T3-19	Oh	06-Feb	1.163	.	.	.
09-Feb	1	T6-2	Oo	26-Jan	1.251	0.186	0.800	0.986
09-Feb	2	T6-2	Oo	26-Jan	1.212	0.179	0.960	1.139
09-Feb	3	T6-2	Oo	26-Jan	1.241	0.173	0.888	1.061
09-Feb	4	T6-2	Oo	26-Jan	1.261	0.190	0.870	1.060
09-Feb	5	T6-2	Oo	26-Jan	1.286	0.186	1.001	1.187
09-Feb	1	T6-3	Ho	26-Jan	1.262	0.323	1.057	1.380
09-Feb	2	T6-3	Ho	26-Jan	1.361	0.204	1.135	1.339
09-Feb	3	T6-3	Ho	26-Jan	1.346	0.197	1.050	1.247
09-Feb	4	T6-3	Ho	26-Jan	1.364	0.245	1.075	1.320
09-Feb	5	T6-3	Ho	26-Jan	1.353	0.227	1.063	1.290
09-Feb	1	T6-16	Ho	06-Feb	1.178	0.215	0.775	0.990
09-Feb	2	T6-16	Ho	06-Feb	1.227	0.186	0.644	0.830
09-Feb	3	T6-16	Ho	06-Feb	1.258	0.187	0.640	0.827
09-Feb	4	T6-16	Ho	06-Feb	1.206	0.239	0.826	1.065
09-Feb	5	T6-16	Ho	06-Feb	1.292	0.198	0.704	0.902
09-Feb	1	T6-18	Ho	06-Feb	1.259	0.198	0.884	1.082
09-Feb	2	T6-18	Ho	06-Feb	1.268	0.206	0.597	0.803
09-Feb	3	T6-18	Ho	06-Feb	1.328	0.213	0.606	0.819
09-Feb	4	T6-18	Ho	06-Feb	1.295	0.225	0.681	0.906

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
09-Feb	5	T6-18	Ho	06-Feb	1.309	0.164	0.586	0.750
09-Feb	6	T6-18	Ho	06-Feb	1.308	.	.	.
09-Feb	7	T6-18	Ho	06-Feb	1.258	.	.	.
09-Feb	8	T6-18	Ho	06-Feb	1.237	.	.	.
09-Feb	9	T6-18	Ho	06-Feb	1.262	.	.	.
09-Feb	10	T6-18	Ho	06-Feb	1.186	.	.	.
09-Feb	1	T6-19	Oo	06-Feb	1.074	0.133	0.483	0.616
09-Feb	2	T6-19	Oo	06-Feb	1.154	0.172	0.506	0.678
09-Feb	3	T6-19	Oo	06-Feb	1.158	0.230	0.872	1.102
09-Feb	4	T6-19	Oo	06-Feb	1.086	0.127	0.459	0.586
09-Feb	5	T6-19	Oo	06-Feb	1.231	0.243	0.722	0.965
09-Feb	6	T6-19	Oo	06-Feb	1.139	.	.	.
09-Feb	7	T6-19	Oo	06-Feb	1.187	.	.	.
09-Feb	8	T6-19	Oo	06-Feb	1.171	.	.	.
09-Feb	9	T6-19	Oo	06-Feb	1.191	.	.	.
09-Feb	10	T6-19	Oo	06-Feb	1.196	.	.	.
14-Feb	1	T2-2	Oo	26-Jan	1.272	0.201	1.098	1.299
14-Feb	2	T2-2	Oo	26-Jan	1.267	0.279	1.019	1.298
14-Feb	3	T2-2	Oo	26-Jan	1.176	0.173	0.946	1.119
14-Feb	4	T2-2	Oo	26-Jan	1.243	0.194	0.854	1.048
14-Feb	5	T2-2	Oo	26-Jan	1.204	0.153	1.001	1.154
14-Feb	1	T2-3	Ho	26-Jan	1.331	0.232	1.082	1.314
14-Feb	2	T2-3	Ho	26-Jan	1.310	0.244	1.083	1.327
14-Feb	3	T2-3	Ho	26-Jan	1.288	0.272	1.022	1.294
14-Feb	4	T2-3	Ho	26-Jan	1.350	0.212	1.255	1.467
14-Feb	5	T2-3	Ho	26-Jan	1.385	0.238	1.299	1.537
14-Feb	1	T2-19	Ho	06-Feb	1.234	0.181	0.776	0.957
14-Feb	2	T2-19	Ho	06-Feb	1.236	0.189	0.750	0.939
14-Feb	3	T2-19	Ho	06-Feb	1.231	0.158	0.473	0.631
14-Feb	4	T2-19	Ho	06-Feb	1.211	0.125	0.457	0.582
14-Feb	5	T2-19	Ho	06-Feb	1.194	0.181	0.448	0.629
14-Feb	6	T2-19	Ho	06-Feb	1.240		.	.
14-Feb	7	T2-19	Ho	06-Feb	1.254		.	.
14-Feb	1	T2-20	Oo	06-Feb	1.262	0.296	0.586	0.882
14-Feb	2	T2-20	Oo	06-Feb	1.148	0.177	0.718	0.895
14-Feb	3	T2-20	Oo	06-Feb	1.182	.	.	.
14-Feb	4	T2-20	Oo	06-Feb	1.054	.	.	.
14-Feb	5	T2-20	Oo	06-Feb	1.258	.	.	.
14-Feb	6	T2-20	Oo	06-Feb	1.144	.	.	.
14-Feb	7	T2-20	Oo	06-Feb	0.932	.	.	.
14-Feb	8	T2-20	Oo	06-Feb	1.092	.	.	.
14-Feb	9	T2-20	Oo	06-Feb	1.232	.	.	.
14-Feb	10	T2-20	Oo	06-Feb	1.115	.	.	.
14-Feb	11	T2-20	Oo	06-Feb	1.271	.	.	.
14-Feb	1	T3-2	Oh	26-Jan	1.175	0.202	0.925	1.127
14-Feb	2	T3-2	Oh	26-Jan	1.299	0.304	0.943	1.247
14-Feb	3	T3-2	Oh	26-Jan	1.185	0.167	1.065	1.232
14-Feb	4	T3-2	Oh	26-Jan	1.287	0.253	1.009	1.262
14-Feb	5	T3-2	Oh	26-Jan	1.153	0.151	0.959	1.110
14-Feb	6	T3-2	Oh	26-Jan	1.159	.	.	.
14-Feb	7	T3-2	Oh	26-Jan	1.532	.	.	.

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
14-Feb	8	T3-2	Oh	26-Jan	1.078			
14-Feb	9	T3-2	Oh	26-Jan	1.091			
14-Feb	10	T3-2	Oh	26-Jan	1.184			
14-Feb	1	T3-3	Hh	26-Jan	1.342	0.213	1.242	1.455
14-Feb	2	T3-3	Hh	26-Jan	1.376	0.259	1.146	1.405
14-Feb	3	T3-3	Hh	26-Jan	1.345	0.235	1.049	1.284
14-Feb	4	T3-3	Hh	26-Jan	1.306	0.314	1.129	1.443
14-Feb	5	T3-3	Hh	26-Jan	1.325	0.352	1.095	1.447
14-Feb	6	T3-3	Hh	26-Jan	1.068	.	.	.
14-Feb	7	T3-3	Hh	26-Jan	1.186	.	.	.
14-Feb	8	T3-3	Hh	26-Jan	1.202	.	.	.
14-Feb	9	T3-3	Hh	26-Jan	1.135	.	.	.
14-Feb	10	T3-3	Hh	26-Jan	1.126	.	.	.
16-Feb	1	T2-2	Oo	26-Jan	1.164	0.210	0.952	1.162
16-Feb	2	T2-2	Oo	26-Jan	1.169	0.207	0.867	1.074
16-Feb	3	T2-2	Oo	26-Jan	1.239	0.192	0.907	1.099
16-Feb	4	T2-2	Oo	26-Jan	1.154	0.182	0.915	1.097
16-Feb	5	T2-2	Oo	26-Jan	1.222	0.260	0.962	1.222
16-Feb	1	T2-3	Ho	26-Jan	1.299	0.218	1.109	1.327
16-Feb	2	T2-3	Ho	26-Jan	1.340	0.239	1.115	1.354
16-Feb	3	T2-3	Ho	26-Jan	1.288	0.228	1.084	1.312
16-Feb	4	T2-3	Ho	26-Jan	1.320	0.208	0.916	1.124
16-Feb	5	T2-3	Ho	26-Jan	1.371	0.168	1.159	1.327
16-Feb	1	T2-7	Ho	26-Jan	1.180	0.143	0.915	1.058
16-Feb	2	T2-7	Ho	26-Jan	1.061	0.109	0.688	0.797
16-Feb	3	T2-7	Ho	26-Jan	1.093	0.168	0.831	0.999
16-Feb	4	T2-7	Ho	26-Jan	1.127	0.123	0.776	0.899
16-Feb	5	T2-7	Ho	26-Jan	1.144	0.146	0.727	0.873
16-Feb	1	T2-15	Oo	04-Feb	1.018	0.109	0.553	0.662
16-Feb	2	T2-15	Oo	04-Feb	1.282	0.148	0.629	0.777
16-Feb	3	T2-15	Oo	04-Feb	1.264	0.181	0.539	0.720
16-Feb	4	T2-15	Oo	04-Feb	1.198	0.152	0.555	0.707
16-Feb	5	T2-15	Oo	04-Feb	1.240	0.203	0.812	1.015
16-Feb	6	T2-15	Oo	04-Feb	1.040	0.033		
16-Feb	7	T2-15	Oo	04-Feb	1.210			
16-Feb	1	T2-17	Ho	06-Feb	1.147	0.220	0.528	0.748
16-Feb	2	T2-17	Ho	06-Feb	1.264	0.188	0.865	1.053
16-Feb	3	T2-17	Ho	06-Feb	1.150	0.166	0.808	0.974
16-Feb	4	T2-17	Ho	06-Feb	1.173	0.122	0.525	0.647
16-Feb	5	T2-17	Ho	06-Feb	1.148	0.215	0.457	0.672
16-Feb	1	T2-19	Ho	06-Feb	1.289	0.198	0.579	0.777
16-Feb	2	T2-19	Ho	06-Feb	1.252	0.198	0.498	0.696
16-Feb	3	T2-19	Ho	06-Feb	1.297	0.197	0.694	0.891
16-Feb	4	T2-19	Ho	06-Feb	1.299	0.215	0.484	0.699
16-Feb	5	T2-19	Ho	06-Feb	1.388	0.206	0.557	0.763
16-Feb	1	T2-20	Oo	06-Feb	1.093	0.163	0.456	0.619
16-Feb	2	T2-20	Oo	06-Feb	1.062	0.123	0.509	0.632
16-Feb	3	T2-20	Oo	06-Feb	1.073	0.125	0.450	0.575
16-Feb	4	T2-20	Oo	06-Feb	1.093	0.155	0.451	0.606
16-Feb	5	T2-20	Oo	06-Feb	1.095	0.136	0.526	0.662
16-Feb	1	T3-2	Oh	26-Jan	1.282	0.234	0.945	1.179

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
16-Feb	2	T3-2	Oh	26-Jan	1.126	0.179	0.917	1.096
16-Feb	3	T3-2	Oh	26-Jan	1.117	0.173	0.165	0.338
16-Feb	4	T3-2	Oh	26-Jan	1.194	0.272	0.971	1.243
16-Feb	5	T3-2	Oh	26-Jan	1.218	0.165	0.979	1.144
16-Feb	1	T3-16	Hh	06-Feb	1.137	0.163	0.816	0.979
16-Feb	2	T3-16	Hh	06-Feb	1.116	0.186	0.953	1.139
16-Feb	3	T3-16	Hh	06-Feb	1.206	0.148	0.519	0.667
16-Feb	4	T3-16	Hh	06-Feb	1.129	0.251	0.392	0.643
16-Feb	5	T3-16	Hh	06-Feb	1.210	0.257	0.901	1.158
16-Feb	6	T3-16	Hh	06-Feb	1.221	-	.	.
16-Feb	7	T3-16	Hh	06-Feb	1.883	-	.	.
16-Feb	1	T3-18	Hh	06-Feb	1.290	0.209	0.478	0.687
16-Feb	2	T3-18	Hh	06-Feb	1.211	0.221	0.552	0.773
16-Feb	3	T3-18	Hh	06-Feb	1.227	0.194	0.792	0.986
16-Feb	4	T3-18	Hh	06-Feb	1.301	0.236	0.602	0.838
16-Feb	5	T3-18	Hh	06-Feb	1.227	0.209	0.686	0.895
16-Feb	1	T3-19	Oh	06-Feb	1.233	0.147	0.762	0.909
16-Feb	2	T3-19	Oh	06-Feb	1.224	0.225	0.510	0.735
16-Feb	3	T3-19	Oh	06-Feb	1.156	0.159	0.267	0.426
16-Feb	4	T3-19	Oh	06-Feb	1.022	0.132	0.393	0.525
16-Feb	5	T3-19	Oh	06-Feb	1.067	0.160	0.534	0.694
16-Feb	1	T5-2	Oh	26-Jan	1.181	0.175	0.869	1.044
16-Feb	2	T5-2	Oh	26-Jan	1.215	0.171	0.879	1.050
16-Feb	3	T5-2	Oh	26-Jan	1.118	0.188	0.845	1.033
16-Feb	4	T5-2	Oh	26-Jan	1.178	0.166	1.063	1.229
16-Feb	5	T5-2	Oh	26-Jan	1.374	0.212	0.975	1.187
16-Feb	1	T5-3	Hh	26-Jan	1.256	0.233	1.009	1.242
16-Feb	2	T5-3	Hh	26-Jan	1.246	0.178	0.989	1.167
16-Feb	3	T5-3	Hh	26-Jan	1.186	0.244	0.972	1.216
16-Feb	4	T5-3	Hh	26-Jan	1.128	0.160	0.889	1.049
16-Feb	5	T5-3	Hh	26-Jan	1.195	0.179	1.032	1.211
17-Feb	1	T5-16	Hh	06-Feb	1.207	0.235	0.808	1.043
17-Feb	2	T5-16	Hh	06-Feb	1.279	0.229	0.621	0.850
17-Feb	3	T5-16	Hh	06-Feb	1.268	0.165	0.481	0.646
17-Feb	4	T5-16	Hh	06-Feb	1.230	0.206	0.904	1.110
17-Feb	5	T5-16	Hh	06-Feb	1.235	0.230	0.877	1.107
17-Feb	1	T5-18	Hh	06-Feb	1.188	0.224	0.857	1.081
17-Feb	2	T5-18	Hh	06-Feb	1.293	0.205	0.804	1.009
17-Feb	3	T5-18	Hh	06-Feb	1.325	0.204	0.783	0.987
17-Feb	4	T5-18	Hh	06-Feb	1.262	0.161	0.871	1.032
17-Feb	5	T5-18	Hh	06-Feb	1.285	0.178	0.808	0.986
17-Feb	1	T5-19	Oh	06-Feb	1.058	0.121	0.653	0.774
17-Feb	2	T5-19	Oh	06-Feb	1.077	0.126	0.717	0.843
17-Feb	3	T5-19	Oh	06-Feb	1.096	0.132	0.678	0.810
17-Feb	4	T5-19	Oh	06-Feb	1.094	0.169	0.787	0.956
17-Feb	5	T5-19	Oh	06-Feb	1.042	0.127	0.656	0.783
19-Feb	1	T6-2	Oo	26-Jan	1.367	0.106	1.070	1.176
19-Feb	2	T6-2	Oo	26-Jan	1.204	0.182	0.986	1.168
19-Feb	3	T6-2	Oo	26-Jan	1.247	0.079	0.989	1.068
19-Feb	1	T6-3	Ho	26-Jan	1.357	0.181	1.361	1.542
19-Feb	2	T6-3	Ho	26-Jan	1.369	0.100	1.027	1.127

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
19-Feb	3	T6-3	Ho	26-Jan	1.332	0.206	0.922	1.128
19-Feb	4	T6-3	Ho	26-Jan	1.313	0.243	1.344	1.587
19-Feb	5	T6-3	Ho	26-Jan	1.334	0.236	1.146	1.382
19-Feb	1	T6-15	Oo	04-Feb	1.290	0.168	0.778	0.946
19-Feb	2	T6-15	Oo	04-Feb	0.991	0.127	0.184	0.311
19-Feb	3	T6-15	Oo	04-Feb	1.317	0.204	1.067	1.271
19-Feb	4	T6-15	Oo	04-Feb	0.973	0.086	0.597	0.683
19-Feb	5	T6-15	Oo	04-Feb	1.035	0.197	0.735	0.932
19-Feb	6	T6-15	Oo	04-Feb	1.177	.	.	.
19-Feb	7	T6-15	Oo	04-Feb	1.154	.	.	.
19-Feb	8	T6-15	Oo	04-Feb	1.293	.	.	.
19-Feb	9	T6-15	Oo	04-Feb	0.944	.	.	.
19-Feb	10	T6-15	Oo	04-Feb	1.260	.	.	.
19-Feb	1	T6-16	Ho	06-Feb	1.237	0.186	0.854	1.040
19-Feb	2	T6-16	Ho	06-Feb	1.174	0.201	0.856	1.057
19-Feb	3	T6-16	Ho	06-Feb	1.202	0.192	0.847	1.039
19-Feb	4	T6-16	Ho	06-Feb	1.160	0.202	0.969	1.171
19-Feb	5	T6-16	Ho	06-Feb	1.303	0.240	0.814	1.054
19-Feb	6	T6-16	Ho	06-Feb	1.123	.	.	.
19-Feb	7	T6-16	Ho	06-Feb	1.143	.	.	.
19-Feb	1	T6-18	Ho	06-Feb	1.294	0.198	0.920	1.118
19-Feb	2	T6-18	Ho	06-Feb	1.234	0.194	0.604	0.798
19-Feb	3	T6-18	Ho	06-Feb	1.278	0.201	0.919	1.120
19-Feb	4	T6-18	Ho	06-Feb	1.221	0.162	0.660	0.822
19-Feb	5	T6-18	Ho	06-Feb	1.332	0.203	0.980	1.183
19-Feb	6	T6-18	Ho	06-Feb	1.313	.	.	.
19-Feb	1	T6-19	Oo	06-Feb	1.084	0.153	0.710	0.863
19-Feb	2	T6-19	Oo	06-Feb	1.079	0.178	0.787	0.965
19-Feb	3	T6-19	Oo	06-Feb	1.118	0.164	0.788	0.952
19-Feb	4	T6-19	Oo	06-Feb	1.144	0.143	0.856	0.999
19-Feb	5	T6-19	Oo	06-Feb	1.122	0.145	0.617	0.762
23-Feb	1	T2-2	Oo	26-Jan	1.197	0.209	1.090	1.299
23-Feb	2	T2-2	Oo	26-Jan	1.229	0.215	0.948	1.163
23-Feb	3	T2-2	Oo	26-Jan	1.224	0.122	0.942	1.064
23-Feb	4	T2-2	Oo	26-Jan	1.241	0.212	1.033	1.245
23-Feb	5	T2-2	Oo	26-Jan	1.305	0.191	1.146	1.337
23-Feb	1	T2-3	Ho	26-Jan	1.447	0.140	1.061	1.201
23-Feb	2	T2-3	Ho	26-Jan	1.261	0.186	1.027	1.213
23-Feb	3	T2-3	Ho	26-Jan	1.237	0.154	1.140	1.294
23-Feb	4	T2-3	Ho	26-Jan	1.327	0.195	1.036	1.231
23-Feb	5	T2-3	Ho	26-Jan	1.402	0.182	1.073	1.255
23-Feb	1	T2-7	Ho	26-Jan	.	0.152	0.154	0.306
23-Feb	2	T2-7	Ho	26-Jan	.	0.130	0.674	0.804
23-Feb	3	T2-7	Ho	26-Jan	.	0.123	0.416	0.539
23-Feb	4	T2-7	Ho	26-Jan	.	0.169	0.480	0.649
23-Feb	5	T2-7	Ho	26-Jan	.	0.134	0.443	0.577
23-Feb	1	T2-15	Oo	04-Feb	0.999	0.167	0.715	0.882
23-Feb	2	T2-15	Oo	04-Feb	1.022	0.152	0.798	0.950
23-Feb	3	T2-15	Oo	04-Feb	1.009	0.095	0.731	0.826
23-Feb	4	T2-15	Oo	04-Feb	1.019	0.111	0.781	0.892
23-Feb	5	T2-15	Oo	04-Feb	1.009	0.145	0.781	0.926

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
23-Feb	1	T2-17	Ho	06-Feb	1.236	0.129	0.979	1.108
23-Feb	2	T2-17	Ho	06-Feb	1.133	0.254		
23-Feb	3	T2-17	Ho	06-Feb	1.217	0.243	0.879	1.122
23-Feb	4	T2-17	Ho	06-Feb	1.207	0.208	0.844	1.052
23-Feb	5	T2-17	Ho	06-Feb	1.242	0.460	1.032	1.492
23-Feb	1	T2-19	Ho	06-Feb	1.250	0.181	1.067	1.248
23-Feb	2	T2-19	Ho	06-Feb	1.295	0.168	0.886	1.054
23-Feb	3	T2-19	Ho	06-Feb	1.184	0.171	0.975	1.146
23-Feb	4	T2-19	Ho	06-Feb	1.289	0.245	0.962	1.207
23-Feb	5	T2-19	Ho	06-Feb	1.242	0.205	0.927	1.132
23-Feb	1	T2-20	Oo	06-Feb	1.115	0.136	0.787	0.923
23-Feb	2	T2-20	Oo	06-Feb	1.114	0.137	0.707	0.844
23-Feb	3	T2-20	Oo	06-Feb	1.087	0.142	0.644	0.786
23-Feb	1	T3-2	Oh	26-Jan	1.231	0.152	1.176	1.328
23-Feb	2	T3-2	Oh	26-Jan	1.309	0.202	1.055	1.257
23-Feb	3	T3-2	Oh	26-Jan		0.224	0.839	1.063
23-Feb	4	T3-2	Oh	26-Jan	1.208	0.156	1.036	1.192
23-Feb	5	T3-2	Oh	26-Jan	1.235	0.210	0.746	0.956
23-Feb	1	T3-16	Hh	06-Feb	1.123	0.294	0.846	1.140
23-Feb	2	T3-16	Hh	06-Feb	1.140	0.215	0.818	1.033
23-Feb	3	T3-16	Hh	06-Feb	1.166	0.188	0.876	1.064
23-Feb	4	T3-16	Hh	06-Feb	1.193	0.219	0.973	1.192
23-Feb	5	T3-16	Hh	06-Feb	1.284	0.171	0.988	1.159
23-Feb	1	T3-16	Hh	06-Feb	1.285	0.349	1.025	1.374
23-Feb	2	T3-16	Hh	06-Feb	1.291	0.211	0.994	1.205
23-Feb	3	T3-16	Hh	06-Feb	1.250	0.291	1.015	1.306
23-Feb	4	T3-16	Hh	06-Feb	1.304	0.175	1.024	1.199
23-Feb	5	T3-16	Hh	06-Feb	1.241	0.224	0.931	1.155
23-Feb	1	T3-19	Oh	06-Feb	1.107	0.089	0.803	0.892
23-Feb	2	T3-19	Oh	06-Feb	1.245	0.252	0.843	1.095
23-Feb	3	T3-19	Oh	06-Feb	1.137	0.187	0.868	1.055
23-Feb	4	T3-19	Oh	06-Feb	1.113	0.228	0.847	1.075
23-Feb	1	T5-2	Hh	26-Jan	1.372	0.224	0.462	0.686
23-Feb	2	T5-2	Hh	26-Jan	1.219	0.281	0.797	1.078
23-Feb	3	T5-2	Hh	26-Jan	1.280	0.281	1.142	1.423
23-Feb	4	T5-2	Hh	26-Jan	1.245	0.314	0.848	1.162
23-Feb	5	T5-2	Hh	26-Jan	1.022			
23-Feb	6	T5-2	Hh	26-Jan				
23-Feb	7	T5-2	Hh	26-Jan	1.459	0.297	1.388	1.685
23-Feb	1	T5-3	Hh	26-Jan	1.406	0.194	0.538	0.732
23-Feb	2	T5-3	Hh	26-Jan	1.397	0.266	1.102	1.368
23-Feb	1	T5-16	Hh	06-Feb	1.246	0.227	1.044	1.271
23-Feb	2	T5-16	Hh	06-Feb	1.254	0.230	1.059	1.289
23-Feb	3	T5-16	Hh	06-Feb	1.159	0.193	0.941	1.134
23-Feb	4	T5-16	Hh	06-Feb	1.281	0.263	1.031	1.294
23-Feb	5	T5-16	Hh	06-Feb	1.299	0.258	1.181	1.439
23-Feb	1	T5-18	Hh	06-Feb	1.267	0.214	1.093	1.307
23-Feb	2	T5-18	Hh	06-Feb	1.214	0.235	0.972	1.207
23-Feb	3	T5-18	Hh	06-Feb	1.319	0.248	1.222	1.470
23-Feb	4	T5-18	Hh	06-Feb	1.350	0.232	1.089	1.321
23-Feb	5	T5-18	Hh	06-Feb	1.253	0.270	1.200	1.470

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
23-Feb	1	T5-19	Oh	06-Feb	1.111	0.161	0.926	1.087
23-Feb	2	T5-19	Oh	06-Feb	1.117	0.218	0.671	0.889
23-Feb	3	T5-19	Oh	06-Feb	1.169	0.182	0.882	1.064
23-Feb	4	T5-19	Oh	06-Feb	1.066	0.303	0.804	1.107
23-Feb	5	T5-19	Oh	06-Feb	1.156	0.139	0.935	1.074
23-Feb	6	T5-19	Oh	06-Feb	1.256	.	.	.
23-Feb	7	T5-19	Oh	06-Feb	1.159	.	.	.
23-Feb	8	T5-19	Oh	06-Feb	1.077	.	.	.
23-Feb	9	T5-19	Oh	06-Feb	1.128	.	.	.
23-Feb	10	T5-19	Oh	06-Feb	1.272	.	.	.
23-Feb	11	T5-19	Oh	06-Feb	1.166	.	.	.
23-Feb	1	T6-2	Oo	26-Jan	1.231	.	.	.
23-Feb	2	T6-2	Oo	26-Jan	1.288	.	.	.
23-Feb	3	T6-2	Oo	26-Jan	1.261	.	.	.
23-Feb	4	T6-2	Oo	26-Jan	1.175	.	.	.
23-Feb	1	T6-3	Ho	26-Jan	1.321	.	.	.
23-Feb	2	T6-3	Ho	26-Jan	1.222	.	.	.
23-Feb	3	T6-3	Ho	26-Jan	1.369	.	.	.
23-Feb	1	T6-15	Oo	04-Feb	0.971	0.138	0.663	0.801
23-Feb	2	T6-15	Oo	04-Feb	1.290	0.199	1.074	1.273
23-Feb	3	T6-15	Oo	04-Feb	0.963	.	.	.
23-Feb	4	T6-15	Oo	04-Feb	0.997	.	.	.
23-Feb	5	T6-15	Oo	04-Feb	0.982	.	.	.
23-Feb	6	T6-15	Oo	04-Feb	1.014	.	.	.
23-Feb	1	T6-16	Ho	06-Feb	1.188	0.248	0.558	0.806
23-Feb	2	T6-16	Ho	06-Feb	1.068	0.208	0.780	0.988
23-Feb	3	T6-16	Ho	06-Feb	1.157	0.199	0.789	0.988
23-Feb	4	T6-16	Ho	06-Feb	1.090	0.205	0.609	0.814
23-Feb	5	T6-16	Ho	06-Feb	1.429	0.199	1.041	1.240
23-Feb	6	T6-16	Ho	06-Feb	1.172	.	.	.
23-Feb	7	T6-16	Ho	06-Feb	1.161	.	.	.
23-Feb	8	T6-16	Ho	06-Feb	1.221	.	.	.
23-Feb	9	T6-16	Ho	06-Feb	1.262	.	.	.
23-Feb	10	T6-16	Ho	06-Feb	1.144	.	.	.
23-Feb	11	T6-16	Ho	06-Feb	1.124	.	.	.
23-Feb	1	T6-18	Ho	06-Feb	1.335	0.323	1.140	1.463
23-Feb	2	T6-18	Ho	06-Feb	1.260	0.286	1.085	1.371
23-Feb	3	T6-18	Ho	06-Feb	1.281	0.379	0.929	1.308
23-Feb	4	T6-18	Ho	06-Feb	1.405	0.242	1.154	1.396
23-Feb	5	T6-18	Ho	06-Feb	1.258	0.298	0.974	1.272
23-Feb	1	T6-19	Oo	06-Feb	1.098	0.297	0.726	1.023
23-Feb	2	T6-19	Oo	06-Feb	1.162	0.136	0.934	1.070
23-Feb	3	T6-19	Oo	06-Feb	1.269	.	.	.
23-Feb	4	T6-19	Oo	06-Feb	1.074	.	.	.
23-Feb	5	T6-19	Oo	06-Feb	1.076	.	.	.
23-Feb	6	T6-19	Oo	06-Feb	1.160	.	.	.
27-Feb	1	T2-2	Oo	26-Jan	1.175	0.301	0.685	0.986
27-Feb	2	T2-2	Oo	26-Jan	1.335	0.214	0.953	1.167
27-Feb	1	T2-3	Ho	26-Jan	1.349	0.169	1.207	1.376
27-Feb	2	T2-3	Ho	26-Jan	1.338	0.227	1.196	1.423
27-Feb	3	T2-3	Ho	26-Jan	1.326	0.202	0.782	0.984

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
27-Feb	4	T2-3	Ho	26-Jan	1.384	0.170	1.115	1.285
27-Feb	5	T2-3	Ho	26-Jan	1.344	0.194	1.059	1.253
27-Feb	1	T2-7	Ho	26-Jan	1.101			
27-Feb	2	T2-7	Ho	26-Jan	1.056			
27-Feb	1	T2-15	Oo	04-Feb	1.047	0.148	0.779	0.927
27-Feb	2	T2-15	Oo	04-Feb	1.023	0.142	0.794	0.936
27-Feb	3	T2-15	Oo	04-Feb	1.071	0.123	0.734	0.857
27-Feb	4	T2-15	Oo	04-Feb	1.052	0.112	0.747	0.859
27-Feb	5	T2-15	Oo	04-Feb	1.046	0.126	0.600	0.726
27-Feb	6	T2-15	Oo	04-Feb	1.058	.	.	.
27-Feb	7	T2-15	Oo	04-Feb	1.277	.	.	.
27-Feb	8	T2-15	Oo	04-Feb	1.246	.	.	.
27-Feb	9	T2-15	Oo	04-Feb	1.031	.	.	.
27-Feb	10	T2-15	Oo	04-Feb	1.133	.	.	.
27-Feb	11	T2-15	Oo	04-Feb	1.015	.	.	.
27-Feb	1	T2-17	Ho	06-Feb	1.271	0.175	1.040	1.215
27-Feb	2	T2-17	Ho	06-Feb	1.150	0.217	0.967	1.184
27-Feb	3	T2-17	Ho	06-Feb	1.263	0.209	0.974	1.183
27-Feb	4	T2-17	Ho	06-Feb	1.255	0.345	1.147	1.492
27-Feb	5	T2-17	Ho	06-Feb	1.184	0.225	1.052	1.277
27-Feb	6	T2-17	Ho	06-Feb	1.223	.	.	.
27-Feb	7	T2-17	Ho	06-Feb	1.067	.	.	.
27-Feb	8	T2-17	Ho	06-Feb	1.198	.	.	.
27-Feb	9	T2-17	Ho	06-Feb	1.175	.	.	.
27-Feb	10	T2-17	Ho	06-Feb	1.167	.	.	.
27-Feb	1	T2-19	Ho	06-Feb	1.282	0.194	1.013	1.207
27-Feb	2	T2-19	Ho	06-Feb	1.224	0.185	0.971	1.156
27-Feb	3	T2-19	Ho	06-Feb	1.308	0.213	1.078	1.291
27-Feb	4	T2-19	Ho	06-Feb	1.252	0.167	1.002	1.169
27-Feb	5	T2-19	Ho	06-Feb	1.230	0.210	0.912	1.122
27-Feb	1	T3-2	Oh	26-Jan	1.247	0.212	1.091	1.303
27-Feb	2	T3-2	Oh	26-Jan	1.189	0.169	0.942	1.111
27-Feb	3	T3-2	Oh	26-Jan	1.172	.	.	.
27-Feb	4	T3-2	Oh	26-Jan	1.172	.	.	.
27-Feb	5	T3-2	Oh	26-Jan	1.154	.	.	.
27-Feb	6	T3-2	Oh	26-Jan	1.138	.	.	.
27-Feb	7	T3-2	Oh	26-Jan	1.168	.	.	.
27-Feb	1	T3-16	Hh	06-Feb	1.253	0.211	0.975	1.186
27-Feb	2	T3-16	Hh	06-Feb	1.138	0.083	0.921	1.004
27-Feb	3	T3-16	Hh	06-Feb	1.156	0.169	0.879	1.048
27-Feb	4	T3-16	Hh	06-Feb	1.298	0.246	1.016	1.262
27-Feb	5	T3-16	Hh	06-Feb	1.289	0.202	1.058	1.260
27-Feb	6	T3-16	Hh	06-Feb	1.207	.	.	.
27-Feb	7	T3-16	Hh	06-Feb	1.242	.	.	.
27-Feb	8	T3-16	Hh	06-Feb	1.274	.	.	.
27-Feb	9	T3-16	Hh	06-Feb	1.234	.	.	.
27-Feb	1	T3-18	Hh	06-Feb	1.275	0.284	0.996	1.280
27-Feb	2	T3-18	Hh	06-Feb	1.326	0.217	1.174	1.391
27-Feb	3	T3-18	Hh	06-Feb	1.280	0.233	1.092	1.325
27-Feb	4	T3-18	Hh	06-Feb	1.297	0.224	1.113	1.337
27-Feb	5	T3-18	Hh	06-Feb	1.226	0.194	0.985	1.179

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
27-Feb	6	T3-18	Hh	06-Feb	1.323			
27-Feb	7	T3-18	Hh	06-Feb	1.322			
27-Feb	8	T3-18	Hh	06-Feb	1.207			
27-Feb	1	T3-19	Oh	06-Feb	1.049	0.115	0.705	0.820
27-Feb	2	T3-19	Oh	06-Feb	1.076	0.155	0.842	0.997
27-Feb	3	T3-19	Oh	06-Feb	1.106	0.156	0.805	0.961
27-Feb	4	T3-19	Oh	06-Feb	1.262	0.258	0.596	0.854
27-Feb	5	T3-19	Oh	06-Feb	1.117	0.199	0.854	1.053
27-Feb	6	T3-19	Oh	06-Feb	1.233	.	.	.
27-Feb	7	T3-19	Oh	06-Feb	1.166	.	.	.
27-Feb	8	T3-19	Oh	06-Feb	1.207	.	.	.
27-Feb	9	T3-19	Oh	06-Feb	1.182	.	.	.
27-Feb	10	T3-19	Oh	06-Feb	1.126	.	.	.
27-Feb	1	T5-2	Oh	26-Jan	1.290	0.248	1.053	1.301
27-Feb	2	T5-2	Oh	26-Jan	1.354	0.278	1.184	1.462
27-Feb	1	T5-18	Hh	06-Feb	1.265	0.239	1.121	1.360
27-Feb	2	T5-18	Hh	06-Feb	1.335	0.243	1.155	1.398
27-Feb	3	T5-18	Hh	06-Feb	1.292	0.199	1.061	1.260
27-Feb	4	T5-18	Hh	06-Feb	1.256	0.211	1.106	1.317
27-Feb	5	T5-18	Hh	06-Feb	1.294	0.315	1.096	1.411
27-Feb	1	T6-2	Oo	26-Jan	1.298	0.246	1.150	1.396
27-Feb	2	T6-2	Oo	26-Jan	1.194	0.267	1.071	1.338
27-Feb	3	T6-2	Oo	26-Jan	1.341	0.212	1.309	1.521
27-Feb	1	T6-15	Oo	04-Feb	1.345	0.229	1.233	1.462
27-Feb	2	T6-15	Oo	04-Feb	1.183	0.254	0.771	1.025
27-Feb	3	T6-15	Oo	04-Feb	0.998	0.122	0.808	0.930
27-Feb	4	T6-15	Oo	04-Feb	1.326	0.220	1.042	1.262
27-Feb	1	T6-18	Ho	06-Feb	1.266	0.201	0.235	0.436
27-Feb	2	T6-18	Ho	06-Feb	1.245	0.205	0.141	0.346
27-Feb	3	T6-18	Ho	06-Feb	1.316	0.128	0.328	0.456
27-Feb	4	T6-18	Ho	06-Feb	1.261	0.073	0.272	0.345
27-Feb	5	T6-18	Ho	06-Feb	1.323	0.130	0.358	0.488
13-Mar	1	T2-3	Ho	26-Jan	1.563	0.233	0.457	0.690
13-Mar	1	T2-15	Oo	04-Feb	1.292	0.222	1.094	1.316
13-Mar	1	T2-17	Ho	06-Feb	1.220	0.257	0.464	0.721
13-Mar	1	T2-19	Ho	06-Feb	1.325	0.199		
13-Mar	2	T2-19	Ho	06-Feb	1.347			
13-Mar	3	T2-19	Ho	06-Feb	1.344			
13-Mar	4	T2-19	Ho	06-Feb	1.309			
13-Mar	5	T2-19	Ho	06-Feb	1.325			
13-Mar	1	T2-20	Oo	06-Feb	1.597	0.326	0.484	0.810
13-Mar	1	T3-2	Oh	26-Jan	1.251			
13-Mar	2	T3-2	Oh	26-Jan	3.000			
13-Mar	1	T3-16	Hh	06-Feb	1.126	0.221	0.959	1.180
13-Mar	2	T3-16	Hh	06-Feb	1.224	0.177	0.330	0.507
13-Mar	3	T3-16	Hh	06-Feb	1.206	0.151	0.334	0.485
13-Mar	1	T3-18	Hh	06-Feb	1.245	0.487	0.985	1.472
13-Mar	2	T3-18	Hh	06-Feb	1.241	0.335	0.506	0.841
13-Mar	3	T3-18	Hh	06-Feb	1.332	0.348	1.104	1.452
13-Mar	4	T3-18	Hh	06-Feb	1.346	0.355	1.073	1.428
13-Mar	1	T3-19	Oh	06-Feb	1.030	0.130	0.544	0.674

Sample Date	Egg Lot No.	Tank	Oxygen Treatment	Spawn Date	Egg Diameter (mm)	Oil Drop Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
03-Feb	1	T6-2	Oo	26-Jan	1.136	0.161	0.539	0.700
13-Mar	2	T3-19	Oh	06-Feb	1.267	0.262	0.163	0.425
13-Mar	3	T3-19	Oh	06-Feb	1.187	0.146	0.561	0.707
13-Mar	1	T5-16	Hh	06-Feb	1.317	0.183	0.399	0.582
13-Mar	2	T5-16	Hh	06-Feb	1.254	0.124	0.310	0.434
13-Mar	3	T5-16	Hh	06-Feb	1.190	0.260	0.541	0.801
13-Mar	4	T5-16	Hh	06-Feb	1.237	0.156	0.216	0.372
13-Mar	1	T5-18	Hh	06-Feb	1.220	0.319	0.094	0.413
13-Mar	2	T5-18	Hh	06-Feb	1.218	0.298	0.937	1.235
13-Mar	3	T5-18	Hh	06-Feb	1.370	0.106	0.413	0.519
13-Mar	4	T5-18	Hh	06-Feb	1.314	0.173	0.448	0.621
13-Mar	5	T5-18	Hh	06-Feb	1.334	0.277	0.964	1.241
13-Mar	1	T5-19	Oh	06-Feb	1.169	0.201	0.375	0.576
13-Mar	2	T5-19	Oh	06-Feb	1.096	0.114	0.292	0.406
13-Mar	3	T5-19	Oh	06-Feb	1.164	0.233	0.462	0.695
13-Mar	4	T5-19	Oh	06-Feb	1.067	0.317	0.818	1.135
13-Mar	1	T6-15	Oo	04-Feb	1.065	0.171	0.200	0.371
13-Mar	1	T6-16	Ho	06-Feb	1.261	0.108	0.536	0.644
13-Mar	2	T6-16	Ho	06-Feb	1.327	0.361	0.655	1.016
13-Mar	3	T6-16	Ho	06-Feb	1.288	0.258	0.472	0.730
13-Mar	4	T6-16	Ho	06-Feb	1.310	0.181	0.379	0.560
13-Mar	5	T6-16	Ho	06-Feb	1.217	0.233	0.551	0.784
13-Mar	1	T6-18	Ho	06-Feb	1.280	0.295	0.519	0.814
13-Mar	2	T6-18	Ho	06-Feb	1.338	0.156	0.412	0.568
13-Mar	3	T6-18	Ho	06-Feb	1.296	0.239	0.483	0.722
13-Mar	4	T6-18	Ho	06-Feb	1.333	0.324	0.667	0.991
13-Mar	5	T6-18	Ho	06-Feb	1.277	0.344	0.390	0.734
13-Mar	1	T6-19	Oo	06-Feb	1.121	0.197	0.385	0.582
13-Mar	2	T6-19	Oo	06-Feb	1.138	0.333	0.684	1.017
13-Mar	3	T6-19	Oo	06-Feb	1.143	0.238	0.668	0.906
13-Mar	4	T6-19	Oo	06-Feb	1.108	0.155	0.421	0.576
20-Mar	1	T2-3	Ho	26-Jan	1.372	0.238	0.397	0.635
20-Mar	1	T2-19	Ho	06-Feb	1.124	0.297		
20-Mar	1	T6-18	Ho	06-Feb	1.306	0.688	0.866	1.554
20-Mar	2	T6-18	Ho	06-Feb	1.647	1.294	1.591	2.885
20-Mar	3	T6-18	Ho	06-Feb	1.323	0.628	0.993	1.621
20-Mar	4	T6-18	Ho	06-Feb	1.308	0.620	0.812	1.432
20-Mar	5	T6-18	Ho	06-Feb	1.374	0.703	1.002	1.705

Table 8. Total length and cross-sectional areas of the yolk and oil-droplet of burbot larvae hatched from eggs originating from adults reared in normoxic (O) or hypoxic (H) water and incubated at normoxic (o) and hypoxic (h) conditions.

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694			
23-Feb	1	T5-2	Oh	26-Jan	3.337	0.220		
23-Feb	2	T5-2	Oh	26-Jan	3.138	0.247	0.534	0.781
23-Feb	1	T5-3	Hh	26-Jan	3.080	0.188	0.749	0.937
23-Feb	2	T5-3	Hh	26-Jan	3.050	0.234	0.849	1.083
23-Feb	3	T5-3	Hh	26-Jan	3.065	0.286	0.601	0.887
23-Feb	4	T5-3	Hh	26-Jan	3.217	0.212	0.985	1.197
23-Feb	1	T5-16	Hh	06-Feb	3.380	0.193	0.535	0.728
23-Feb	1	T6-2	Oo	26-Jan	3.030	0.250		
27-Feb	1	T2-2	Oo	26-Jan	3.165	0.213	0.415	0.628
27-Feb	2	T2-2	Oo	26-Jan	2.613	0.290	0.569	0.859
27-Feb	3	T2-2	Oo	26-Jan	3.056	0.241	0.746	0.987
27-Feb	4	T2-2	Oo	26-Jan	2.623	0.216	0.504	0.720
27-Feb	5	T2-2	Oo	26-Jan	3.126	0.201	0.476	0.677
27-Feb	1	T2-7	Ho	26-Jan	3.326			
27-Feb	2	T2-7	Ho	26-Jan	3.747			
27-Feb	3	T2-7	Ho	26-Jan	3.537			
27-Feb	4	T2-7	Ho	26-Jan	3.164	0.174	0.276	0.450
27-Feb	5	T2-7	Ho	26-Jan	2.947	0.256	0.371	0.627
27-Feb	1	T3-2	Oh	26-Jan	3.754	0.219	0.513	0.732
27-Feb	2	T3-2	Oh	26-Jan	3.574	0.265	0.586	0.851
27-Feb	3	T3-2	Oh	26-Jan	2.630	0.168	0.452	0.620
27-Feb	4	T3-2	Oh	26-Jan	3.324	0.239	0.513	0.752
27-Feb	5	T3-2	Oh	26-Jan	3.012	0.232	0.368	0.600
27-Feb	1	T5-2	Oh	26-Jan	3.180	0.314	0.616	0.930
27-Feb	2	T5-2	Oh	26-Jan	3.401	0.174	0.429	0.603

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694			
27-Feb	3	T5-2	Oh	26-Jan	2.244	0.235	0.348	0.583
27-Feb	4	T5-2	Oh	26-Jan	3.565	0.208	0.465	0.673
27-Feb	5	T5-2	Oh	26-Jan	3.775	0.228	0.637	0.865
27-Feb	1	T6-2	Oo	26-Jan	3.458	0.661	1.005	1.666
27-Feb	2	T6-2	Oo	26-Jan	3.945	0.746	0.970	1.716
27-Feb	3	T6-2	Oo	26-Jan	4.004	0.354	0.720	1.074
27-Feb	4	T6-2	Oo	26-Jan	3.412	0.204	0.357	0.561
27-Feb	5	T6-2	Oo	26-Jan	3.845	0.258	0.462	0.720
27-Feb	1	T6-15	Oo	04-Feb	3.237	0.230	0.597	0.827
27-Feb	2	T6-15	Oo	04-Feb	3.520	0.441	0.722	1.163
27-Feb	3	T6-15	Oo	04-Feb	3.186	1.213	1.213	2.426
27-Feb	4	T6-15	Oo	04-Feb	3.235	0.499	0.378	0.877
13-Mar	1	T2-2	Oo	26-Jan	3.934	0.176	0.371	0.547
13-Mar	2	T2-2	Oo	26-Jan	3.321	0.339	0.453	0.792
13-Mar	3	T2-2	Oo	26-Jan	3.455	0.142	0.650	0.792
13-Mar	4	T2-2	Oo	26-Jan	3.469	0.200	0.604	0.804
13-Mar	1	T2-3	Ho	26-Jan	3.554	0.232	0.468	0.700
13-Mar	2	T2-3	Ho	26-Jan	3.605	0.224	0.659	0.883
13-Mar	3	T2-3	Ho	26-Jan	3.294	0.252	0.489	0.741
13-Mar	4	T2-3	Ho	26-Jan	3.771	0.213	0.413	0.626
13-Mar	5	T2-3	Ho	26-Jan	4.211	0.222	0.624	0.846
13-Mar	1	T2-15	Oo	04-Feb	3.573	0.598	0.648	1.246
13-Mar	2	T2-15	Oo	04-Feb	3.380	0.537	0.429	0.966
13-Mar	3	T2-15	Oo	04-Feb	3.758	0.562	0.562	1.124
13-Mar	4	T2-15	Oo	04-Feb	3.988		0.915	
13-Mar	5	T2-15	Oo	04-Feb	3.145		0.660	
13-Mar	1	T2-17	Ho	06-Feb	3.909	0.351	0.542	0.893
13-Mar	1	T3-2	Oh	26-Jan	4.469	0.162	0.443	0.605

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694	.	.	.
13-Mar	2	T3-2	Oh	26-Jan	4.317	0.220	0.507	0.727
13-Mar	3	T3-2	Oh	26-Jan	3.134	.	.	.
13-Mar	4	T3-2	Oh	26-Jan	4.031	0.214	0.386	0.600
13-Mar	5	T3-2	Oh	26-Jan	4.214	0.226	0.488	0.714
13-Mar	6	T3-2	Oh	26-Jan	4.268	0.174	0.305	0.479
13-Mar	1	T3-3	Hh	26-Jan	4.421	0.230	0.476	0.706
13-Mar	2	T3-3	Hh	26-Jan	4.455	0.219	0.616	0.835
13-Mar	3	T3-3	Hh	26-Jan	2.898	0.179	0.509	0.688
13-Mar	4	T3-3	Hh	26-Jan	4.463	0.241	0.732	0.973
13-Mar	5	T3-3	Hh	26-Jan	4.478	0.216	0.612	0.828
13-Mar	1	T3-15	Oh	04-Feb	4.086	.	0.910	.
13-Mar	2	T3-15	Oh	04-Feb	3.875	.	0.490	.
13-Mar	3	T3-15	Oh	04-Feb	3.994	.	0.609	.
13-Mar	4	T3-15	Oh	04-Feb	4.062	.	0.582	.
13-Mar	5	T3-15	Oh	04-Feb	4.106	0.154	0.289	0.443
13-Mar	6	T3-15	Oh	04-Feb	4.089	0.300	0.502	0.802
13-Mar	1	T2-18	Ho	06-Feb	3.888	0.259	0.794	1.053
13-Mar	1	T3-19	Ho	06-Feb	3.399	0.181	0.391	0.572
13-Mar	2	T3-19	Ho	06-Feb	3.261	0.172	0.335	0.507
13-Mar	3	T3-19	Ho	06-Feb	3.752	0.161	0.176	0.337
13-Mar	4	T3-19	Ho	06-Feb	3.651	0.132	0.097	0.229
13-Mar	5	T3-19	Ho	06-Feb	3.462	0.169	0.361	0.530
13-Mar	1	T5-2	Oh	26-Jan	4.373	0.178	0.306	0.484
13-Mar	2	T5-2	Oh	26-Jan	4.395	0.209	0.334	0.543
13-Mar	3	T5-2	Oh	26-Jan	3.409	0.178	0.350	0.528
13-Mar	4	T5-2	Oh	26-Jan	4.376	0.212	0.185	0.397
13-Mar	5	T5-2	Oh	26-Jan	3.269	0.145	0.646	0.791
13-Mar	1	T5-18	Hh	06-Feb	3.672	0.145	0.080	0.225

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694			
13-Mar	1	T6-2	Oo	26-Jan	3.701		0.624	
13-Mar	2	T6-2	Oo	26-Jan	4.019		0.554	
13-Mar	3	T6-2	Oo	26-Jan	4.300	0.215	0.167	0.382
13-Mar	4	T6-2	Oo	26-Jan	3.460		0.309	
13-Mar	5	T6-2	Oo	26-Jan	3.503		0.688	
13-Mar	1	T6-3	Ho	26-Jan	4.544	0.190	0.466	0.656
13-Mar	2	T6-3	Ho	26-Jan	4.695	0.256	0.379	0.635
13-Mar	3	T6-3	Ho	26-Jan	4.449	0.204	0.240	0.444
13-Mar	4	T6-3	Ho	26-Jan	4.494	0.236	0.321	0.557
13-Mar	5	T6-3	Ho	26-Jan	4.391	0.241	0.299	0.540
13-Mar	1	T6-15	Oo	04-Feb	3.726		0.381	
13-Mar	2	T6-15	Oo	04-Feb	3.969	0.271	0.165	0.436
13-Mar	3	T6-15	Oo	04-Feb	3.570	0.191	0.349	0.540
13-Mar	4	T6-15	Oo	04-Feb	3.816	0.344	0.169	0.513
13-Mar	5	T6-15	Oo	04-Feb	4.145	0.246	0.247	0.493
13-Mar	1	T6-16	Ho	06-Feb	4.017	0.298	0.402	0.700
13-Mar	2	T6-16	Ho	06-Feb	3.295	0.444	0.559	1.003
13-Mar	1	T6-19	Oo	06-Feb	3.669	0.755	0.811	1.566
20-Mar	1	T2-2	Oo	26-Jan	3.932	0.183	0.422	0.605
20-Mar	2	T2-2	Oo	26-Jan	4.495	0.161	0.545	0.706
20-Mar	3	T2-2	Oo	26-Jan	3.839	0.176	0.367	0.543
20-Mar	4	T2-2	Oo	26-Jan	4.382	0.152	0.425	0.577
20-Mar	5	T2-2	Oo	26-Jan	3.904	0.156	0.351	0.507
20-Mar	1	T2-7	Ho	26-Jan	4.250	0.105	0.430	0.535
20-Mar	2	T2-7	Ho	26-Jan	4.211	0.083	0.285	0.368
20-Mar	3	T2-7	Ho	26-Jan	4.235	0.122	0.404	0.526
20-Mar	4	T2-7	Ho	26-Jan	4.343	0.149	0.410	0.559
20-Mar	5	T2-7	Ho	26-Jan	4.085	0.110	0.383	0.493

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694			
20-Mar	1	T2-15	Oo	04-Feb	3.724	0.181	0.440	0.621
20-Mar	2	T2-15	Oo	04-Feb	3.796	0.338	0.629	0.967
20-Mar	3	T2-15	Oo	04-Feb	3.620	0.184	0.581	0.765
20-Mar	4	T2-15	Oo	04-Feb	3.920	0.238	0.370	0.608
20-Mar	5	T2-15	Oo	04-Feb	3.983	0.346	0.606	0.952
20-Mar	1	T2-17	Ho	06-Feb	3.850	0.704	1.014	1.718
20-Mar	2	T2-17	Ho	06-Feb	3.915	0.281	0.515	0.796
20-Mar	3	T2-17	Ho	06-Feb	3.858	0.225	0.601	0.826
20-Mar	4	T2-17	Ho	06-Feb	3.973	0.282	0.459	0.741
20-Mar	5	T2-17	Ho	06-Feb	3.411	0.215	0.542	0.757
20-Mar	1	T2-20	Oo	06-Feb	3.971	0.511	0.813	1.324
20-Mar	2	T2-20	Oo	06-Feb	3.800	0.397	0.678	1.075
20-Mar	3	T2-20	Oo	06-Feb	3.803	0.183	0.307	0.490
20-Mar	4	T2-20	Oo	06-Feb	4.084	0.185	0.340	0.525
20-Mar	5	T2-20	Oo	06-Feb	4.048	0.509	0.590	1.099
20-Mar	1	T3-2	Oh	26-Jan	4.439	0.087	0.439	0.526
20-Mar	2	T3-2	Oh	26-Jan	4.509	0.270	0.360	0.630
20-Mar	3	T3-2	Oh	26-Jan	4.028	0.454	0.602	1.056
20-Mar	4	T3-2	Oh	26-Jan	4.204	0.225	0.385	0.610
20-Mar	5	T3-2	Oh	26-Jan	4.405	0.164	0.491	0.655
20-Mar	1	T3-3	Hh	26-Jan	4.307	0.200	0.552	0.752
20-Mar	2	T3-3	Hh	26-Jan	4.480	0.190	0.500	0.690
20-Mar	3	T3-3	Hh	26-Jan	4.382	0.187	0.419	0.606
20-Mar	4	T3-3	Hh	26-Jan	4.367	0.190	0.522	0.712
20-Mar	5	T3-3	Hh	26-Jan	4.427	0.202	0.459	0.661
20-Mar	1	T3-15	Oh	04-Feb	3.697		0.557	
20-Mar	2	T3-15	Oh	04-Feb	3.978		0.418	
20-Mar	3	T3-15	Oh	04-Feb	3.894		0.476	

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694	.	.	.
20-Mar	4	T3-15	Oh	04-Feb	4.393	.	0.628	.
20-Mar	5	T3-15	Oh	04-Feb	4.229	0.139	0.533	0.672
20-Mar	1	T3-16	Hh	06-Feb	3.623	.	0.483	.
20-Mar	1	T3-18	Hh	06-Feb	4.264	.	0.698	.
20-Mar	2	T3-18	Hh	06-Feb	4.367	.	0.720	.
20-Mar	3	T3-18	Hh	06-Feb	4.093	.	0.810	.
20-Mar	4	T3-18	Hh	06-Feb	4.103	.	0.752	.
20-Mar	5	T3-18	Hh	06-Feb	4.354	.	0.626	.
20-Mar	1	T3-19	Oh	06-Feb	4.117	.	0.642	.
20-Mar	2	T3-19	Oh	06-Feb	3.755	.	0.440	.
20-Mar	3	T3-19	Oh	06-Feb	3.756	0.206	0.518	0.724
20-Mar	4	T3-19	Oh	06-Feb	3.955	0.155	0.290	0.445
20-Mar	5	T3-19	Oh	06-Feb	4.030	.	0.546	.
20-Mar	1	T5-2	Oh	26-Jan	4.351	0.140	0.411	0.551
20-Mar	2	T5-2	Oh	26-Jan	4.473	.	0.445	.
20-Mar	3	T5-2	Oh	26-Jan	4.291	0.152	0.343	0.495
20-Mar	4	T5-2	Oh	26-Jan	4.220	0.152	0.400	0.552
20-Mar	5	T5-2	Oh	26-Jan	4.368	0.106	0.411	0.517
20-Mar	1	T5-3	Hh	26-Jan	4.485	0.202	0.636	0.838
20-Mar	2	T5-3	Hh	26-Jan	4.567	0.181	0.502	0.683
20-Mar	3	T5-3	Hh	26-Jan	4.371	0.186	0.549	0.735
20-Mar	4	T5-3	Hh	26-Jan	4.048	0.240	0.703	0.943
20-Mar	5	T5-3	Hh	26-Jan	4.602	0.272	0.537	0.809
20-Mar	1	T5-16	Hh	06-Feb	3.978	.	0.900	.
20-Mar	2	T5-16	Hh	06-Feb	4.597	0.209	0.533	0.742
20-Mar	3	T5-16	Hh	06-Feb	3.387	0.191	0.975	1.166
20-Mar	1	T5-18	Hh	06-Feb	3.842	0.199	0.669	0.868
20-Mar	2	T5-18	Hh	06-Feb	4.541	0.203	0.571	0.774

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694			
20-Mar	3	T5-18	Hh	06-Feb	4.577	0.190	0.624	0.814
20-Mar	4	T5-18	Hh	06-Feb	4.474	0.256	0.477	0.733
20-Mar	5	T5-18	Hh	06-Feb	4.392	0.157	0.563	0.720
20-Mar	1	T5-19	Oh	06-Feb	3.910		0.243	
20-Mar	2	T5-19	Oh	06-Feb	4.098		0.419	
20-Mar	3	T5-19	Oh	06-Feb	3.895		0.239	
20-Mar	4	T5-19	Oh	06-Feb	3.886		0.616	
20-Mar	1	T6-2	Oo	26-Jan	4.083	0.204	0.457	0.661
20-Mar	2	T6-2	Oo	26-Jan	4.175	0.187	0.439	0.626
20-Mar	3	T6-2	Oo	26-Jan	3.885	0.165	0.403	0.568
20-Mar	4	T6-2	Oo	26-Jan	3.909	0.150	0.285	0.435
20-Mar	5	T6-2	Oo	26-Jan	3.932	0.166	0.420	0.586
20-Mar	1	T6-3	Ho	26-Jan	4.895	0.210	0.454	0.664
20-Mar	2	T6-3	Ho	26-Jan	4.599	0.193	0.500	0.693
20-Mar	3	T6-3	Ho	26-Jan	4.569	0.187	0.521	0.708
20-Mar	4	T6-3	Ho	26-Jan	4.872	0.183	0.507	0.690
20-Mar	5	T6-3	Ho	26-Jan	4.658	0.177	0.406	0.583
20-Mar	1	T6-15	Oo	04-Feb	4.372	0.258	0.496	0.754
20-Mar	2	T6-15	Oo	04-Feb	3.821	0.354	0.525	0.879
20-Mar	3	T6-15	Oo	04-Feb	7.082	0.159	0.384	0.543
20-Mar	4	T6-15	Oo	04-Feb	4.217	0.125	0.360	0.485
20-Mar	5	T6-15	Oo	04-Feb	4.341	0.328	0.520	0.848
20-Mar	1	T6-16	Ho	06-Feb	4.015	0.242	0.520	0.762
20-Mar	2	T6-16	Ho	06-Feb	4.265	0.306	0.544	0.850
20-Mar	3	T6-16	Ho	06-Feb	4.599	0.237	0.372	0.609
20-Mar	4	T6-16	Ho	06-Feb	3.950	0.266	0.559	0.825
20-Mar	5	T6-16	Ho	06-Feb	4.166	0.188	0.425	0.613
20-Mar	1	T6-19	Ho	06-Feb	4.064	0.503	0.585	1.088

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694			
20-Mar	2	T6-19	Ho	06-Feb	4.041	0.256	0.463	0.719
20-Mar	3	T6-19	Ho	06-Feb	4.106	0.567	0.724	1.291
20-Mar	4	T6-19	Ho	06-Feb	4.034	0.235	0.557	0.792
20-Mar	5	T6-19	Ho	06-Feb	3.343	0.190	0.497	0.687
27-Mar	1	T2-2	Ho	26-Jan	4.381		0.494	
27-Mar	2	T2-2	Ho	26-Jan	4.095		0.648	
27-Mar	3	T2-2	Ho	26-Jan	4.701		0.682	
27-Mar	4	T2-2	Ho	26-Jan	4.594		0.601	
27-Mar	5	T2-2	Ho	26-Jan	4.344		0.572	
27-Mar	1	T2-3	Ho	26-Jan	4.633	0.073	0.399	0.472
27-Mar	1	T2-7	Ho	26-Jan	4.051	0.078	0.218	0.296
27-Mar	2	T2-7	Ho	26-Jan	3.710	0.047	0.229	0.276
27-Mar	3	T2-7	Ho	26-Jan	4.171	0.086	0.234	0.320
27-Mar	4	T2-7	Ho	26-Jan	4.457		0.391	
27-Mar	5	T2-7	Ho	26-Jan	4.344	0.132	0.353	0.485
27-Mar	1	T2-15	Oo	04-Feb	3.536		0.426	
27-Mar	2	T2-15	Oo	04-Feb	3.585	0.339	0.395	0.734
27-Mar	3	T2-15	Oo	04-Feb	4.013	0.251	0.421	0.672
27-Mar	4	T2-15	Oo	04-Feb	4.531	0.207	0.619	0.826
27-Mar	5	T2-15	Oo	04-Feb	3.833		0.477	
27-Mar	1	T2-17	Ho	06-Feb	4.514		0.747	
27-Mar	1	T2-20	Oo	06-Feb	4.195		0.479	
27-Mar	2	T2-20	Oo	06-Feb	4.410	0.166	0.428	0.594
27-Mar	3	T2-20	Oo	06-Feb	4.462	0.196	0.416	0.612
27-Mar	4	T2-20	Oo	06-Feb	4.221	0.280	0.440	0.720
27-Mar	5	T2-20	Oo	06-Feb	4.227	0.236	0.336	0.572
27-Mar	1	T3-2	Oh	26-Jan	4.112	0.158	0.501	0.659
27-Mar	2	T3-2	Oh	26-Jan	4.511	0.105	0.621	0.726

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694			
27-Mar	3	T3-2	Oh	26-Jan	4.435	0.158	0.499	0.657
27-Mar	4	T3-2	Oh	26-Jan	4.279	0.149	0.405	0.554
27-Mar	5	T3-2	Oh	26-Jan	4.397	0.163	0.443	0.606
27-Mar	1	T3-3	Hh	26-Jan	4.403	0.240	0.486	0.726
27-Mar	2	T3-3	Hh	26-Jan	4.775	0.228	0.374	0.602
27-Mar	3	T3-3	Hh	26-Jan	4.716	0.220	0.403	0.623
27-Mar	4	T3-3	Hh	26-Jan	4.434	0.230	0.427	0.657
27-Mar	5	T3-3	Hh	26-Jan	4.685	0.234	0.411	0.645
27-Mar	1	T3-15	Oh	04-Feb	4.100	0.126	0.332	0.458
27-Mar	2	T3-15	Oh	04-Feb	4.040	0.099	0.222	0.321
27-Mar	3	T3-15	Oh	04-Feb	4.006	0.132	0.260	0.392
27-Mar	4	T3-15	Oh	04-Feb	4.078	0.098	0.245	0.343
27-Mar	5	T3-15	Oh	04-Feb	4.348	0.137	0.319	0.456
27-Mar	1	T3-16	Hh	06-Feb	3.589		1.078	
27-Mar	2	T3-16	Hh	06-Feb	4.438		0.596	
27-Mar	3	T3-16	Hh	06-Feb	3.346		0.747	
27-Mar	1	T3-18	Hh	06-Feb	4.429	0.263	0.473	0.736
27-Mar	2	T3-18	Hh	06-Feb	4.606	0.348	0.587	0.935
27-Mar	3	T3-18	Hh	06-Feb	4.186	0.215	0.569	0.784
27-Mar	4	T3-18	Hh	06-Feb	4.432	0.241	0.460	0.701
27-Mar	5	T3-18	Hh	06-Feb	4.486	0.265	0.460	0.725
27-Mar	1	T3-19	Oh	06-Feb	4.047	0.122	0.512	0.634
27-Mar	2	T3-19	Oh	06-Feb	3.946	0.261	0.603	0.864
27-Mar	3	T3-19	Oh	06-Feb	3.602	0.189	0.335	0.524
27-Mar	4	T3-19	Oh	06-Feb	3.849	0.127	0.495	0.622
27-Mar	5	T3-19	Oh	06-Feb	3.784	0.159	0.462	0.621
27-Mar	1	T5-2	Oh	26-Jan	4.518	0.170	0.466	0.636
27-Mar	2	T5-2	Oh	26-Jan	4.405	0.150	0.348	0.498

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694			
27-Mar	3	T5-2	Oh	26-Jan	4.414	0.180	0.396	0.576
27-Mar	4	T5-2	Oh	26-Jan	4.390	0.327	0.440	0.767
27-Mar	5	T5-2	Oh	26-Jan	4.715	0.502	0.763	1.265
27-Mar	1	T5-3	Hh	26-Jan	4.751	0.176	0.462	0.638
27-Mar	2	T5-3	Hh	26-Jan	4.694	0.184	0.490	0.674
27-Mar	3	T5-3	Hh	26-Jan	4.458	0.170	0.495	0.665
27-Mar	4	T5-3	Hh	26-Jan	4.751	0.193	0.480	0.673
27-Mar	5	T5-3	Hh	26-Jan	4.861	0.197	0.459	0.656
27-Mar	1	T5-16	Hh	06-Feb	4.366	0.242	0.517	0.759
27-Mar	2	T5-16	Hh	06-Feb	4.394	0.257	0.458	0.715
27-Mar	3	T5-16	Hh	06-Feb	3.941	0.242	0.398	0.640
27-Mar	4	T5-16	Hh	06-Feb	4.434	0.231	0.505	0.736
27-Mar	5	T5-16	Hh	06-Feb	4.738	0.199	0.436	0.635
27-Mar	1	T5-18	Hh	06-Feb	4.391	0.181	0.529	0.710
27-Mar	2	T5-18	Hh	06-Feb	4.285	0.111	0.276	0.387
27-Mar	3	T5-18	Hh	06-Feb	4.490	0.224	0.524	0.748
27-Mar	4	T5-18	Hh	06-Feb	4.500	0.154	0.499	0.653
27-Mar	5	T5-18	Hh	06-Feb	4.440	0.221	0.606	0.827
27-Mar	1	T5-19	Oh	06-Feb	4.079	0.196	0.274	0.470
27-Mar	2	T5-19	Oh	06-Feb	4.091	0.151	0.342	0.493
27-Mar	3	T5-19	Oh	06-Feb	4.087	0.144	0.299	0.443
27-Mar	4	T5-19	Oh	06-Feb	4.095	0.188	0.312	0.500
27-Mar	5	T5-19	Oh	06-Feb	3.912	0.106	0.334	0.440
27-Mar	1	T6-2	Oo	26-Jan	3.941	0.110	0.687	0.797
27-Mar	2	T6-2	Oo	26-Jan	4.153		0.473	
27-Mar	3	T6-2	Oo	26-Jan	3.825		0.622	
27-Mar	1	T6-3	Ho	26-Jan	4.571	0.125	0.387	0.512
27-Mar	2	T6-3	Ho	26-Jan	4.586	0.151	0.385	0.536

Sample Date	Larval Group #	Tank	Oxygen Treatment	Spawn Date	Total Length (mm)	Oil Area (mm^2)	Yolk Area (mm^2)	Total Area (mm^2)
23-Feb	1	T3-2	Oh	26-Jan	2.694			
27-Mar	3	T6-3	Ho	26-Jan	4.744	0.198	0.555	0.753
27-Mar	4	T6-3	Ho	26-Jan	4.647	0.156	0.544	0.700
27-Mar	5	T6-3	Ho	26-Jan	4.819	0.127	0.457	0.584
27-Mar	1	T6-15	Oo	04-Feb	3.996	0.121	0.376	0.497
27-Mar	2	T6-15	Oo	04-Feb	3.831	0.129	0.393	0.522
27-Mar	3	T6-15	Oo	04-Feb	4.227	0.131	0.325	0.456
27-Mar	4	T6-15	Oo	04-Feb	4.125	0.142	0.316	0.458
27-Mar	5	T6-15	Oo	04-Feb	4.327	0.131	0.344	0.475
27-Mar	1	T6-16	Ho	06-Feb	3.955	0.243	0.476	0.719
27-Mar	2	T6-16	Ho	06-Feb	4.215	0.278	0.522	0.800
27-Mar	3	T6-16	Ho	06-Feb	4.223	0.274	0.532	0.806
27-Mar	4	T6-16	Ho	06-Feb	4.255	0.240	0.472	0.712
27-Mar	5	T6-16	Ho	06-Feb	4.396	0.217	0.475	0.692
27-Mar	1	T6-18	Ho	06-Feb	4.139	0.183	0.483	0.666
27-Mar	2	T6-18	Ho	06-Feb	4.273	0.177	0.522	0.699
27-Mar	3	T6-18	Ho	06-Feb	4.451	0.212	0.545	0.757
27-Mar	4	T6-18	Ho	06-Feb	3.877	0.207	0.590	0.797
27-Mar	5	T6-18	Ho	06-Feb	4.117	0.200	0.654	0.854
27-Mar	1	T6-19	Oo	06-Feb	4.060	0.199	0.347	0.546
27-Mar	2	T6-19	Oo	06-Feb	3.561	0.204	0.332	0.536
27-Mar	3	T6-19	Oo	06-Feb	3.899	0.176	0.435	0.611
27-Mar	4	T6-19	Oo	06-Feb	4.045	0.214	0.477	0.691
27-Mar	5	T6-19	Oo	06-Feb	3.781	0.159	0.311	0.470

Table 9. Spawn date, treatment codes and percent survivorship to 50 % hatch of burbot eggs originating from parents reared in normoxic (O) and hypoxic (H) water during sexual maturation. Eggs were incubated under normoxic (o) and hypoxic (h) conditions.

Date of Spawn	Treatment Code	Total Percent Survivorship to 50% Hatch										Avg	Std Dev
		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10		
26-Jan	Oo	1.75	1.38									1.56	0.19
	Oh	4.69	10.9									7.81	3.13
	Ho	4.50	2.75	2.06	23.1	23.7	3.88					9.99	9.50
	Hh	14.3	21.6	11.5	17.5	10.6	6.13					13.60	4.97
31-Jan	Oo	0.50	0.00	0.00	0.00	0.00	0.25	0.00	0.50	0.31	0.88	0.24	0.29
	Oh	0.13	0.38	0.13	0.25	0.00	0.00	0.00	0.00	0.06	0.19	0.11	0.12
	Ho												
	Hh												
01-Feb	Oo	0.00	0.00	8.19	14.9							5.78	6.25
	Oh	4.94	11.1	7.25	3.75							6.75	2.79
	Ho												
	Hh												
04-Feb	Oo	4.31	30.0	22.4	27.5							21.05	10.0
	Oh	32.0	36.6	55.6	0.00							31.06	20.1
	Ho												
	Hh												
06-Feb	Oo	0.88	1.44	6.19	1.38							2.47	2.16
	Oh	7.25	8.88	6.56	3.69							6.59	1.88
	Ho	2.00	0.63	8.06	8.75							4.86	3.59
	Hh	1.56	7.75	2.50	7.44							4.81	2.80
09-Feb	Oo												
	Oh												
	Ho	0.00	0.00	0.00	0.00	0.00	0.00					0.00	0.00
	Hh	0.00	4.19	4.06	0.00	0.06	0.63					1.49	1.88
21-Feb	Oo												
	Oh												
	Ho	0.00	0.00	0.06	0.00							0.02	0.03
	Hh	0.00	0.00	0.00	0.00							0.00	0.00
11-Mar	Oo												
	Oh												
	Ho	0.00	0.00									0.00	0.00
	Hh	0.00	0.00									0.00	0.00

Table 10. Embryo hatching under hypoxic and normoxic conditions. Cross codes indicate embyos originating from parents held in normoxic (O) or hypoxic (H) water and normoxic (o) or hypoxic (h) incubation conditions.

Date of Spawning:Jan 26			Normoxy Incubation									
Cross Code	T2-2(Oo)			T2-3(Ho)			T2-4(Ho)			T2-5(Ho)		
Date	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)
03-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
07-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
09-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
14-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
17-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
20-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
23-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
27-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
02-Mar	0	1	0.0	0	0	0.0	0	0	0.0	0	0	0.0
06-Mar	0	0	0.0	1	1	1.2	0	0	0.0	0	0	0.0
09-Mar	0	0	0.0	4	0	6.0	0	0	0.0	1	0	2.6
12-Mar	0	0	0.0	12	0	20.2	3	0	6.4	1	0	5.1
13-Mar	1	0	2.4	12	0	34.5	6	0	19.1	1	1	7.7
14-Mar	0	0	2.4	5	0	40.5	7	0	34.0	3	0	15.4
16-Mar	3	2	9.8	17	5	60.7	9	0	53.2	17	4	59.0
17-Mar	3	0	17.1	2	0	63.1	2	0	57.4	2	0	64.1
20-Mar	8	4	36.6	12	3	77.4	14	2	87.2	6	0	79.5
23-Mar	8	1	56.1	6	3	84.5	3	1	93.6	2	1	84.6
27-Mar	5	5	68.3	1	0	85.7	0	0	93.6	0	0	84.6
30-Mar	0	0	68.3	0	0	85.7	0	0	93.6	0	0	84.6
03-Apr	0	0	68.3	0	0	85.7	0	0	93.6	0	0	84.6
06-Apr	0	0	68.3	0	0	85.7	0	0	93.6	0	0	84.6
	28	13		72	12		44	3		33	6	

Cross Code	T2-7(Ho)			T6-1(Ho)			T6-2(Oo)			T6-3(Ho)			T6-4(Ho)		
Date	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)
03-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
07-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
09-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
14-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
17-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
20-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
23-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
27-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
02-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
06-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
09-Mar	3	0	2.7	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
12-Mar	10	0	11.7	3	0	0.8	1	0	4.5	0	0	0.0	0	0	0.0
13-Mar	17	0	27.0	46	0	13.2	1	0	9.1	134	0	35.4	2	0	3.2
14-Mar	4	0	30.6	0	0	13.2	0	0	9.1	0	0	35.4	0	0	3.2
16-Mar	10	0	39.6	63	0	30.2	4	0	27.3	32	0	43.8	20	0	35.5
17-Mar	5	0	44.1	39	1	40.7	0	0	27.3	9	0	46.2	0	0	35.5
20-Mar	15	1	57.7	22	0	46.6	6	0	54.5	40	0	56.7	7	0	46.8
23-Mar	26	4	81.1	10	0	49.3	7	0	86.4	25	0	63.3	7	0	58.1
27-Mar	16	0	95.5	78	1	70.4	3	0	100.0	69	0	81.5	26	0	100.0
30-Mar	0	0	95.5	86	0	93.5	0	0	100.0	61	0	97.6	0	0	100.0
03-Apr	0	0	95.5	22	0	99.5	0	0	100.0	9	0	100.0	0	0	100.0
06-Apr	0	0	95.5	0	0	99.5	0	0	100.0	0	0	100.0	0	0	100.0
	106	5		369	2		22	0		379	0		62	0	

Date of Spawning:Feb 4				Normoxy incubation								
Cross Code	T2-15(Oo)			T2-16(Oo)			T6-13(Oo)			T6-15(Oo)		
Date	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)
03-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
07-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
09-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
14-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
17-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
20-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
23-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
27-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
02-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
06-Mar	2	0	2.7	0	0	0.0	0	0	0.0	0	0	0.0
09-Mar	1	0	4.1	2	0	0.4	0	0	0.0	0	0	0.0
12-Mar	5	0	10.8	24	0	5.3	0	0	0.0	0	0	0.0
13-Mar	9	0	23.0	29	1	11.3	3	0	0.8	71	0	16.1
14-Mar	3	0	27.0	23	0	16.0	0	0	0.8	0	0	16.1
16-Mar	12	0	43.2	64	1	29.2	0	0	0.8	90	0	36.6
17-Mar	1	0	44.6	35	2	36.4	116	0	33.1	21	0	41.4
20-Mar	15	4	64.9	132	1	63.6	73	0	53.3	24	0	46.8
23-Mar	5	1	71.6	84	0	80.9	32	0	62.2	38	0	55.5
27-Mar	16	0	93.2	60	1	93.2	81	2	84.7	53	0	67.5
30-Mar	0	0	93.2	16	0	96.5	33	0	93.9	74	0	84.3
03-Apr	0	0	93.2	11	0	98.8	16	0	98.3	62	0	98.4
06-Apr	0	0	93.2	0	0	98.8	4	0	99.4	7	0	100.0
	69	5		480	6		358	2		440	0	

	Hypoxy incubation								
Cross Code	T3-13(Oh)			T3-15(Oh)			T5-13(Oh)		
Date	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)
03-Feb	0	0	0.0	0	0	0.0	0	0	0.0
07-Feb	0	0	0.0	0	0	0.0	0	0	0.0
09-Feb	0	0	0.0	0	0	0.0	0	0	0.0
14-Feb	0	0	0.0	0	0	0.0	0	0	0.0
17-Feb	0	0	0.0	0	0	0.0	0	0	0.0
20-Feb	0	0	0.0	0	0	0.0	0	0	0.0
23-Feb	0	0	0.0	0	0	0.0	0	0	0.0
27-Feb	0	0	0.0	0	0	0.0	0	0	0.0
02-Mar	0	0	0.0	0	0	0.0	0	0	0.0
06-Mar	0	0	0.0	0	0	0.0	0	0	0.0
09-Mar	7	1	1.3	5	0	0.8	0	0	0.0
12-Mar	101	0	20.8	100	0	17.3	8	0	0.9
13-Mar	4	3	21.5	117	21	36.6	21	0	3.3
14-Mar	0	0	21.5	0	0	36.6	0	0	3.3
16-Mar	108	0	42.3	56	0	45.8	36	0	7.3
17-Mar	31	0	48.3	28	0	50.4	61	0	14.2
20-Mar	56	0	59.0	56	0	59.6	123	0	28.0
23-Mar	32	0	65.2	17	0	62.4	86	0	37.6
27-Mar	56	0	76.0	91	0	77.4	161	0	55.7
30-Mar	20	1	79.8	19	0	80.6	123	0	69.6
03-Apr	52	0	89.8	65	0	91.3	150	0	86.4
06-Apr	45	3	98.5	32	0	96.5	121	0	100.0
	512	8		586	21		890	0	

Date of Spawning: Feb 6			Normoxy incubation												
Cross Code	T2-17(Ho)			T2-18(Ho)			T2-19(Ho)			T2-20(Oo)			T2-21(Oo)		
Date	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)
03-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
07-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
09-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
14-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
17-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
20-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
23-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
27-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
02-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
06-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
09-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
12-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
13-Mar	0	0	0.0	2	0	18.2	0	1	0.0	0	0	0.0	0	0	0.0
14-Mar	0	0	0.0	0	0	18.2	0	0	0.0	0	0	0.0	0	0	0.0
16-Mar	2	3	5.6	0	1	18.2	0	0	0.0	0	0	0.0	2	0	8.0
17-Mar	0	0	5.6	0	0	18.2	0	0	0.0	0	0	0.0	0	0	8.0
20-Mar	6	0	22.2	5	0	63.6	0	0	0.0	3	0	21.4	9	0	44.0
23-Mar	6	0	38.9	2	0	81.8	0	0	0.0	1	0	28.6	0	2	44.0
27-Mar	1	0	41.7	1	0	90.9	0	0	0.0	10	0	100.0	12	0	92.0
30-Mar	3	0	50.0	0	0	90.9	0	0	0.0	0	0	100.0	0	0	92.0
03-Apr	0	0	50.0	0	0	90.9	0	0	0.0	0	0	100.0	0	0	92.0
06-Apr	14	1	88.9	0	0	90.9	0	0	0.0	0	0	100.0	0	0	92.0
	32	4		10	1		0	1		14	0		23	2	

Cross	T6-16(Ho)			T6-17(Ho)			T6-18(Ho)			T6-19(Oo)		
Date	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)	Live Hatch	Dead Hatch	Live Hatch (%)
03-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
07-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
09-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
14-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
17-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
20-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
23-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
27-Feb	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
02-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
06-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
09-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
12-Mar	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
13-Mar	1	0	0.8	0	0	0.0	0	0	0.0	0	0	0.0
14-Mar	0	0	0.8	0	0	0.0	0	0	0.0	0	0	0.0
16-Mar	12	0	10.1	16	0	11.4	22	0	7.3	12	0	12.1
17-Mar	0	0	10.1	0	0	11.4	0	0	7.3	0	0	12.1
20-Mar	17	0	23.3	19	0	25.0	0	0	7.3	4	0	16.2
23-Mar	11	0	31.8	11	0	32.9	13	0	11.6	7	0	23.2
27-Mar	18	0	45.7	25	0	50.7	22	0	18.9	11	0	34.3
30-Mar	33	0	71.3	38	0	77.9	48	0	34.9	19	0	53.5
03-Apr	37	0	100.0	31	0	100.0	95	0	66.4	29	0	82.8
06-Apr	0	0	100.0	0	0	100.0	101	0	100.0	17	0	100.0
	129	0		140	0		301	0		99	0	