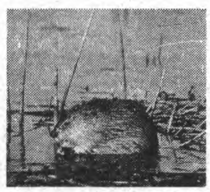
Canada Alberta Northwest Territories

Northern River Basins Study





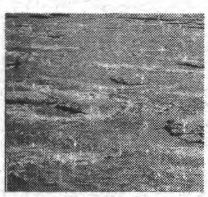



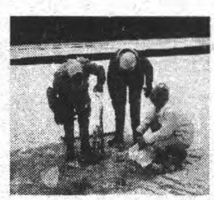


NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 120

DISSOLVED OXYGEN REQUIREMENTS FOR FISH

OF THE PEACE, ATHABASCA AND SLAVE RIVER BASINS: A LABORATORY STUDY OF BULL TROUT (*Salvelinus confluentus*) AND MOUNTAIN WHITEFISH (*Prosopium williamsoni*)







Prepared for the
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by

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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.

NORTHERN RIVER BASINS STUDY
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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,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

(Dr. Fred J. Wrona, Science Director) — 14 May 96 (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",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
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

(Dr. P. A. Larkin, Ph.D., Chair) — 24 May/96 (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, Co-chair) — May 29/96 (Date)

(Robert McLeod, Co-chair) — May 21/96 (Date)

DISSOLVED OXYGEN REQUIREMENTS FOR FISH OF THE PEACE, ATHABASCA AND SLAVE RIVER BASINS: A LABORATORY STUDY OF BULL TROUT (*Salvelinus confluentus*) AND MOUNTAIN WHITEFISH (*Prosopium williamsoni*)

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.

This report chronicles the findings of one of the first laboratory investigations undertaken by the Study into the response of developing eggs to low DO levels and low water temperatures. An attempt to investigate the influence of a contaminant associated with pulp mill effluent (2,4,6,-triclorophenol), during periods of diminished DO, was abandoned due to the unavailability of certified contaminant during start-up of the laboratory studies.

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.*

The first two species to be studied included bull trout (eggs spawned **into** the substrate), and mountain whitefish (eggs broadcast **onto** the substrate). Mountain whitefish and bull trout eggs were monitored for their survival, embryonic development, hatching success and quality of larvae incubated at various DO levels and low water temperatures. Results of the laboratory work indicated that long-term exposure to DO concentrations from 3 to 13.5 mg/l did not cause a significant mortality or increase in deformities of either species. However, the alteration of DO levels did influence embryonic development by delaying the emergence of mountain whitefish by up to 10 weeks and reducing the length of bull trout alevins. Delayed hatching of the mountain whitefish did not affect the size, thermal tolerance (maximum water temperature before a fish loses mobility) or ability to catch food. Similarly, there was no change in the thermal tolerance of bull trout alevins.

Results of the initial laboratory work suggest that significant reductions of DO (~ 3 mg/l) would not cause widespread death to the incubating eggs of mountain whitefish and bull trout but it would likely affect the timing of hatch. Such a delay may affect the viability of emerged alevins to develop sufficiently to overwinter the following winter. Recommendations were made for follow-up fieldwork to corroborate the laboratory findings. Subsequent work is to be done with burbot (late winter spawner, broadcast eggs onto substrate).

REPORT SUMMARY

This report, about "Dissolved Oxygen Requirements of the Eggs of Bull Trout, Salvelinus confluentus, and Mountain Whitefish, Prosopium williamsoni, has been submitted as a partial fulfillment of contractual obligations to the Northern River Basins Study. The main objective of the study was to identify the effects upon survival, embryonic development, hatching success, and quality of larvae of bull trout and mountain whitefish eggs incubated at various levels of hypoxia at low water temperature.

In early October 1993, fertilized bull trout eggs were collected from the Hill Creek Hatchery in British Columbia and whitefish eggs were collected from the upper reaches of the Athabasca River near the confluence of the Snaring River. The eggs were transported to the Freshwater Institute, in Winnipeg, Manitoba, and incubated at nominal dissolved concentrations of 3, 5, 7, 9, and 13.5 mg/l at 2°C. These oxygen concentrations are equivalent to oxygen saturations of 22.3, 37.2, 52.0, 66.9, and 100 percent of air saturation for that locality. The period of incubation under hypoxic conditions extended from November 27, 1993 to May 5, 1994. Each dissolved oxygen treatment was replicated thrice for whitefish and, because of insufficient numbers of eggs, once for bull trout. The oxygen treatments contained 28 incubators: replicate one consisted of 14 bull trout incubators (15 eggs/incubator) and 14 whitefish incubators (50 eggs/incubator); replicates two and three consisted of 26 whitefish incubators (50 to 60 eggs/incubator) and 1 or 2 bull trout incubators (10 to 14 eggs/incubator). Dissolved oxygen and water temperature were monitored daily and egg mortality and hatching were recorded at least three times weekly. At several intervals during embryonic development the oxygen consumption, residual oxygen levels, egg and alevin weights and lengths were recorded from the bull trout. In addition to these records, cardiac rates and measurements of egg and yolk size, and of eye diameter and interorbital distance were obtained for whitefish. Following hatch the thermal tolerance of bull trout and feeding success and thermal tolerance of whitefish from each dissolved oxygen treatment were examined.

Exposure to reduced oxygen did not result in any increase in egg mortality of either species. Survival rates were high in all treatments and mortality during the period of hypoxia (Nov. 27, 1993 to May 5, 1994) was less than 10% in hypoxic and normoxic treatment groups of both species. Exposure to hypoxia reduced oxygen consumption by the embryos of both species with the degree of reduction being directly related to the severity of the hypoxia. Residual oxygen levels (the amount of oxygen remaining when the embryo died from hypoxia) were very low and ranged from 0.2 to 0.7 mg/l (1.5 to 5.5% of saturation) in bull trout eggs and alevins and from 0.4 to 1.0 mg/l (2.8 to 7.5% of saturation) in whitefish. Cardiac rate was reduced by 8 to 22% in whitefish embryos exposed to dissolved oxygen of 3 mg/l but was unaffected at higher oxygen levels. Mortality during hatching was insignificant in both species with hatching success generally exceeding 95% except for one replicate at 3 mg/l where 86% hatched. The timing of hatch in bull trout eggs was not strongly influenced by hypoxia but the level of development as illustrated by the amount of yolk remaining and smaller body size in the hatched alevins was reduced in embryos incubated at $<$ 7 mg/l of dissolved oxygen. In whitefish, however, hatching was delayed in embryos incubated at reduced oxygen levels such that the time from fertilization to 50% hatch was 151, 174, 185, 204, and 221 days in eggs from the 13.5, 9, 7, 5, and 3 mg/l treatments, respectively. Whitefish larvae from all treatments were of similar size

ACKNOWLEDGEMENTS

The senior author would like to thank the many poeple who assisted with this project. Carl Hunt, Don Hildebrandt and especially Rudy Hawryluk from Alberta Natural Resources in Edson, Alberta, provided considerable advice and assistance in attempts to collect eggs from Rock Lake. Grant Thorp and Diane Koller from the Hill Creek Hatchery, RR# 2, Nakusp, British Columbia, kindly supplied the fertilized bull trout eggs used in this study even though their own requirements for eggs had not been met. The assistance of Jim O'Neil and the crew from RL&L Consultants, Edmonton, Alberta was essential in capturing the spawning mountain whitefish by electrofishing in the Athabasca River and bringing them alive to the spawning site. I greatly appreciate their help. Last of all, I would like to express my appreciation to Mary Giles, my wife, who helped in spawning the whitefish, transporting the eggs overnight to distant airports, and providing support during this work.

1.0 INTRODUCTION

Dissolved oxygen (DO) levels in surface waters are known to influence the survival and distribution of aquatic biota including fish. DO does vary substantially in natural systems. For example, the hypolimnion in many lakes becomes hypoxic after the thermocline is established and shallow eutrophic or hypertrophic lakes sometimes exhibit depressed oxygen levels as the result of the decay of aquatic vegetation and algae. In streams during the winter the input of hypoxic groundwater relative to the aerated surface water may increase and cause localized reductions in dissolved oxygen, especially in the streambed gravel. The ice on some Arctic lakes may fail to thaw in certain years and hypoxia can develop because of the inhibition of re-aeration during the spring turnover. Normally, however, the fish and other aquatic organisms inhabiting such environments have developed physiological, biochemical, or behavioural mechanisms which permit the popuulations to survive such events.

Reductions in DO which result from human activities may have more severe impacts upon aquatic biota because of both the magnitude and timing of the stress. In addition, different species within the aquatic community exhibit enormous differences in sensitivity to reduced oxygen. For these reasons the concept of a single, fixed dissolved oxygen criterion to protect a particular aquatic species or community generally has been discarded. As noted by Barton and Taylor (1994), the current practice is to attempt to establish "criteria with varying DO limits according to family or temperature preference, life stage and degree of risk to the population (EPA, 1986; CCREM, 1987)." The identification of responses to hypoxia under conditions which reflect realistic conditions in the environment is inherent in this process. In the NRB Study Area, for example, significant reduction in DO occurs following freeze-up in areas of rivers receiving effluents with a substantial oxygen demand (Noton and Allan, 1994). The impact of the oxygen demand may continue for many miles downstream of the source because re-aeration is inhibited by the ice cover. Only criteria for DO determined at very low water temperatures are appropriate to these circumstance. Unfortunately, most tests of hypoxia on fish and fish eggs have been determined at much higher temperatures and in a comparatively small number of species. Both metabolic and developmental rates of eggs of fish are exponential functions of water temperature (Blaxter, 1988; Rombough, 1988), so comparatively small reductions in water temperature can result in substantial reductions in these processes. Because temperature strongly influences the demand for oxygen, it is unlikely that the effects of hypoxia observed at high water temperatures can be applied directly to conditions approaching those in rivers in the NRB Study Area during the winter.

Barton and Taylor (1994) have identified the deficiencies in dissolved oxygen criteria for a number of fish species and life stages of importance to the NRB Study. Two of these species, bull trout, Salvelinus confluentus, and mountain whitefish, Prosopium williamsoni, spawn in late autumn just prior to freeze-up. The developing eggs and larvae would be subjected to the full extent of hypoxia during the winter. This investigation was undertaken to identify the effects of reduced oxygen at low water temperature upon the survival and development of these two species during the period of embryonic development.

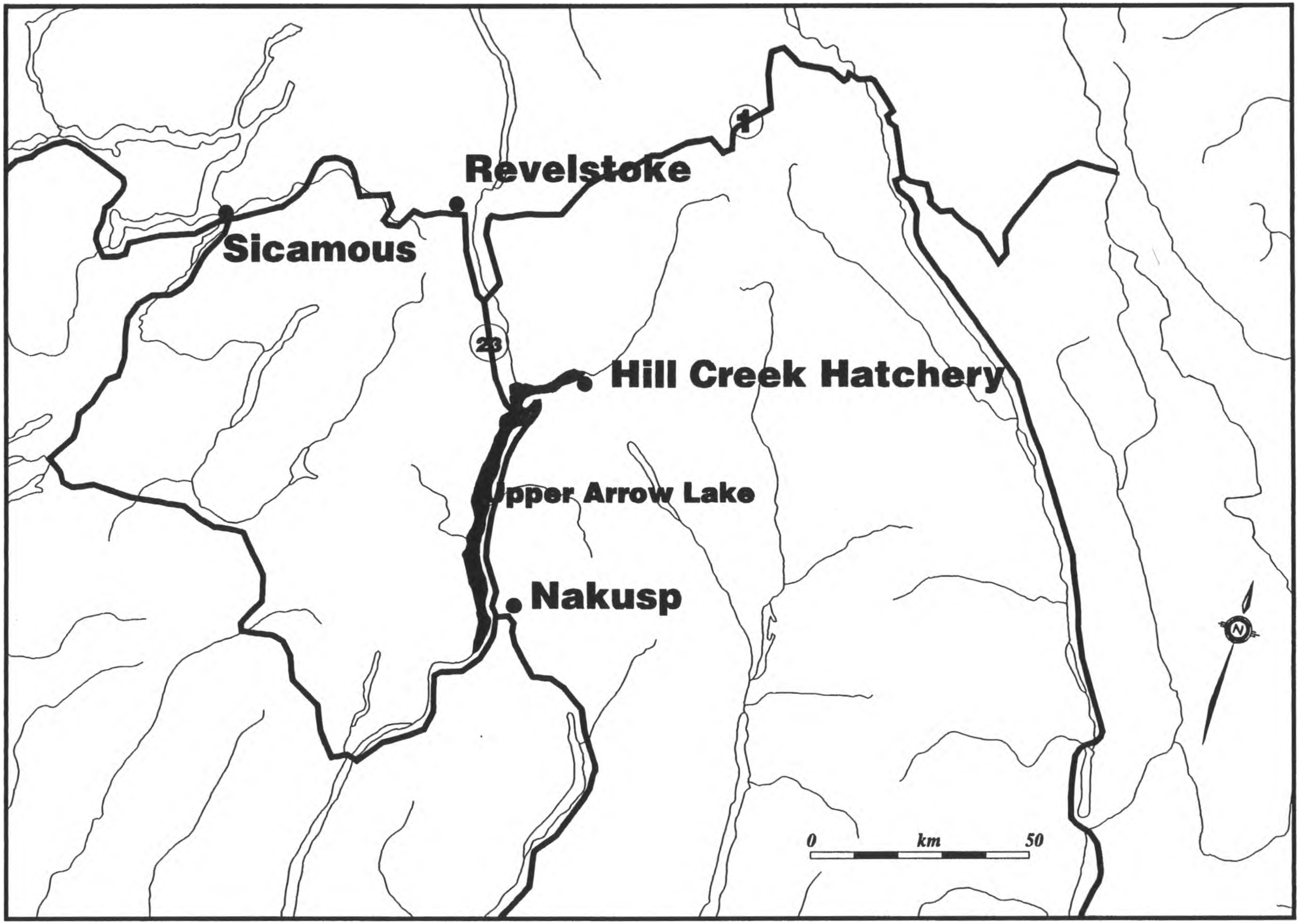

Figure 1. **Collection Site for Bull Trout Eggs at the Hill Creek Hatchery, British Columbia.**

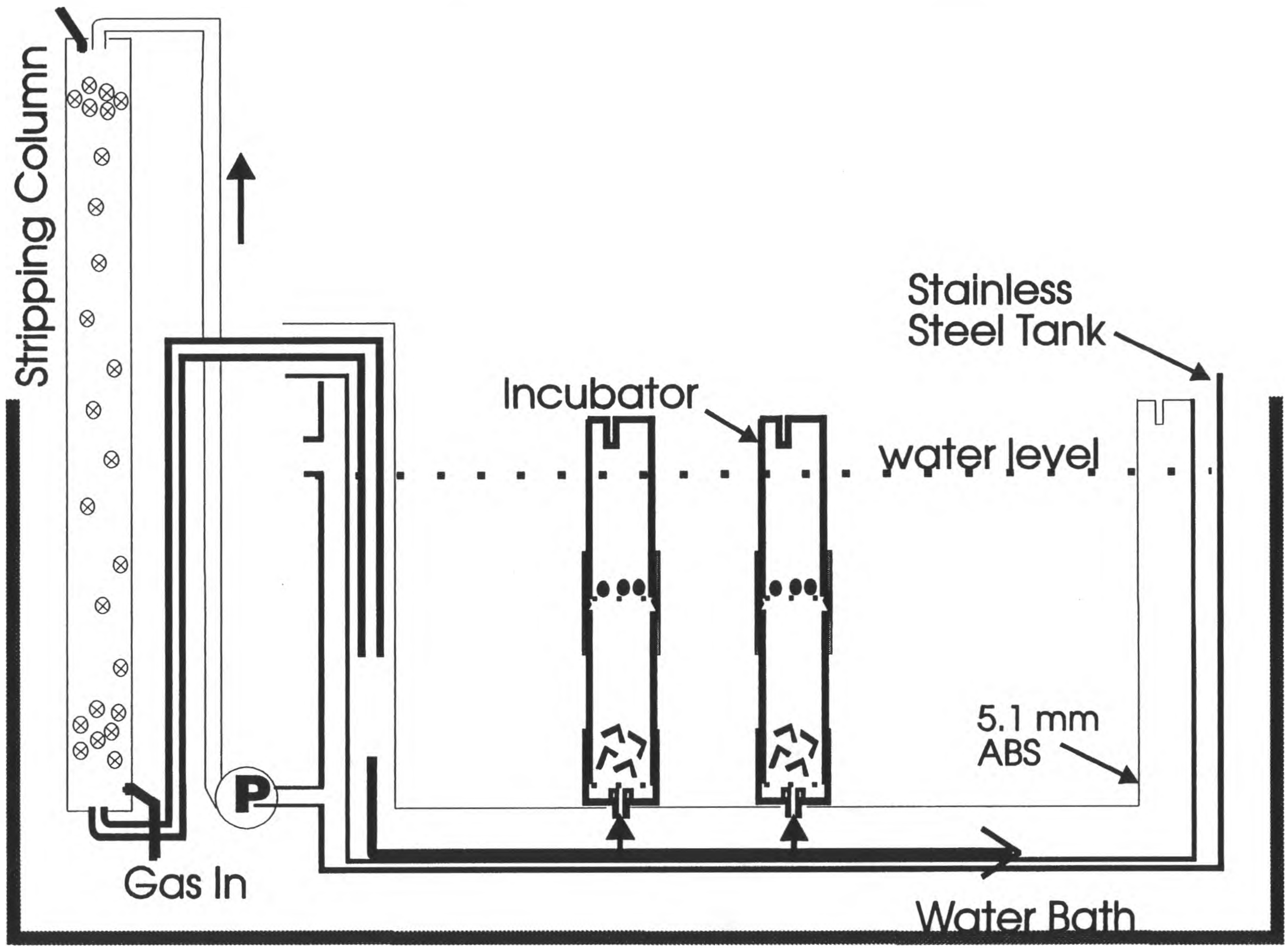

Figure 3. **Side View of an Incubation Unit. Each unit held 28 incubators. P indicates a 15 watt submersible pump.**

Water temperature was controlled at 2°C from November 7, 1993 to May 11, 1994 when it was raised by approximately 0.6°C/day to 10.5°C on May 24, 1994. Winnipeg municipal water was used in the study. The raw, declorinated water was treated at the Freshwater Institute through a system which incorporated physical filtration, activated carbon filtration, ozonation, temperature and dissolved oxygen equilibration, and a final treatment with ultraviolet irradiation (Wagemann et al., 1987). The chemical characteristics of the treated water have been described in detail (Wagemann et al., 1987) and fall within the values required in the terms of reference. Free chlorine concentrations were monitored continuously (model 1570 Chlorine Monitor; IC Controls Ltd., Orangeville, Ontario). Total NH_4-nitrogen was measured colorimetrically (Stainton et al., 1977) and un-ionized ammonia concentrations calculated by extrapolation of the data of Trussell (1972) for appropriate water temperature and pH. Free chlorine levels were below detection limits ($< 3\ \mu g/l$) and ammonia levels were 1.5 $\pm$2.5 μg/l (mean $\pm$ 1 standard deviation).

2.2.2 Incubation Protocol

Only five incubation units, designated as T1, T2, T3, T4, and T5, were operational when the fertilized eggs arrived at the laboratory. At this time 50 whitefish eggs were placed in 14 incubators and 15 bull trout eggs were placed in the remaining 14 incubators of each unit. The remaining eggs were placed in a Heath Incubator which was supplied with water from the water bath system. All eggs were held at 3 to 3.5°C prior to November 7, after which the water temperature was maintained at 2.1 to 2.3 $\pm$0.2°C for the remaining period of embryonic development. Prophylactic treatment for fungus was not initiated until November 16, when fungal growth was observed on the whitefish eggs in the Heath Incubator. No fungal development was observed in the bull trout eggs. At this time the whitefish eggs were removed from the Heath trays, and soaked in a 0.15 percent aqueous formaldehyde solution at 2°C for 15 minutes, rinsed in fresh, chilled water and separated from the fungal web. These eggs were then incubated in a 6 l hatchery jar until November 23. During this period dead eggs were removed by aspiration. On November 23 these eggs and the remaining bull trout eggs were distributed among the last ten incubation units (designated T6 to T15). Approximately 60 whitefish eggs, estimated by volume, were placed in each incubator. A second formaldehyde treatment was applied to T6 -T15 on December 6, 1993 and T6, T7, and T8 were treated for a third time on February 6, 1994. Eggs in T1 to T5 were treated on November 20 and December 5, 1993. Dead eggs were removed and enumerated at least three times weekly throughout the incubation period. Samples of eggs for various analyses were removed from a single incubator in each tank until it was empty when the next adjacent incubator would be used to supply the samples. Water temperature was measured once daily with National Bureau of Standards certified thermometer and recorded at 2.6 h intervals with a HOBO-TEMP data-logger (Onset Computer Corp.). Dissolved oxygen was measured at least once daily in each tank using a Radiometer PHM72 Mk2 acid-base analyzer fitted with an oxygen electrode (Radiometer, type E5046) housed in a thermostatted cell maintained at the same temperature as the incubators. The meters were calibrated with pure nitrogen and air with appropriate corrections for water vapor pressure and atmospheric pressure. Oxygen concentration was calculated from oxygen partial pressure as:

N = original number of eggs in the incubator;
ΣE_d = cumulative number of dead eggs to date;
ΣS = cumulative number of eggs removed for samples;

Larvae or alevins which died during the process of hatching were recorded as dead eggs, not as dead larvae. These individuals were still partially enclosed in the egg shell when they died. Mortality of mountain whitefish larvae was recorded only during the period when the larvae were maintained in the holding baskets in the incubation units. Larvae which died during acclimation to 10°C and the initiation of feeding were not recorded. Physical deformities, such as twisted spines, abnormal yolk sacs or truncated tails, of larvae and alevins were recorded when the fish were moved from the incubators to the holding baskets.

To determine the effects of changes in dissolved oxygen during the late stages of embryonic development upon the timing of hatch and hatching mortality, groups of whitefish eggs were exchanged between the 3 mg/l treatment and the higher oxygen treatments on March 28, 1994. Five whitefish incubators from the tanks receiving 3 mg/l of dissolved oxygen (tanks 5, 6, and 7) were switched with incubators from tanks 1, 2, 3, 4, 9, 11, 13, and 15 which received nominal dissolved oxygen of 13.5, 9, 5, 7, 9, 7, 5, and 13.5 mg/l, respectively.

Approximately 7 to 10 d after hatching the mountain whitefish larvae were transferred to holding baskets in aerated tanks containing water at 2°C. The temperature in the tank was increased to 10°C at the rate of 0.75 to 1°C per day. The larvae were then fed a suspension of <u>Artemia</u> nauplii augmented with powdered Fry Feed Kyowa (size C1700; Biokyowa Inc., Cape Gerardeau, Missouri, USA) fish feed over a 6 h period each day. These larvae were employed in tests of critical thermal maxima and feeding efficiency.

2.4 WEIGHT and LENGTH MEASUREMENTS

Samples of eggs were removed by aspiration from each dissolved oxygen treatment and gently blotted on absorbent tissue to remove excess moisture. The samples were weighed individually to the nearest 0.1 mg on tared aluminum pans with a Mettler AE160 microbalance and then dried for 24 h at 80°C in an oven (Blue M; model OV-124). The dried tissue was cooled to room temperature in a desiccator and the dry weight measured. For whitefish larvae and bull trout alevins the wet weights were not recorded since the yolks tended to rupture when the excess moisture was removed. Dry weights of these samples were determined as above except the weights were measured to the nearest 0.01 mg with a Perkin-Elmer Autobalance (model AD-6). Subsets of dried bull trout alevins were dissected to separate the yolk from the remaining tissues and the weights of the yolk and body measured individually. Length measurements of mountain whitefish larvae were taken from fish preserved in 4 percent buffered formalin. The larvae were first anesthetized in 2-phenoxyethanol (0.25 ml/l) to prevent curling when preserved. The total length of preserved larvae was measured with calipers at 10x magnification under a dissecting microscope. Anesthetized bull trout alevins were photographed and total length measured with calipers from the photographic prints.

oxygen level. The eggs were placed in Petri dishes fitted with a well containing their respective treatment water and surrounded with crushed ice which maintained water temperature within 0.2°C of the incubation temperature. The time required for two sets of 30 beats and one set of sixty beats was recorded for each embryo using a 20x binocular dissecting microscope with fiber optics illumination. Cardiac rates (beats/min) were estimated from the average of the three readings. Bull trout cardiac rates were not determined because the yolk was too opaque to permit observation of the heart.

2.7 CRITICAL THERMAL MAXIMA

Groups of 10 bull trout or mountain whitefish fry which had been acclimated to water temperatures of 10 to 11°C for at least 10 d were used in the critical thermal maxima (CTM) tests. The fish were placed in four 3.3 l test chambers in a 75 l tank which recycled water from a heating manifold at the rate of 8 l/min/chamber and allowed to acclimate to the chamber at 10 to 11°C for 60 min prior to testing. After acclimation the water temperature was raised at a rate of 0.32°C/min (Becker and Genoway, 1979). The water in the tank was aerated vigorously to eliminate the potential for gas supersaturation as the water temperature was raised. The temperature at which the fish lost equilibrium was estimated by recording the exact time of equilibrium loss and relating this time to the time:temperature relationship measured at 60 second intervals over the test period. The mean $\pm$ 1 standard deviation of these temperatures was used to estimate the critical thermal maximum for each test group.

2.8 LARVAL FEEDING TRIALS

Feeding success of mountain whitefish fry was tested by determining the number of Artemia nauplii the fish could capture in a set period of time. The fry were placed in 4 l glass tanks enclosed in a water bath at 10°C. The tank was supplied with vigorous aeration to maintain a high level of water circulation. After 60 min of acclimation Artemia nauplii which had been hatched 6 to 12 hours previously were added to the tank and the fry were allowed to feed for 20 min. After feeding the fry were anesthetized without disturbance in the tank with a lethal dose of 2-phenoxyethanol, removed from the tank, and preserved in buffered formalin. The preserved fish were measured for total length and their digestive system dissected. The number of Artemia nauplii and unhatched eggs was counted under a dissecting microscope. Because of the severe lack of synchrony of hatching in whitefish from different dissolved oxygen regimes, it was not possible to test all treatment groups at the same time and stage of development. Tests conducted on March 29, 1994 employed fry originating from incubation tanks 1 to 4 and which had been acclimated to 10°C on March 22, 1994 and fed until March 27. These fish were not fed on March 28. The test performed on April 11 used fry from incubation tanks 5 to 13 which had started acclimation to 10°C on May 4 and completed acclimation on May 10. These fish had not been exposed to any food prior to the feeding tests. Feeding trials for bull trout were unsuccessful. The alevins were easily frightened and tended to aggregate in tight groups in darker areas. Since yolk absorption was still incomplete when the study was terminated it

3.0 RESULTS

3.1 INCUBATION CONDITIONS

3.1.1 Dissolved Oxygen and Water Temperature During Incubation

Regulation of dissolved oxygen in the incubators was initiated on November 23, 1993 and completed by November 29. Regulation was maintained until May 5, 1994 when the oxygen levels in all tanks were allowed to rise to saturation. The variation in dissolved oxygen over the entire period was greater than expected and tended to increase inversely with the level of deoxygenation (Figure 5). At a nominal dissolved oxygen concentration (DO) of 3 mg/l the coefficient of variation (standard deviation/mean) was 14 to 23 percent. The variations observed, however, represented the maximum levels possible since daily adjustments to the equilibration columns were not integrated into the calculation of the standard deviation. The daily oscillations in DO for each tank are presented in Figures 6, 7, and 8. Daily mean, minimum, and maximum water temperature in tanks 1 to 7 and tanks 8 to 15 are shown in Figures 9 and 10, respectively. Variation in dissolved oxygen among individual incubators within an incubation unit were negligible.

Upon arrival at the Freshwater Institute the eggs of both species were incubated at 2 to 3°C (Figure 9). From November 17, 1993 to May 11, 1994, water temperature was regulated at 2.1 ± 0.2°C and 2.3 ±0.2°C in tanks 1 to 7 and 8 to 15, respectively, (Figures 9 and 10). From May 11 to 24 the water temperature was gradually raised to 10°C. An overnight pump failure in water bath A on March 14 resulted in a rise in temperature to 7.2°C in tanks 1 to 7 before the pump was replaced. Water temperature control was restored within three hours but the increase resulted in accelerated hatching of bull trout and mountain whitefish eggs over the next several days.

3.2 EFFECT OF DISSOLVED OXYGEN UPON EGG MORTALITY AND HATCHING

3.2.1 Bull Trout

Because of a poor spawning success only 1200 bull trout eggs were collected from the Hill Creek Hatchery. Fifteen eggs were placed in each of 14 incubators in tanks 1 to 5 while the remaining eggs were distributed among the remaining tanks after initially being incubated in the Heath incubator. The eggs in tank 8 ([DO] = 9 mg/l) were not included in the analysis because of a probable contamination of the water in the tank with zinc from an overhead fitting. The patterns of egg mortality and hatching and the initial numbers of eggs in each treatment and tank are presented in Figures 11 to 15. Approximately 10 to 20 percent of the eggs in tanks 1 to 5 had died by December 2. This mortality was not related to oxygen treatment and probably represents non-fertile or injured eggs. A similar

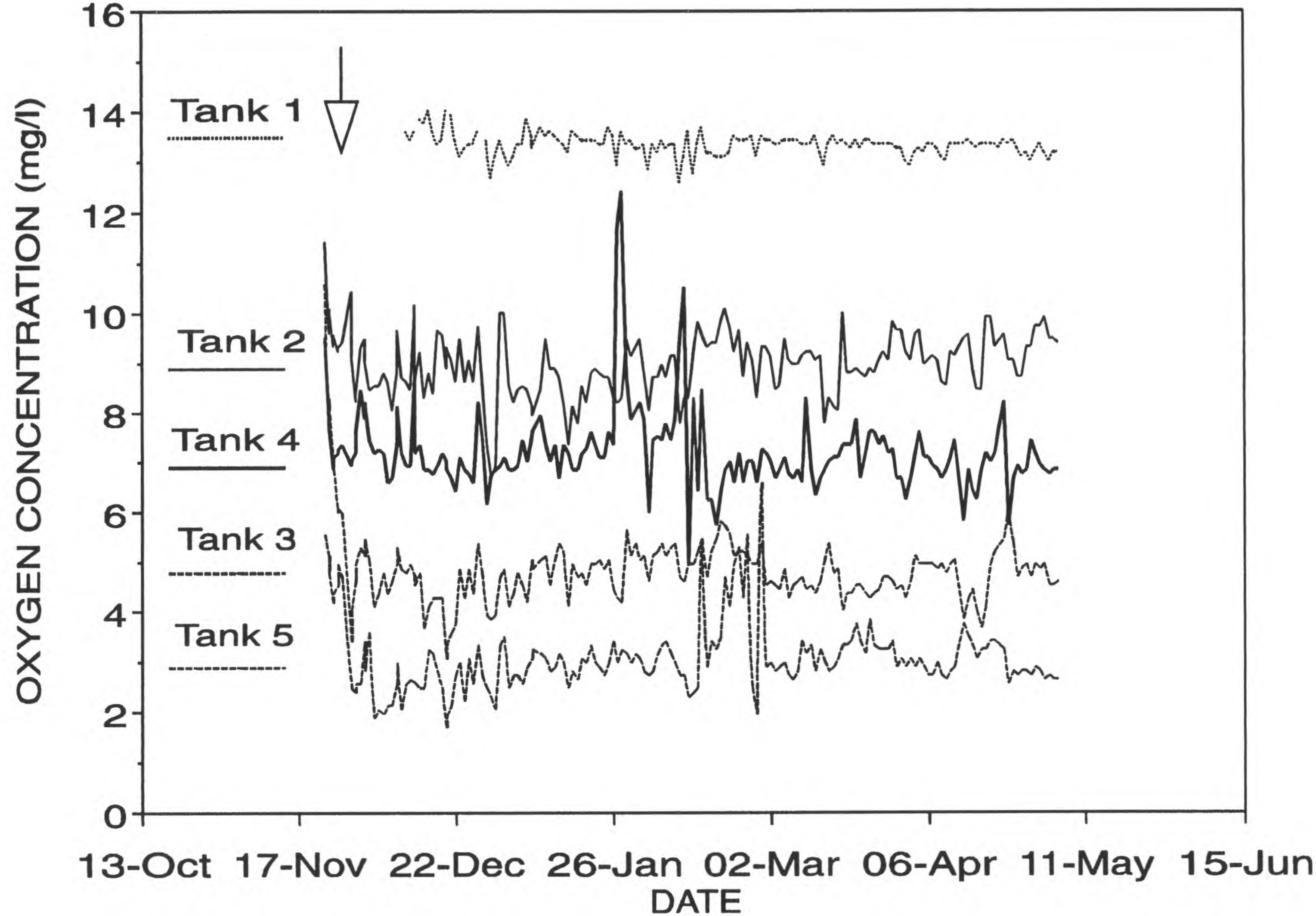

Figure 6. **Daily Dissolved Oxygen Concentrations in Incubation Units 1 to 5. The arrow indicates the initiation of dissolved oxygen regulation.**

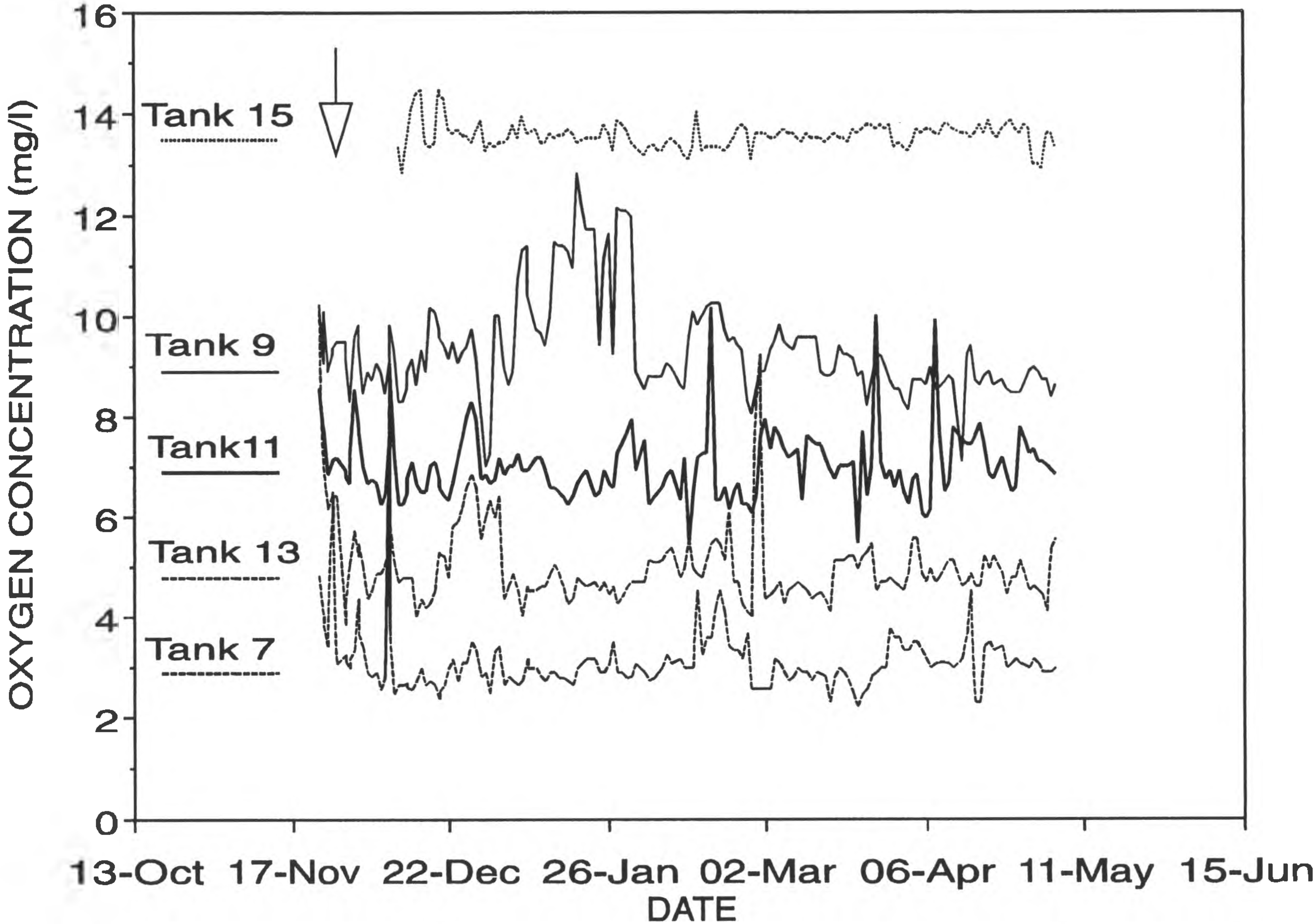

Figure 8. **Daily Dissolved Oxygen Concentrations in Incubation Units 7, 9, 11, 13, and 15. The arrow indicates the initiation of dissolved oxygen regulation.**

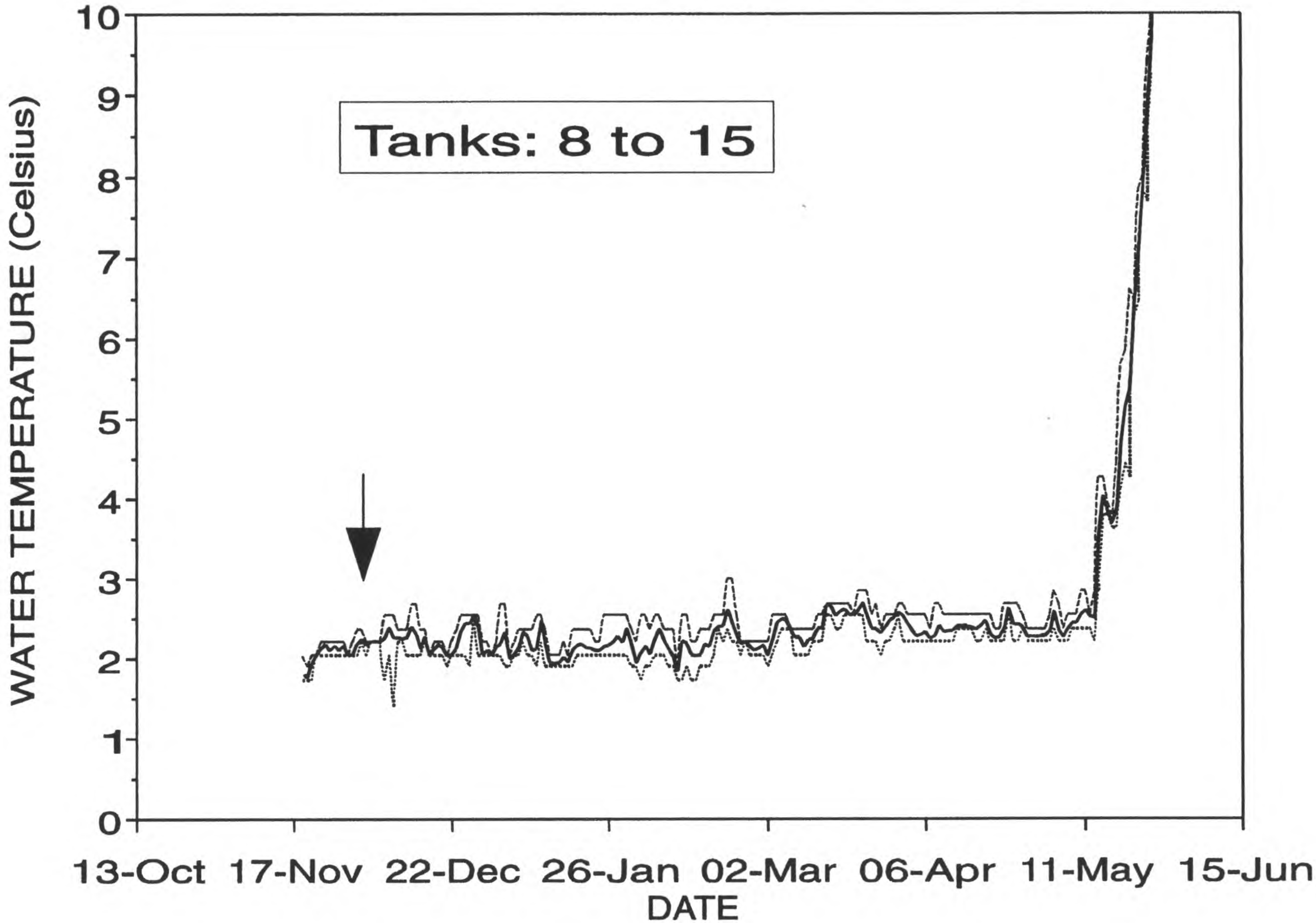

Figure 10. **Daily Water Temperatures for Incubation Units 8 to 15 Showing Mean (solid), Minimum (dotted), and Maximum (dashed) Temperatures. The date on which the nominal dissolved oxygen levels were attained (solid arrow) are shown.**

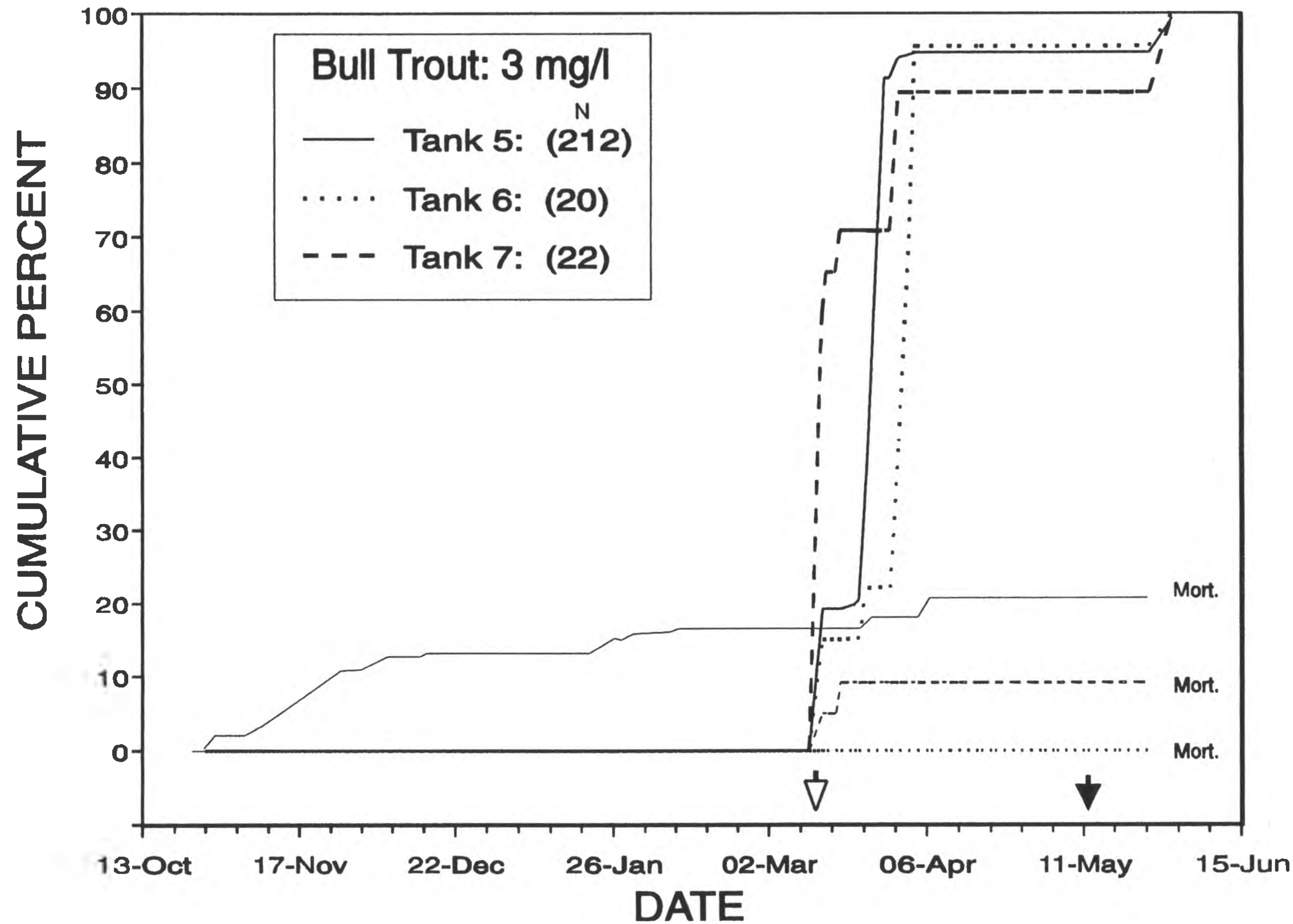

Figure 11. **Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 3 mg/l. The tank numbers and total number of live alevins (N) are shown for each replicate. Water temperature rose to 7.2°C for a short period on March 14 (open arrow) and was purposely raised by 0.6°C/day beginning May 11 (solid arrow).**

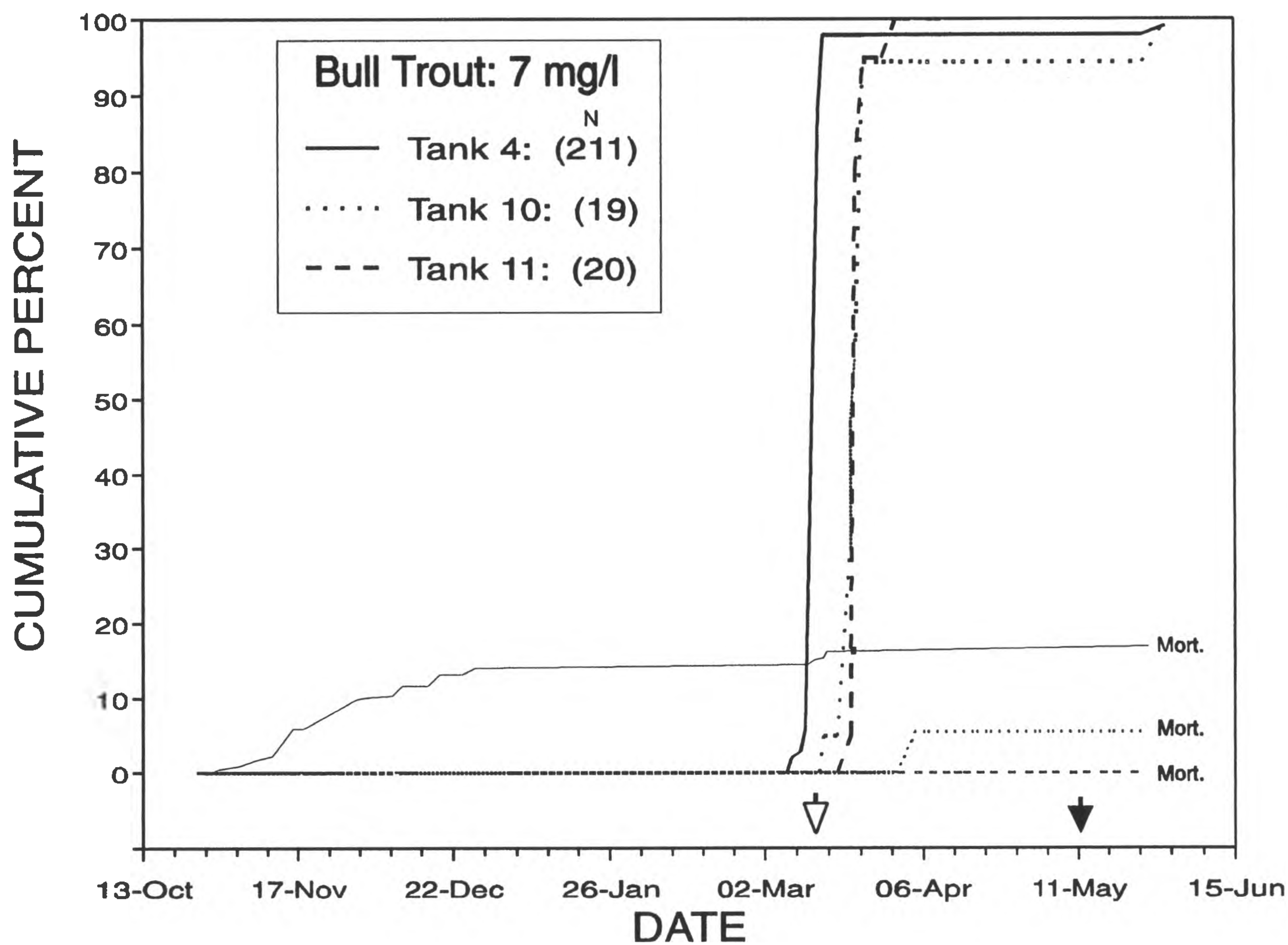

Figure 13. Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 7 mg/l. The tank numbers and total number of live alevins (N) are shown for each replicate. Water temperature rose to 7.2°C in tank 4 for a short period on March 14 (open arrow) and was raised purposely by 0.6°C/day in all tanks beginning May 11 (solid arrow).

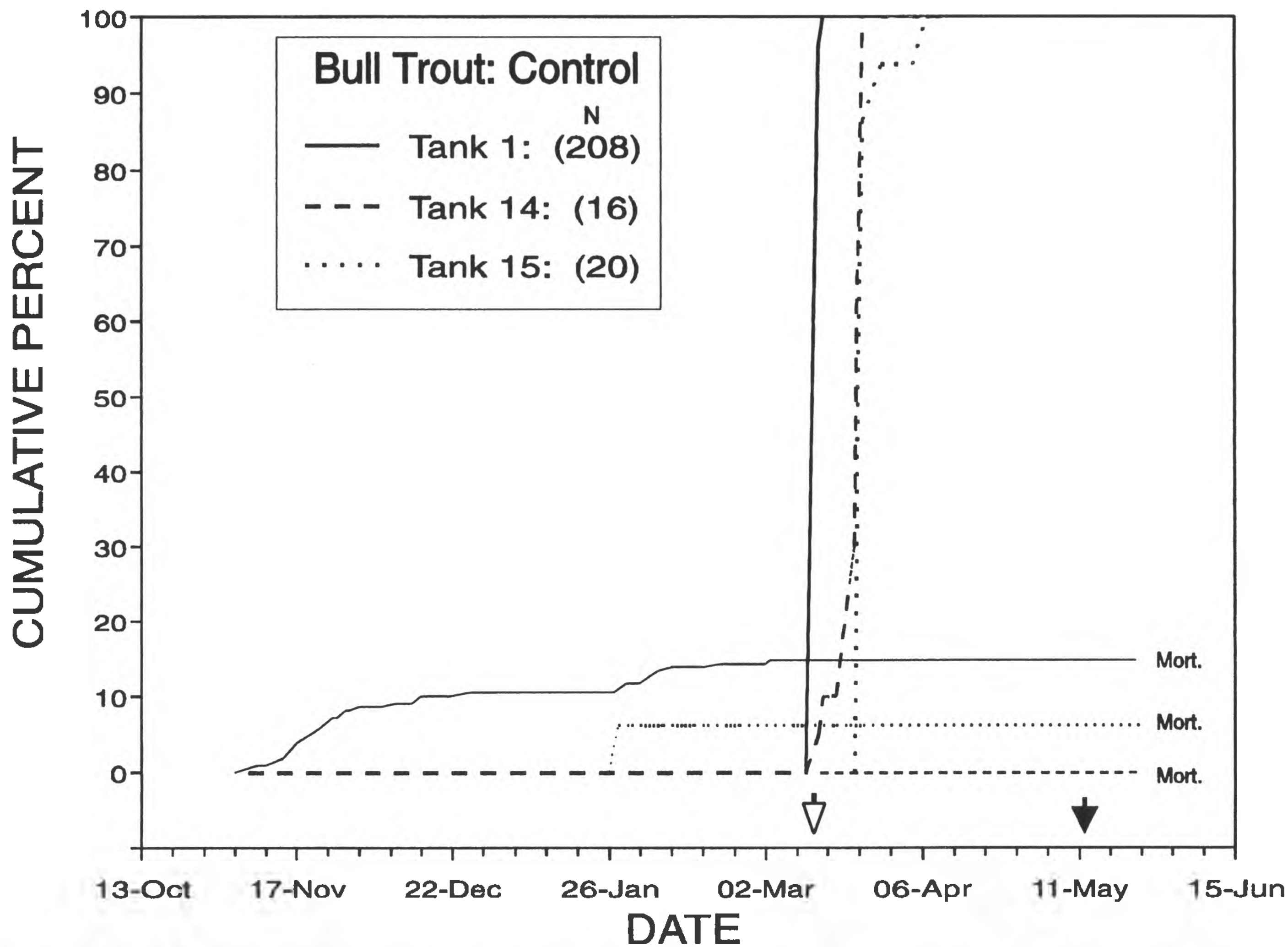

Figure 15. **Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 13.5 mg/l. The tank numbers and total number of live alevins (N) are shown for each replicate. Water temperature rose to 7.2°C in tank 1 for a short period on March 14 (open arrow) and was raised purposely by 0.6°C/day in all tanks beginning May 11 (solid arrow).**

for the eggs reared at [DO] of 3 mg/l in tank 5 was 85%. Whitefish eggs in tank 8 hatched prematurely, possibly as a result of the contamination noted previously, and were excluded from any further analysis. The effect of hypoxia during embryonic development of mountain whitefish eggs is clearly shown in Figure 22. With the exception of the eggs at [DO] of 3 mg/l the results in Figure 22 are for eggs which did not experience the temperature rise. The dates at which 50% of the eggs had hatched were March 19, April 2, April 13, May 2, and May 19 for nominal [DO] treatments of 13.5, 9, 7, 5, and 3 mg/l, respectively. This represents delays in hatching of 15, 28, 47, and 64 days relative to control fish for whitefish incubated at dissolved oxygen concentrations of 9, 7, 5, and 3 mg/l , respectively. It should be noted, however, that the dissolved oxygen levels were returned to saturation on May 5 so that eggs at 3 mg/l had two weeks of development at normoxic conditions. On March 28 sets of 10 incubators of whitefish eggs which had been reared at [DO] of 3 mg/l were transferred to tanks containing 5, 7, 9, and 13.5 mg/l of dissolved oxygen. In addition eggs from 5 and 7 mg/l were transferred to incubation tanks at [DO] of 3 mg/l. Egg mortality was unaffected by any of the transfers. Hatching was accelerated by approximately 2 days in eggs transferred to 7 mg/l and 4 days in eggs transferred to 9 or 13.5 mg/l but was unaffected by transfer to 5 mg/l (Table 17, Appendix B).

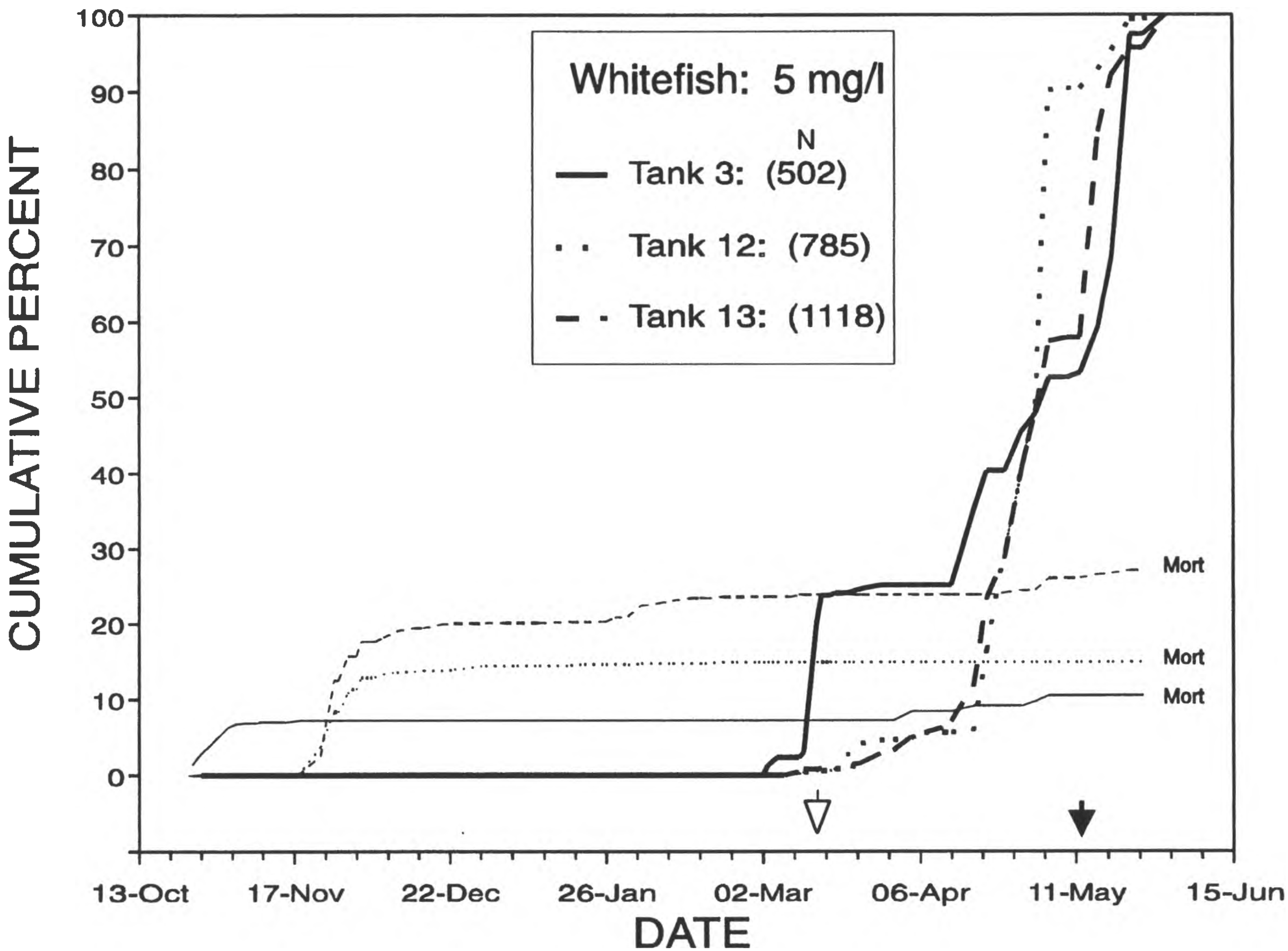

Figure 18. **Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 5 mg/l. The tank numbers and total number of live larvae (N) are shown for each replicate. Water temperature rose to 7.2°C in tank 3 for a short period on March 14 (open arrow) and was raised purposely by 0.6°C/day in all tanks beginning May 11 (solid arrow).**

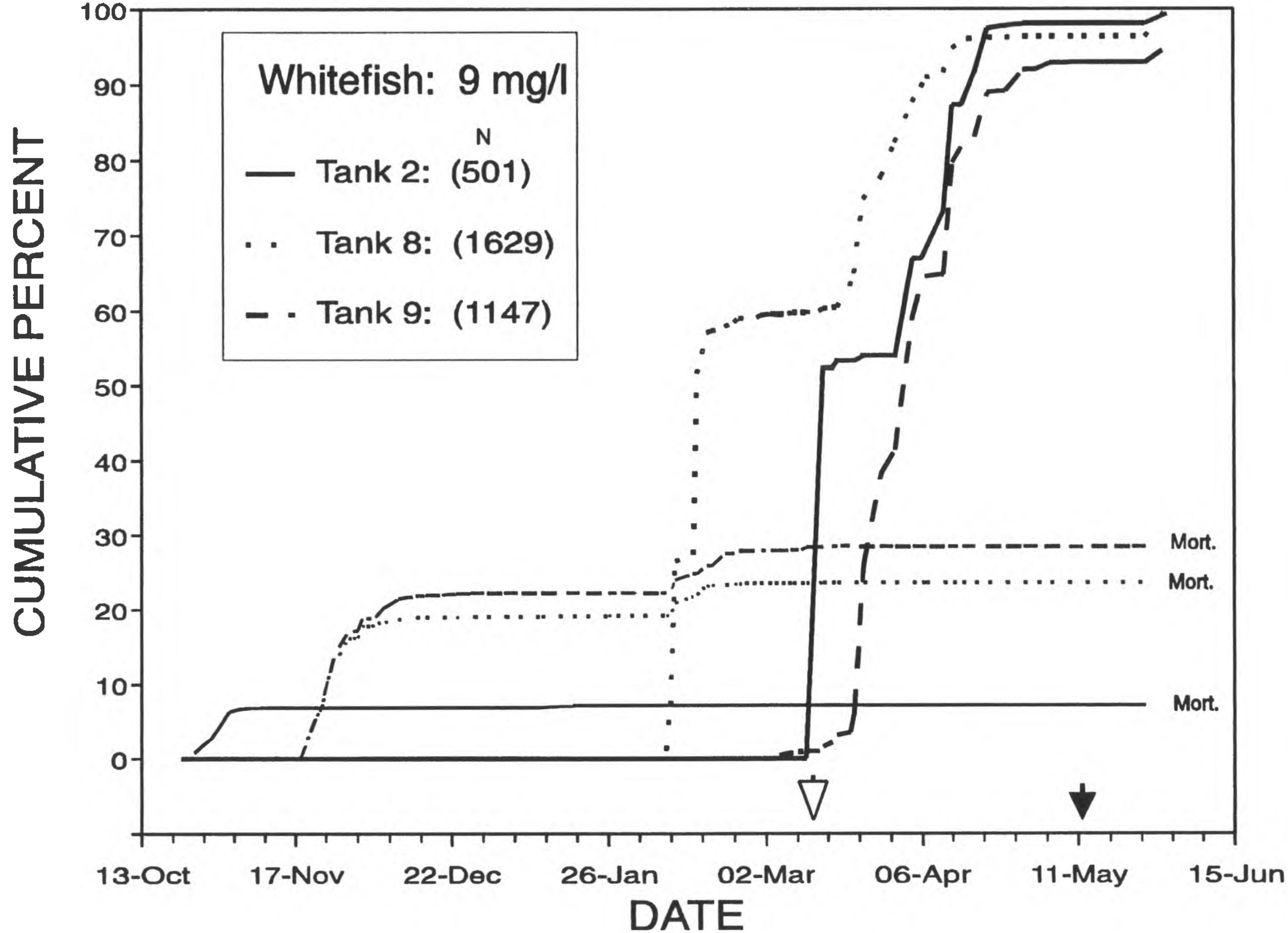

Figure 20. **Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 9 mg/l. The tank numbers and total number of live larvae (N) are shown for each replicate. Water temperature rose to 7.2°C in tank 2 for a short period on March 14 (open arrow) and was raised purposely by 0.6°C/day in all tanks beginning May 11 (solid arrow).**

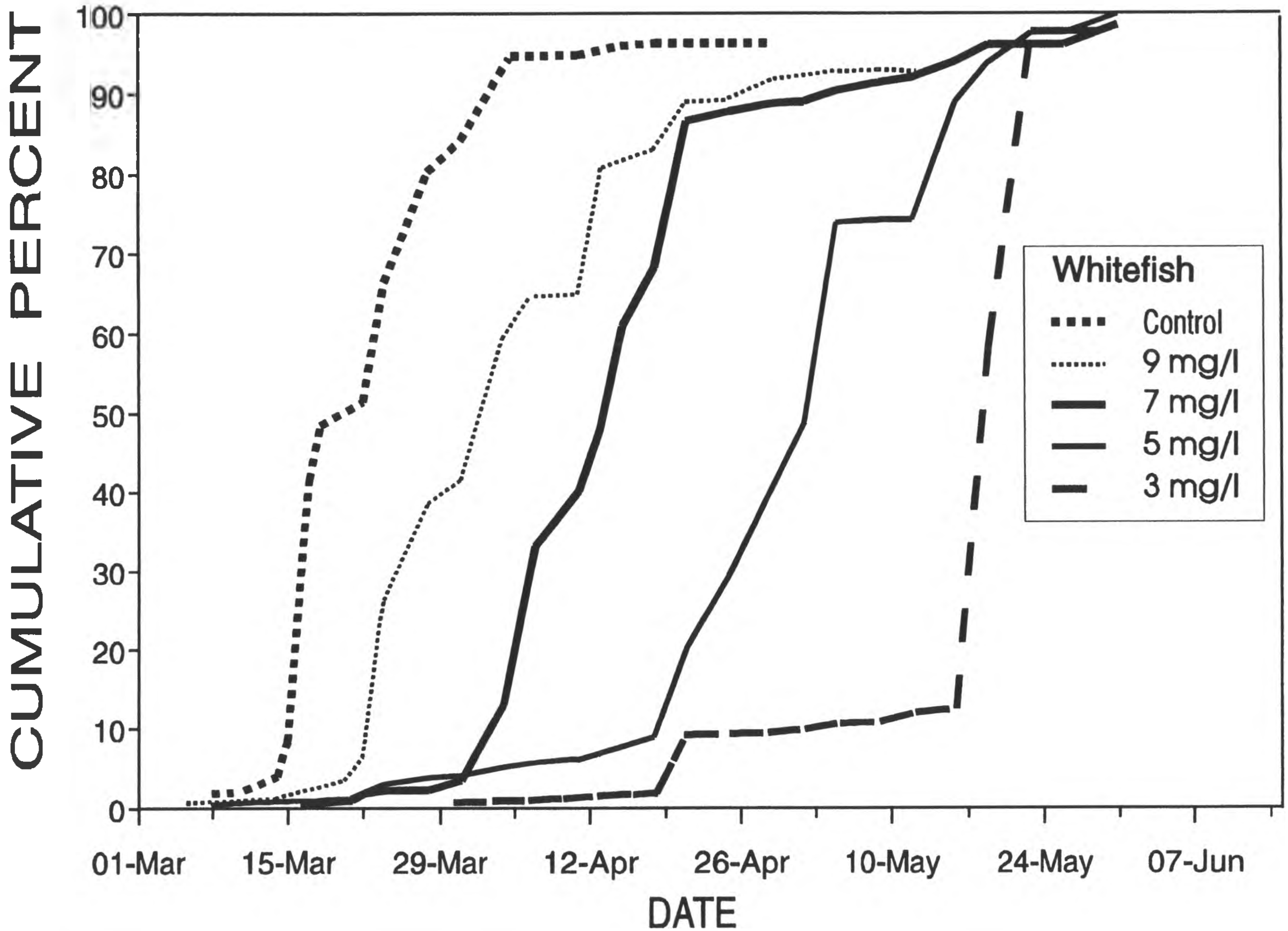

Figure 22. **Comparison of Hatching Patterns of Mountain Whitefish Eggs Incubated at Different Concentrations of Dissolved Oxygen.**

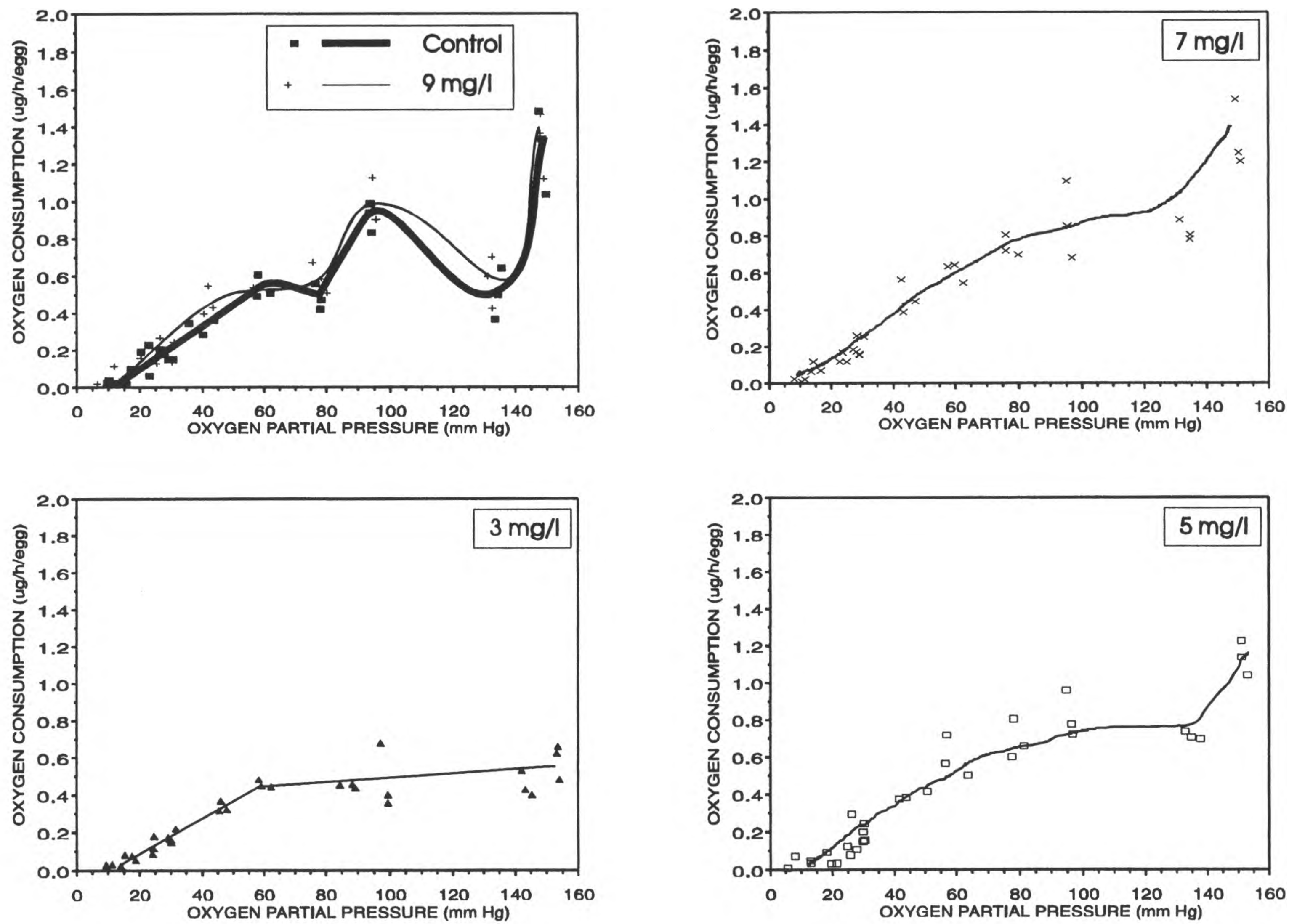

Figure 23. **Oxygen Consumption of Bull Trout Eggs (January 25). The lines are fitted by eye.**

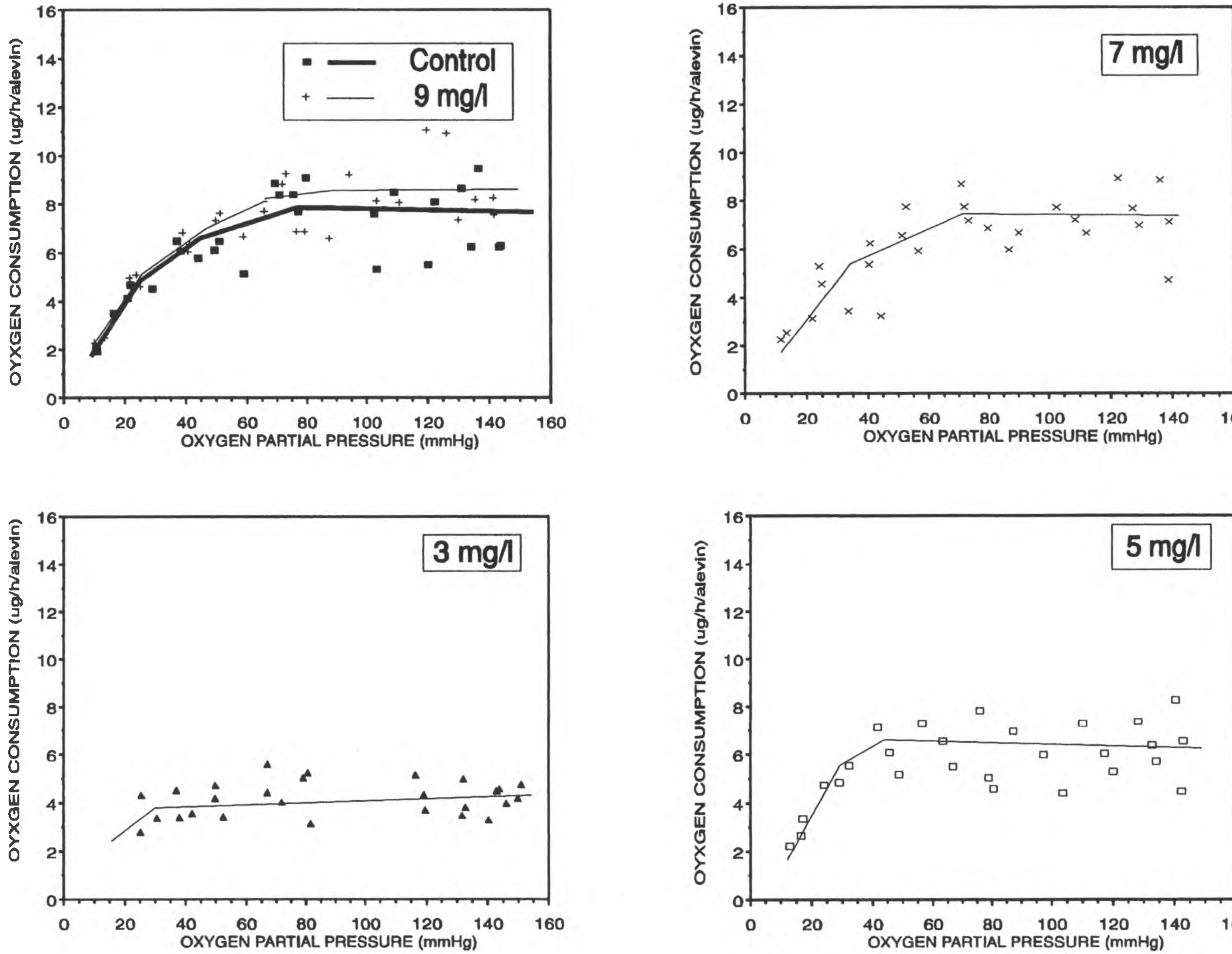

Figure 25. **Oxygen Consumption of Bull Trout Alevins (April 22). The lines are fitted by eye.**

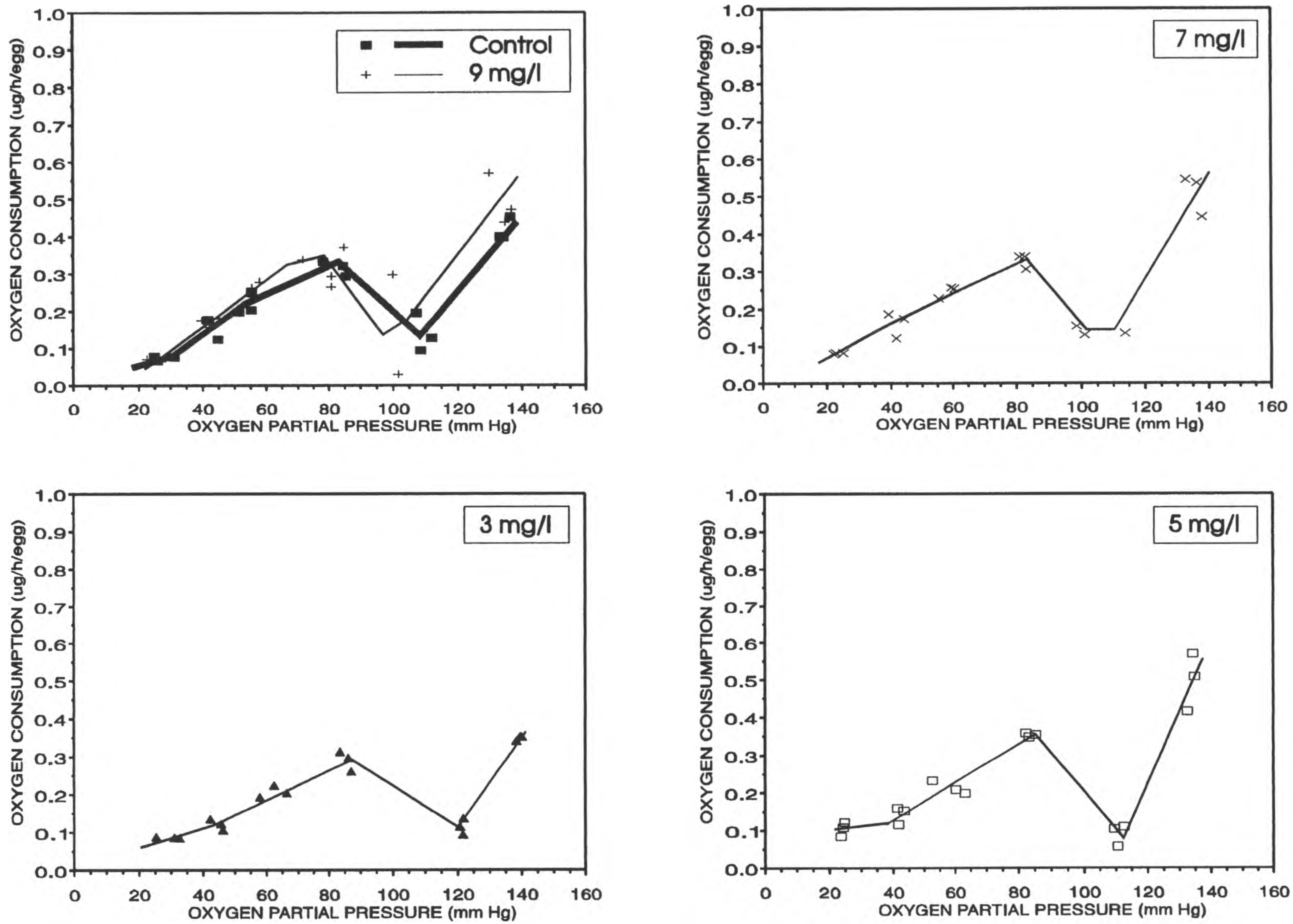

Figure 27. Oxygen Consumption of Mountain Whitefish Eggs (January 20). The lines are fitted by eye.

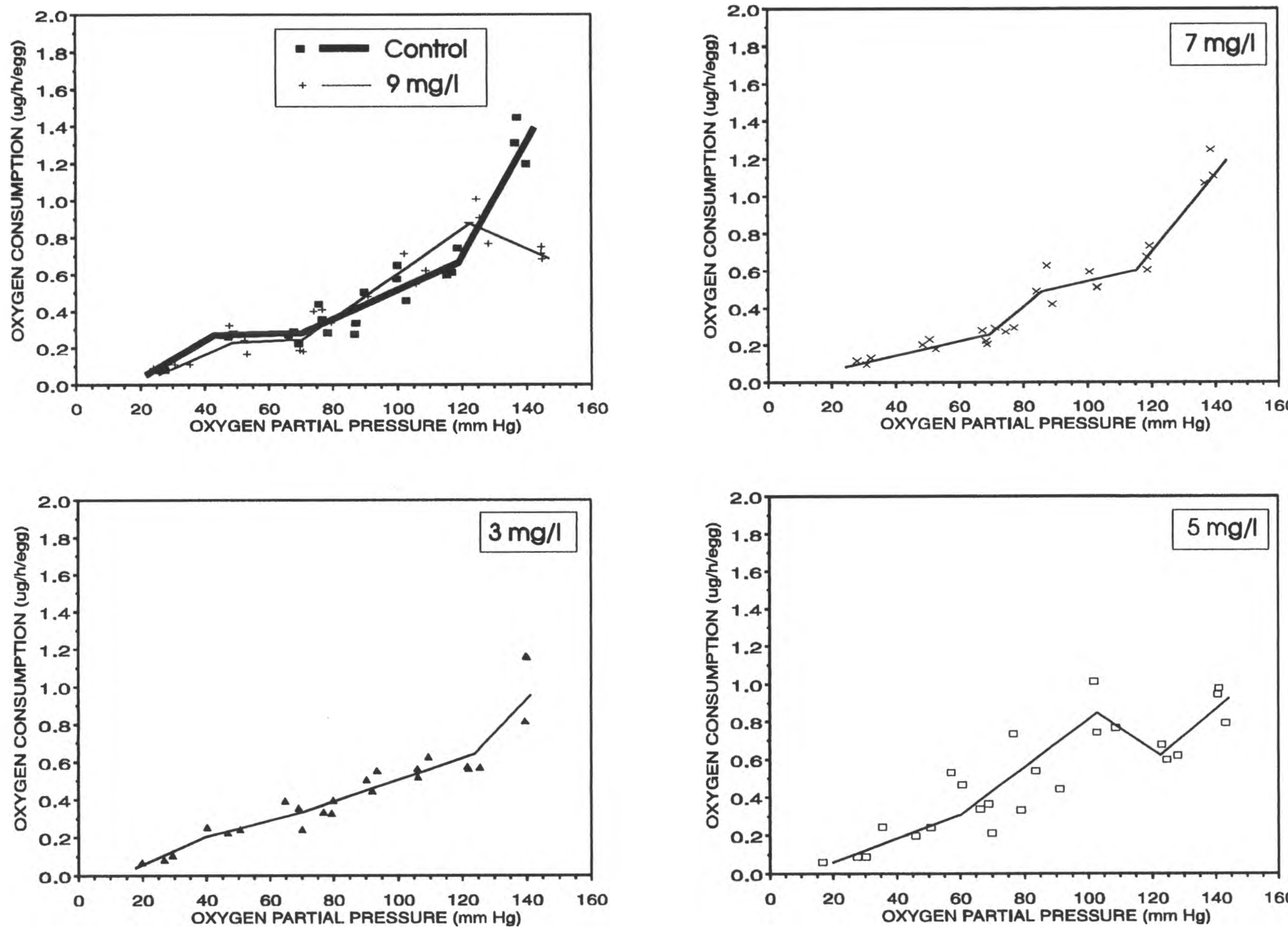

Figure 29. Oxygen Consumption of Mountain Whitefish Eggs (February 23). The lines are fitted by eye.

February 9 and 23, respectively. Groups of eggs incubated at [DO] of 3 mg/l were transferred to higher oxygen levels on March 28 and the effects of the increased oxygen regimes on Q_{O_2} measured at oxygen tensions ≥ 100 mm Hg on April 11 to 13 (Figure 30). Although the results exhibited substantial variability, very little change in Q_{O_2} was recorded in eggs exposed to 5 and 7 mg/l of dissolved oxygen. A relatively small (25% at 140 mm Hg) elevation in oxygen consumption was recorded in eggs exposed to [DO] ≥ 9 mg/l during this interval.

3.3.3 Q_{O_2} Of Bull Trout and Mountain Whitefish Eggs At Incubation Conditions

Estimates of Q_{O_2} at the different levels of dissolved oxygen in the incubators were derived from the data in Figures 23 to 29. Oxygen consumption was clearly related to the oxygen level in the incubator in both species (Figure 31). In bull trout Q_{O_2} increased in an approximately linear manner from February 2 to March 28 in eggs and alevins incubated at saturated [DO] levels. At lower oxygen levels Q_{O_2} was reduced in developing eggs in a dose-dependent manner. After hatch, however, the oxygen consumption of alevins reared at 9 and 7 mg/l of dissolved oxygen approached values recorded in the control fish. Consumption of oxygen was reduced slightly in alevins reared at 5 mg/l [DO] and by more than 50% in alevins reared at 3 mg/l. These reductions may be related to the smaller proportion of total body weight as developed tissue versus yolk present in these alevins (Section 3.7.2). Whitefish also exhibited an oxygen-dependent reduction in Q_{O_2}. However, the relative increases in oxygen consumption with development time were substantially less than those observed in bull trout. Oxygen consumption in whitefish eggs on February 23, approximately 3 weeks prior to the initiation of hatch, was 0.2, 0.28, 0.48, 0.7, and 1.35 μg/h/egg in eggs reared at [DO] of 3, 5, 7, 9, and 13.5 mg/l, respectively. An inverse correlation between the time to 50 percent hatch (Section 3.2.2) and these levels of oxygen consumption was evident such that:

$$T_h = 161.9 - 80.7(Log Q_{O_2})$$

where: T_h = time to 50% hatch in days;
Q_{O_2} = oxygen consumption (μg/h/egg) on February 23;
The correlation coefficient for this relationship was 0.9899 which is highly significant ($P < 0.01$, df = 3).

3.3.4 Residual Oxygen Levels

Residual oxygen levels were determined during some of the oxygen consumption studies on bull trout and mountain whitefish. Residual oxygen represents the oxygen remaining at the time of death. In the tests with eggs it was sometimes possible to determine the death of the eggs by observing the cessation of heart contractions but in others it was necessary to measure the concentration of oxygen

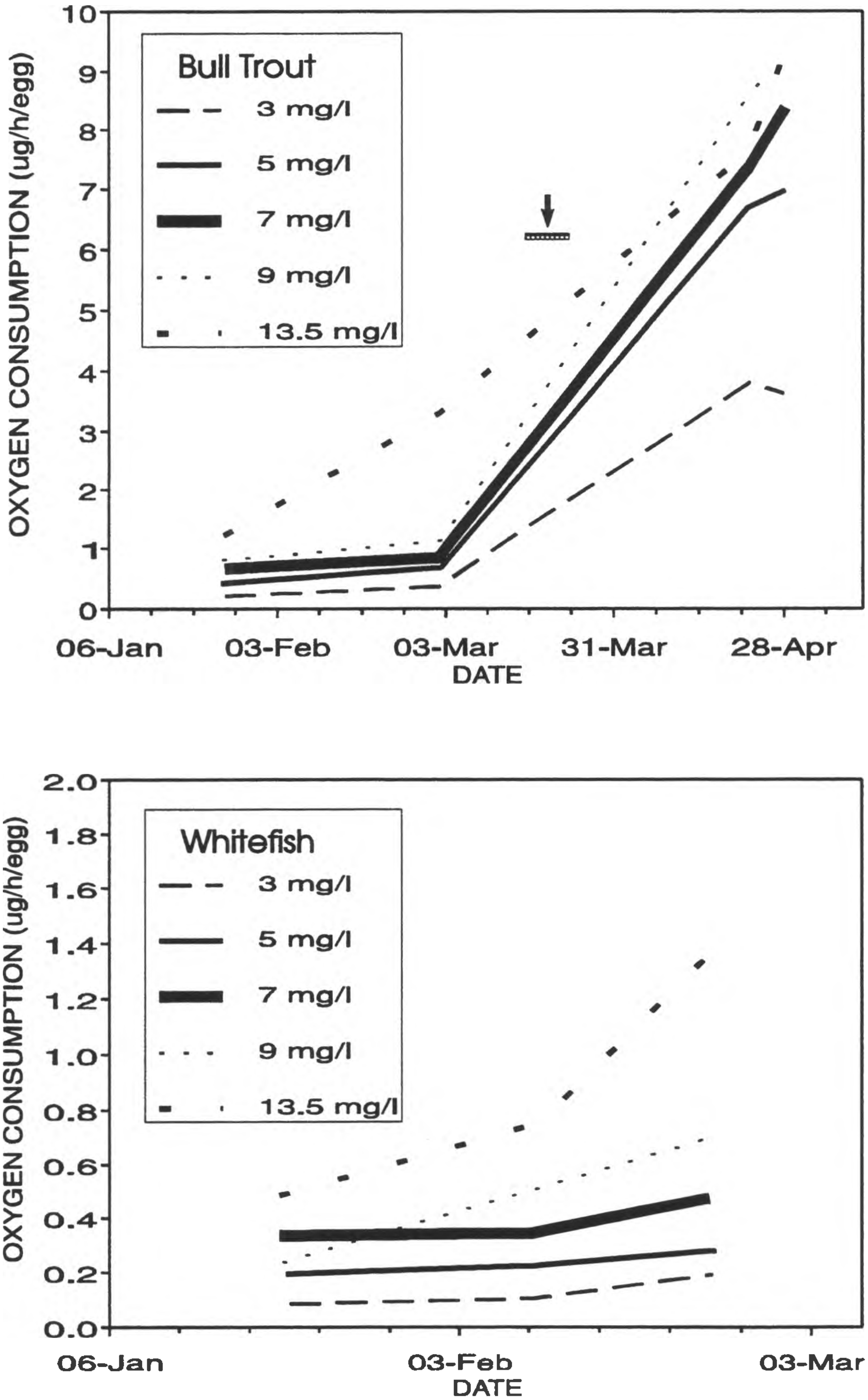

Figure 31. Oxygen Consumption (Qo_2) of Bull Trout and Mountain Whitefish Eggs at the Actual Dissolved Oxygen Concentrations of Incubation. The estimates of Qo_2 were derived from the eye-fitted lines in Figures 23 to 28. The hatching period for bull trout eggs is indicated by the cross-hatched bar and arrow.

were not included in the analysis because of difficulties with consistency of orientation of the embryos during measurement or lack of clarity during image analysis. Eye length and interorbital distance, features associated with ocular and cranial development, were unaffected by dissolved oxygen concentration during egg incubation (Table 5). Similarly, although egg diameter exhibited small differences among [DO] treatments during early development, the effects were inconsistent and generally disappeared in later stages of development. Yolk utilization, as approximated by the measurement of yolk area, did exhibit treatment-related differences which first appeared in the February 3 samples and was greatly magnified by March 25 (Table 5). Yolk area was significantly greater in whitefish incubated at [DO] < 7 mg/l. Since egg and larval weight (Table 25, Appendix G) and egg size (Table 5) were similar among the treatments the elaboration of body tissues was retarded at lower oxygen treatments during later stages of development. This retardation, however, was not associated with an increase in gross physical abnormalities in the hatched larvae since, with the exception of larvae from tank 7, the occurrence of such abnormalities was less than 1% from all treatments. In tank 7, 16% of the whitefish which hatched exhihited a curvature of the trunk into a semicircle. These fish were unable to swim normally and died soon after they were acclimated to 10°C.

3.7.2 <u>Bull Trout</u>

Embryonic development of bull trout was not analyzed in the same detail as whitefish because it was not posssible to photograph the physical structures inside the darker colored eggs. Estimates of the dry and wet weights of the eggs and alevins and of the proportion of total weight as yolk in alevins taken from a small number of samples (Table 6) demonstrated, however, that the conversion of yolk to tissue was substantially delayed in bull trout eggs incubated at 3 and 5 mg/l of dissolved oxygen. This effect was evident by mid-April and was still evident in May, especially at [DO] of 3 mg/l. Although the total weight of the alevins was not related to [DO] treatment, alevins from the 3 and 5 mg/l treatments were shorter than those from less hypoxic treatments (Table 23, Appendix G). Morphological deformities, although rare, were more common in bull trout than in whitefish. Two gross deformities were identified in bull trout alevins. The first was a deformity in the yolk sac where a fluid-filled membrane appeared to surround the yolk sac. The second was a deformity in the spine which caused a kink in the tail. The prevalence of these deformities generally related to the severity of the hypoxia during incubation of the eggs and alevins. Of the 80 alevins from the 3 mg/l treatment, 5 exhibited the yolk sac deformity while none had a spinal deformity. Ten of the 81 alevins from the 5 mg/l were deformed with 9 exhibiting the spinal kink. Deformed spines were observed in 3 of 93 alevins from 7 mg/l while one had a deformed yolk sac. One alevin of 95 fish from 13.5 mg/l had a deformed spine while no deformities were observed in 92 alevins from [DO] of 9 mg/l. These results must be viewed with some caution, however, since the bull trout may have hatched somwhat prematurely in response to the temperature rise in mid-March.

Table 3. Effects of Dissolved Oxygen Concentration During Embryonic Development Upon Feeding Success of Mountain Whitefish Larvae.

Date	Oxygen Treatment (mg/ℓ O_2)	FoodDensity (N/ℓ)		Larvae Tested (N)	Food Consumption			Larval Length (mm)
		Nauplii	Eggs		No. Larvae With No Nauplii	Nauplii/Larvae	Eggs/Larvae	
March 29*	13.5	0	0	10	10	0	1.5±2.3	16.5±0.4
	9	0	0*	9	9	0	3.9±2.4	16.7±0.4
	7	0	0	10	10	0	1.1±1.5	16.4±0.5
	5	0	0	10	10	0	6.0±2.6	16.2±0.4
March 29	13.5	182	62	10	0	59.9±16.3	5.1±3.7	16.9±0.7
	9	"	"	"	0	48.4±9.8	5.4±3.0	17.3±0.4
	7	"	"	"	0	44.1±21.9	3.2±1.5	17.2±0.6
	5	"	"	"	0	30.4±11.9	5.1±2.5	16.9±0.3
March 29	13.5	123	42	10	0	21.9±9.7	6.4±5.6	16.9±0.4
	9	"	"	10	0	25.6±10.6	5.6±2.8	17.3±0.5
	7	"	"	10	0	24.0±12.4	3.7±2.5	16.7±0.6
	5	"	"	10	0	39.4±16.6	5.9±3.3	16.7±0.5
March 29	13.5	62	21	10	0	20.5±12.3	3.8±1.8	16.8±0.7
	9	"	"	ND	ND	ND	ND	ND
	7	"	"	10	0	14.7±9.3	2.6±1.5	16.5±0.6
	5	"	"	8	1	21.4±11.0	5.0±2.6	16.7±0.4

continued...

Table 4. Critical Thermal Maxima of Bull Trout Alevins and Mountain Whitefish Fry Incubated as Eggs at Levels of Hypoxia. Results are presented as mean ± 1 standard deviation for CTM in °C and wet weight, W, in mg for sample size (N).

Acclimation Date		OXYGEN TREATMENT (mg/l) 13.5	9	7	5	3
Whitefish						
Mar. 17	CTM	28.32	28.86	ND	ND	ND
		±0.35(9)	±0.15(12)	ND	ND	ND
	W	ND	ND	ND	ND	ND
Mar. 17	CTM	28.21	ND	ND	ND	ND
		±0.67(9)	ND	ND	ND	ND
	W	ND	ND	ND	ND	ND
Mar. 17	CTM	28.29	28.86	ND	ND	ND
		±1.03(12)	±0.15(12)	ND	ND	ND
	W	0.359	0.325	ND	ND	ND
		±0.155	±0.190	ND	ND	ND
Mar. 17(3)	CTM	ND	ND	28.20	ND	ND
Apr. 17(9)		ND	ND	±0.23(12)	ND	ND
	W	ND	ND	0.203	ND	ND
		ND	ND	±0.196	ND	ND
May 5	CTM	ND	28.14	28.26	28.82	ND
		ND	±0.22(11)	±0.56(11)	±0.24(12)	ND
	W	ND	0.048	0.039	0.033	ND
		ND	±0.077	±0.032	±0.004	ND
May 5	CTM	ND	ND	ND	27.91	ND
		ND	ND	ND	±0.22(10)	ND
	W	ND	ND	ND	0.023	ND
			ND	ND	±0.004	ND
May 26	CTM	ND	ND	ND	ND	28.70
(T7)		ND	ND	ND	ND	±0.11(12)
	W	ND	ND	ND	ND	0.020
		ND	ND	ND	ND	±0.002
May 26	CTM	ND	ND	ND	ND	28.31
(T6)		ND	ND	ND	ND	±0.34(10)
	W	ND	ND	ND	ND	0.019
		ND	ND	ND	ND	±0.004
May 26	CTM	ND	ND	ND	ND	28.48
(T5)		ND	ND	ND	ND	±0.24(12)
	W	ND	ND	ND	ND	0.022
		ND	ND	ND	ND	±0.002
Bull Trout						
May 26	CTM	28.41	28.57	28.59	28.34	27.88
		±0.29(9)	±0.84(10)	±0.49(10)	±0.601(11)	±0.44(10)
	W	0.106	0.108	0.113	0.104	0.107
		±0.015	±0.014	±0.016	±0.009	±0.009

Table 6. Effect of Dissolved Oxygen on Weight of Bull Trout Eggs and Alevins. (D) is developmental stage (E=egg; A=alevins). Values are given as mean ±1 standard deviation.

DATE	OXYGEN TREATMENT (mg/ℓ)	N	D	WEIGHT WET (mg)	WEIGHT DRY (mg)	YOLK (% of DRY WT)
03 Feb 94	13.5	3	E	81.7±1.0	27.3±0.4	ND
	9	3	E	90.0±1.0	29.7±0.4	ND
	7	3	E	93.6±1.9	30.5±0.5	ND
	5	3	E	90.5±5.9	29.6±0.7	ND
	3	3	E	87.4±6.3	29.5±1.8	ND
04 Mar 94	13.5	6	A	70.9±3.9	26.5±1.4	82.5±5.3
	9	6	A	71.7±4.1	26.5±1.6	78.5±3.1
	7	6	A	68.8±4.3	26.7±1.9	78.8±15.2
	5	6	A	66.2±6.9	25.9±2.8	85.0±4.9
	3	6	A	73.8±4.9	26.2±1.8	85.4±8.4
15 Apr 94	13.5	5	A	ND	24.1±1.6	58.9±1.9
	9	5	A	ND	22.6±1.8	60.2±3.5
	7	5	A	ND	25.3±2.4	55.5±3.5
	5	5	A	ND	24.3±2.3	66.6±3.7
	3	5	A	ND	25.8±1.2	79.8±1.8
25 Apr 94	13.5	3	A	ND	19.2±3.0	42.9±8.1
	9	3	A	ND	20.5±0.5	47.7±3.3
	7	3	A	ND	18.1±0.5	48.1±5.6
	5	3	A	ND	22.0±0.6	58.0±10.7
	3	3	A	ND	24.8±3.0	68.2±2.9
03 May 94	13.5	3	A	ND	24.4±3.4	42.5±2.5
	9	3	A	ND	25.2±3.1	42.2±4.9
	7	3	A	ND	25.0±1.9	43.7±4.1
	5	3	A	ND	24.1±2.1	48.1±3.2
	3	3	A	ND	26.0±1.7	66.7±2.7

weight composed of yolk when compared to alevins reared at [DO] ≥ 7 mg/l. Hypoxia-induced increases in time to hatch of salmonid fish exhibiting an alevin stage appear to be species specific. Hatching of coho salmon, Oncorhynchus kisutch, eggs increased by 8 days when [DO] was reduced from 11.6 to 2.7 mg/l whereas hatching was reduced by only 1 day in brook trout, Salvelinus fontinalis, under similar conditions (Siefert and Spoor, 1974). Lake trout eggs hatched 8 days later when incubated at 4.3 mg/l of dissolved oxygen than at 11.4 mg/l (Carlson and Siefert, 1974). The alevin stage in these salmonids can be considered as an extension of the embryological phase of development since the alevins generally continue to reside in the redd and are incapable of surviving outside its protection. These fish leave the spawning site after absorption of the yolk when they are capable of swimming in the water column and utilizing exogenous food sources. Bull trout alevins exposed to 5 mg/l of dissolved oxygen in this study were able to increase yolk utilization between April 15 and May 3 to compensate partially for the retardation in development such that by May 3 they had only 12% more yolk than alevins reared at higher oxygen tensions. At this time alevins from the 3 mg/l [DO] treatment had 56% more yolk than alevins from oxygen levels ≥ 7 mg/l. The increase in yolk utilization was reflected in the increase in oxygen consumption of alevins at 5 mg/l which approached that of the alevins in less hypoxic treatments. The reduction in total length of bull trout embryos reared at [DO] of 3 and 5 mg/l is consistent with similar effects observed in alevins of other species incubated as eggs under severe to moderate hypoxia (Carlson and Siefert, 1974; Siefert and Spoor, 1974). It is unclear, however, if this response represents a difference in yolk conversion efficiency or is simply a reflection of the increased time required to complete somatic growth under hypoxic conditions. Growth efficiency of salmonid embryos while still in the egg may be unaffected whereas that of alevins may be severely reduced (Rombough, 1988) during hypoxia. Levels of hypoxia ≤ 7 mg/l appeared to induce physical deformities in bull trout embryos with spinal deformities most prevalent at 5 and 7 mg/l of dissolved oxygen and yolk sac aberrations most common at DO of 3 mg/l. Unfortunately the incidence of deformities was not strongly related to the level of hypoxia and the usefulness of this response in assessing the levels of stress experienced by natural bull trout embryos in contaminated rivers is questionable.

Mountain whitefish exhibited a progressive increase in time to hatch with increasing levels of hypoxia. Furthermore, there was no apparent threshold for this effect as the time required for 50% hatch was 151, 174, 185, 204, and 221 days in eggs incubated at 13.5, 9, 7, 5, and 3 mg/l, respectively, of dissolved oxygen. The time to hatch for eggs at 3 mg/l is probably longer since these eggs experienced 14 days of normoxic water and an increase in temperature of approximately 2.4°C prior to hatching. A qualitatively similar effect has been observed in several fish exhibiting a free-swimming larval stage including mountain whitefish from Utah (Siefert et al., 1974), lake herring (Brooke and Colby, 1980), and walleye, (Stizostedion vitreum) but not white sucker, (Catostomus commersoni), (Siefert and Spoor, 1974). Oxygen consumption by mountain whitefish eggs from all treatments was oxygen-dependent over the entire range of oxygen tensions examined and only increased by 2 to 3-fold from mid-January to mid-April. An inverse relationship between oxygen consumption and time to hatch was apparent. Since yolk utilization, as estimated by the measurement of cross-sectional area of the yolk sac, also was related inversely to the level of hypoxic treatment it is possible that dissolved oxygen influenced directly the rate of embryological development in the mountain whitefish. This possibility is supported by the observation that neither weight nor length whitefish. Mountain whitefish eggs spawned naturally in the West Gallatin River, Montana, on October 28, began hatching on March 3 after approximately 129 days of development (Brown, 1952), while the normoxic whitefish eggs spawned on October 10 in this study began hatching March 16 after 158 days of development. The degree-days (days x °C) from fertilization to hatch were estimated as 290 and 332, respectively, for these two groups of whitefish eggs. Within limits, time to hatch is an exponential function of water temperature (Blaxter, 1988). In this study, however, the constant incubation temperature may have slowed development relative to that of eggs in a natural environment which experience both warmer and cooler temperatures during development at the same mean temperature. The bull trout required 166 days from fertilization to hatch which is similar to the incubation time required for brook trout development at similar water temperatures (Blaxter, 1988). The water temperature employed in this study may have been more appropriate for the bull trout which may spawn in areas influenced by the presence of warmer spring water (Fairless et al., 1994) than for mountain whitefish which apparently broadcast their eggs (Brown, 1952). The effect of water temperature on hatching was clearly demonstrated from the hatching induced when temperature rose to 7°C for less than 4 hours in incubators 1 to 7. Virtually all of the bull trout at DO ≥ 5 mg/l hatched within one day of this event compared to unaffected eggs which hatched 7 to 10 days later. For whitefish the temperature rise promoted hatching which was 3 to 42 days premature for eggs incubated at dissolved oxygen concentrations of 13.5 and 5 mg/l, respectively.

Oscillations in dissolved oxygen were also experienced in this study. In general, however, the variations were small and were corrected within a few hours. Daily fluctuations in dissolved oxygen as high as 2 mg/l have been recorded in hypoxic regions on the Athabasca River (Noton and Allan, 1994), although variations of 0.5 mg/l are more common during the periods when hypoxia is most severe. The fluctuations in DO recorded in this study were generally within this range. Although Noton and Allan (1994) did not report dissolved oxygen concentrations below 6 mg/l at any of their mainstream sampling sites on the Athabasca River, the present study included a level of 3 mg/l to reflect the potential oxygen gradient of 3 mg/l between mainstream and inter-gravel waters which may occur in the redds of trout (Barton and Taylor, 1994).

4.4 RATIONALE FOR BIOLOGICAL MEASUREMENTS APPLIED IN THIS STUDY

In addition to mortality, hatching pattern, and oxygen consumption, the effects of hypoxia during embryonic development upon several other biological characteristics were examined in this study. These included cardiac rate, residual oxygen levels, aspects of embryological development including eye diameter, interorbital distance, egg diameter, and yolk size, larval length and weight, and thermal tolerance and feeding ability of alevins and larvae soon after hatch. Several of these characteristics were examined because of their potential use in the identification of possible modes of action of hypoxia upon the survivability and viability of the embryos and young fish. For example, increased rates of yolk utilization could suggest changes in efficiency of conversion of yolk to tissue whereas impairment of feeding ability could be related to adverse effects on neuromuscular development (sight, muscular coordination), gape of the mouth, or development of the digestive tract. A second purpose of many of these measurements was to determine their dose-dependent response to hypoxia and potential use for field bioassays in the Study Area. Of the thirteen features measured in this study have been related to input of effluents with a significant oxygen demand. Furthermore, the effect of this demand on dissolved oxygen levels may continue for hundreds of kilometers downstream of the site of input. In the past five years dissolved oxygen concentrations in the range of 6 to 7 mg/l have been recorded at some sites for periods of 4 to 5 weeks during the winter (Noton and Shaw, 1994). These levels are insufficient to cause mortality of the developing eggs of either bull trout or mountain whitefish at the water temperatures existent under the ice even considering the oxygen gradient of 3 mg/l which may exist between the water column and interstitial water in the redds of the bull trout (Barton and Taylor, 1994). Although the effects of hypoxia upon embryological development of bull trout and mountain whitefish observed in the present study were derived from hypoxic exposures spanning the period of November 27 to May 5, it is clear that the level of hypoxia currently occurring at specific sites in the Athabasca River are sufficient to influence the rate of development of both species. Furthermore, the majority of the effects appear to occur during the later stages of development at a time when [DO] levels in the rivers may be at the lowest. The ability of the embryos to accelerate development when the hypoxic stress is lessened or removed was not examined in the present study. However, given the severe developmental retardation found at low oxygen, it is reasonable to assume that a significant delay may occur in the timing of the emergence of fish from their natal sites. This delay could have consequences on the ability of the fish to find suitable feed and grow to sufficient size to survive the following winter.

5.0 CONCLUSIONS

1. Chronic Exposure to dissolved oxygen concentrations ranging from 3 to 13.5 mg/l did not cause significant mortality or increase in physical deformities in developing eggs of either bull trout or mountain whitefish.

2. Low oxygen levels did retard embryonic development as indicated by reductions in the rates of oxygen consumption and yolk utilization in both species. The retardation was expressed by large increases in the size of the yolk and decreases in alevin length of bull trout at hatch and during the alevin stage and by delays in hatching of up to 10 weeks in mountain whitefish.

3. Although hatching was delayed, whitefish larvae from eggs incubated under hypoxic conditions were equal to normoxic larvae in terms of size at hatch, thermal tolerance, and ability to capture live food. In addition, hypoxia did not affect the thermal tolerance of bull trout alevins.

7.0 REFERENCES

Barton, B.A., and B.R. Taylor. 1994. Dissolved Oxygen Requirements for Fish of the Peace, Athabasca, and Slave River Basins. Northern River Basins Study: Edmonton, Alberta. Report No. 29: viii + 104 pp.

Becker, C.D., and R.G. Genoway. 1979. Evaluation of the Critical Thermal Maximum for Determining Thermal Tolerance of Freshwater Fish. Environmental Biology of Fishes 4: 245-256.

Blaxter, J.H.S. 1988. Pattern and Variety in Development. Pages 1-58. in in W.S. Hoar and D.J. Randall, eds. Fish Physiology. Vol. XIA. Academic Press, San Diego, California. 546 pp.

Bollens, S.M., B.W. Frost, H.R. Schwaninger, C.S. Davis, K.J. Way, and M.C. Landsteiner. 1992. Seasonal Plankton Cycles in a Temperate Fjord and Comments on the Match-Mismatch Hypothesis. Journal of Plankton Research. 14: 1279-1305.

Brooks, L.T., and P.J. Colby. 1980. Development and Survival of Embryos of Lake Herring at Different Constant Oxygen Concentrations and Temperatures. The Progressive Fish-Culturist. 42: 3-8.

Brown, C.J.D. 1952. Spawning Habits and Early Development of the Mountain Whitefish, Prosopium williamsoni, in Montana. Copeia. 2: 109-113.

Burdick, G.E., E.J. Harris, H.J. Dean, T.M. Walker, J. Skea, and D. Colby. 1964. The Accumulation of DDT in Lake Trout and the Effect on Reproduction. Transactions of the American Fisheries Society. 93: 127-136.

Canadian Council of Resource and Environmental Ministers. 1987. Canadian Water Quality Guidelines. Environment Canada, Inland Waters Directorate: Ottawa, Ontario. 358pp.

Carlson, A.R., and R.E. Siefert. 1974. Effects of Reduced Oxygen on the Embryos and Larvae of Lake Trout (Salvelinus namaycush) and Largemouth Bass (Micropterus salmoides). Journal of the Fisheries Research Board of Canada. 31: 1393-1396.

Colt, J. 1980. The Computation of Dissolved Gas Levels as a Function of Temperature, Salinity, and Pressure. Department of Civil Engineering, University of California, Davis, California. 81pp.

Ellison, D.G. and W.G. Franzin. 1992. Overview of the Symposium on Walleye Stocks and Stocking. North American Journal of Fisheries Management. 12: 271-275.

Sheedy, B.R., J.M. Lazorchak, D.L. Grunwald, Q.H. Pickering, A. Pilli, D. Hall, and R. Webb. 1991. Effects of Pollution on Freshwater Organisms. Journal Water Pollution Control Federation. 64: 619-696.

Siefert, R.E, and W.A. Spoor. 1974. Effects of Reduced Oxygen on Embryos and Larvae of WhiteSucker, Coho Salmon, Brook Trout, and Walleye. Pages 487-495 in J.H.S. Blaxter, ed. The Early Life History of Fish. Springer-Verlag; Berlin, Germany.

Siefert, R.E., A.R. Carlson, and L.J. Herman. 1974. Effects of Reduced Oxygen Concentration on the Early Life Stages of Mountain Whitefish, Smallmouth Bass, and White Bass. The Progressive Fish-Culturist. 36: 186-190.

Sprague, J.B. 1973. The ABC's of Pollutant Bioassay Using Fish. Pages 6-30. in Biological Methods for the Assessment of Water Quality. American Society for Testing and Materials. STP 528.

Stainton, M.P., M.J. Capel, and F.A.J. Armstrong. 1977. The Chemical Analysis of Fresh Water. Canadian Fisheries and Marine Service Miscellaneous Special Publication. 25: 180 pp.

Steedman, H.F. 1976. General and Applied Data on Formaldehyde Fixation and Preservation. Pages 103-154 in H.F. Steedman, ed. Monographs on Oceanographic Methodology 4. UNESCO Press, Paris. 174 pp.

Trussell, R.P. 1972. The Percent Un-ionized Ammonia in Aqueous Ammonia Solutions at Different pH Levels and Temperatures. Journal of the Fisheries Research Board of Canada. 29: 1505-1507.

Wagemann, R., E. Scherer and J. Czwarno. 1987. New Water Treatment System at the Freshwater Institute: Water Quality Data for One Year of Operation (1985/86). Canadian Data Report of Fisheries and Aquatic Sciences. No. 638: 114 pp.

APPENDIX A:

TERMS OF REFERENCE

NORTHERN RIVER BASINS STUDY

SCHEDULE OF TERMS OF REFERENCE

DISSOLVED OXYGEN REQUIREMENTS OF FISH

Project: 3221-C1

I. PROJECT DESCRIPTION

The Northern River Basins Study requires the contract laboratory to determine the dissolved oxygen requirements for developing eggs and larvae or alevins of mountain whitefish, *Prosopium williamsoni*, and bull trout, *Salvelinus confluentus*, at water temperatures appropriate to the period of hypoxia in major rivers in the study area. Potential interaction between hypoxia and a contaminant, (2,4,6-trichlorophenol), associated with pulp mill effluent will also be identified.

II. TERMS OF REFERENCE

1. The contractor is required to obtain fertilized eggs of bull trout and mountain whitefish from wild populations in western Canada and incubate these eggs using a water temperature regime 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 bull trout eggs will be collected in September when water temperatures are approximately 10°C in the spawning area and will be incubated in the laboratory with a temperature regime which declines to 2°C during the period of mid-September to mid-October. Thereafter the eggs will be maintained at 2.0 ± 0.1°C until mid-May (approximately 210 days).

   c. The whitefish eggs will be collected in early October when water temperatures are approximately 3-5°C in the spawning area. During the period of mid-October to mid-May these eggs will be incubated under the same temperature regime as in 1.a.

2. The contractor is required to assess the impact of lowered dissolved oxygen levels and

in the study area will be included.

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

IV. 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.

V. PROJECT MANAGEMENT PLAN - DFO/Winnipeg physiology laboratory

1. Fertilized eggs of bull trout will be collected from the Hill Creek Spawning Channel in British Columbia in September, 1993. Mountain whitefish eggs will be obtained from wild spawning populations in the headwaters of the Athabaska River, Alberta, in October, 1993. All permits for the transportation and rearing of the eggs will be obtained by the laboratory and regulations concerning the disposition of the hatched fish will be enforced.

2. The Northern River Basins Study Office will be informed at the earliest possible date of any impediments to the execution of this investigation such as mass mortality of eggs or larvae resulting from poor gamete viability.

APPENDIX B:

MORTALITY AND HATCHING OF BULL TROUT AND MOUNTAIN WHITEFISH EGGS INCUBATED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN

Table 7. Mortality and Hatching of Bull Trout Eggs Incubated at 3 mg/l Dissolved Oxygen. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 5: (212 eggs)			Tank 6: (20 eggs)			Tank 7: (22 eggs)		
	Egg Mort.	Total Hatch	Alevin Mort.	Egg Mort.	Total Hatch	Alevin Mort.	Egg Mort.	Total Hatch	Alevin Mort.
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25-Oct-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Oct-93	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Oct-93	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Nov-93	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Nov-93	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09-Nov-93	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Nov-93	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Nov-93	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Nov-93	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Nov-93	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26-Nov-93	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Nov-93	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Nov-93	11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Dec-93	11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07-Dec-93	12.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10-Dec-93	12.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-Dec-93	12.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-Dec-93	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20-Dec-93	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Dec-93	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Dec-93	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-Dec-93	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Jan-94	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06-Jan-94	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Jan-94	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Jan-94	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-Jan-94	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26-Jan-94	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-Jan-94	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31-Jan-94	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Feb-94	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07-Feb-94	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10-Feb-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-Feb-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-Feb-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-Feb-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24-Feb-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-Feb-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
01-Mar-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Mar-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Mar-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Mar-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05-Mar-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07-Mar-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08-Mar-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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Table 8. Mortality and Hatching of Bull Trout Eggs Incubated at 5 mg/l Dissolved Oxygen. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 3: (205 eggs)			Tank 12: (20 eggs)			Tank 13: (20 eggs)		
	Egg Mort.	Total Hatch	Alevin Mort.	Egg Mort.	Total Hatch	Alevin Mort.	Egg Mort.	Total Hatch	Alevin Mort.
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25-Oct-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Oct-93	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Oct-93	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Nov-93	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Nov-93	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09-Nov-93	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Nov-93	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Nov-93	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Nov-93	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Nov-93	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26-Nov-93	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Nov-93	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Nov-93	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-Nov-93	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
01-Dec-93	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Dec-93	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Dec-93	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Dec-93	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05-Dec-94	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07-Dec-93	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10-Dec-93	17.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-Dec-93	17.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-Dec-93	17.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20-Dec-93	18.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Dec-93	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Dec-93	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-Dec-93	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Jan-94	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06-Jan-94	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Jan-94	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Jan-94	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-Jan-94	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26-Jan-94	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-Jan-94	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31-Jan-94	20.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Feb-94	20.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07-Feb-94	20.1	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
10-Feb-94	20.1	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
14-Feb-94	20.1	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
16-Feb-94	20.1	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
17-Feb-94	20.1	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
21-Feb-94	20.6	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
24-Feb-94	20.6	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0

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Table 9. Mortality and Hatching of Bull Trout Eggs Incubated at 7 mg/l Dissolved Oxygen. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 4: (211 eggs)			Tank 10: (19 eggs)			Tank 11 (20 eggs)		
	Egg Mort.	Total Hatch	Alevin Mort.	Egg Mort.	Total Hatch	Alevin Mort.	Egg Mort.	Total Hatch	Alevin Mort.
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25-Oct-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Oct-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Oct-93	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Nov-93	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Nov-93	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09-Nov-93	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Nov-93	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Nov-93	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Nov-93	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Nov-93	8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26-Nov-93	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Nov-93	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Nov-93	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-Nov-93	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
01-Dec-93	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Dec-93	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Dec-93	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Dec-93	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05-Dec-94	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07-Dec-93	11.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10-Dec-93	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-Dec-93	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-Dec-93	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20-Dec-93	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Dec-93	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Dec-93	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-Dec-93	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Jan-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06-Jan-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Jan-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Jan-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-Jan-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26-Jan-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-Jan-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31-Jan-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Feb-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07-Feb-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10-Feb-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-Feb-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-Feb-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-Feb-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-Feb-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24-Feb-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-Feb-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
01-Mar-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Mar-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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Table 10. Mortality and Hatching of Bull Trout Eggs Incubated at 9 mg/l Dissolved Oxygen. The percent hatchinng was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 2: (201 eggs)			Tank 8: (8 eggs)	
	Egg Mort.	Total Hatch	Alevin Mort.	Egg Mort.	Total Hatch
DATE	(%)	(%)	(%)	(%)	(%)
25-Oct-93	0.0	0.0	0.0	0.0	0.0
27-Oct-93	1.3	0.0	0.0	0.0	0.0
29-Oct-93	1.3	0.0	0.0	0.0	0.0
02-Nov-93	2.3	0.0	0.0	0.0	0.0
04-Nov-93	3.7	0.0	0.0	0.0	0.0
09-Nov-93	3.7	0.0	0.0	0.0	0.0
11-Nov-93	3.9	0.0	0.0	0.0	0.0
15-Nov-93	5.5	0.0	0.0	0.0	0.0
18-Nov-93	5.5	0.0	0.0	0.0	0.0
23-Nov-93	6.5	0.0	0.0	0.0	0.0
26-Nov-93	7.3	0.0	0.0	0.0	0.0
27-Nov-93	7.3	0.0	0.0	0.0	0.0
29-Nov-93	7.3	0.0	0.0	0.0	0.0
30-Nov-93	7.3	0.0	0.0	0.0	0.0
01-Dec-93	7.3	0.0	0.0	0.0	0.0
02-Dec-93	8.3	0.0	0.0	0.0	0.0
03-Dec-93	8.3	0.0	0.0	0.0	0.0
04-Dec-93	8.3	0.0	0.0	0.0	0.0
05-Dec-94	8.3	0.0	0.0	0.0	0.0
07-Dec-93	8.3	0.0	0.0	0.0	0.0
10-Dec-93	8.3	0.0	0.0	0.0	0.0
14-Dec-93	8.8	0.0	0.0	0.0	0.0
16-Dec-93	9.3	0.0	0.0	0.0	0.0
20-Dec-93	12.0	0.0	0.0	0.0	0.0
23-Dec-93	12.0	0.0	0.0	0.0	0.0
27-Dec-93	12.0	0.0	0.0	0.0	0.0
30-Dec-93	12.0	0.0	0.0	0.0	0.0
03-Jan-94	12.0	0.0	0.0	0.0	0.0
06-Jan-94	12.0	0.0	0.0	0.0	0.0
11-Jan-94	12.0	0.0	0.0	0.0	0.0
18-Jan-94	12.0	0.0	0.0	0.0	0.0
21-Jan-94	12.0	0.0	0.0	0.0	0.0
26-Jan-94	12.0	0.0	0.0	0.0	0.0
28-Jan-94	12.0	0.0	0.0	0.0	0.0
31-Jan-94	12.0	0.0	0.0	0.0	0.0
03-Feb-94	12.0	0.0	0.0	0.0	0.0
07-Feb-94	12.0	0.0	0.0	0.0	0.0
08-Feb-94	12.0	0.0	0.0	0.0	0.0
09-Feb-94	12.0	0.0	0.0	0.0	0.0
10-Feb-94	12.0	0.0	0.0	0.0	0.0
14-Feb-94	12.0	0.0	0.0	0.0	0.0
15-Feb-94	12.0	0.0	0.0	0.0	0.0
16-Feb-94	12.0	0.0	0.0	0.0	0.0
17-Feb-94	12.8	0.0	0.0	0.0	0.0
18-Feb-94	12.8	0.0	0.0	0.0	0.0

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Table 11. Mortality and Hatching of Bull Trout Eggs Incubated at 13.5 mg/l Dissolved Oxygen. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 1: (208 eggs)			Tank 14: (16 eggs)			Tank 15: (20 eggs)		
	Egg Mort.	Total Hatch	Alevin Mort.	Egg Mort.	Total Hatch	Alevin Mort.	Egg Mort.	Total Hatch	Alevin Mort.
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25-Oct-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Oct-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Oct-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Nov-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Nov-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09-Nov-93	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Nov-93	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Nov-93	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Nov-93	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Nov-93	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26-Nov-93	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Nov-93	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Nov-93	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-Nov-93	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Dec-93	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05-Dec-93	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07-Dec-93	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10-Dec-93	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-Dec-93	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-Dec-93	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20-Dec-93	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Dec-93	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Dec-93	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-Dec-93	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-Jan-94	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06-Jan-94	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Jan-94	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Jan-94	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-Jan-94	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26-Jan-94	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-Jan-94	10.5	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
31-Jan-94	11.7	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
03-Feb-94	11.7	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
07-Feb-94	13.4	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
10-Feb-94	13.9	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
14-Feb-94	13.9	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
17-Feb-94	13.9	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
21-Feb-94	14.4	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
24-Feb-94	14.4	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
28-Feb-94	14.4	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
01-Mar-94	14.4	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
02-Mar-94	14.4	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
03-Mar-94	14.4	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
04-Mar-94	14.8	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
05-Mar-94	14.8	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0

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Table 12. Mortality and Hatching of Mountain Whitefish Eggs Incubated at 3 mg/l Dissolved Oxygen. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 5: (625 eggs)			Tank 6: (422 eggs)			Tank 7: (474 eggs)		
	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25-Oct-93	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Oct-93	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Oct-93	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Nov-93	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Nov-93	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09-Nov-93	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Nov-93	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Nov-93	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Nov-93	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Nov-93	7.5	0.0	0.0	5.2	0.0	0.0	7.8	0.0	0.0
26-Nov-93	7.5	0.0	0.0	12.6	0.0	0.0	15.7	0.0	0.0
27-Nov-93	7.5	0.0	0.0	14.4	0.0	0.0	16.2	0.0	0.0
29-Nov-93	7.5	0.0	0.0	17.7	0.0	0.0	21.4	0.0	0.0
02-Dec-93	7.5	0.0	0.0	19.8	0.0	0.0	22.8	0.0	0.0
07-Dec-93	7.5	0.0	0.0	19.8	0.0	0.0	22.8	0.0	0.0
10-Dec-93	7.5	0.0	0.0	20.0	0.0	0.0	23.1	0.0	0.0
14-Dec-93	7.5	0.0	0.0	20.2	0.0	0.0	23.1	0.0	0.0
16-Dec-93	7.5	0.0	0.0	20.5	0.0	0.0	23.4	0.0	0.0
20-Dec-93	7.5	0.0	0.0	20.5	0.0	0.0	23.4	0.0	0.0
23-Dec-93	7.5	0.0	0.0	20.5	0.0	0.0	23.4	0.0	0.0
27-Dec-93	7.5	0.0	0.0	20.5	0.0	0.0	23.4	0.0	0.0
30-Dec-93	7.5	0.0	0.0	20.5	0.0	0.0	23.4	0.0	0.0
03-Jan-94	7.5	0.0	0.0	20.5	0.0	0.0	23.4	0.0	0.0
06-Jan-94	7.5	0.0	0.0	20.7	0.0	0.0	23.4	0.0	0.0
11-Jan-94	7.5	0.0	0.0	20.7	0.0	0.0	23.4	0.0	0.0
18-Jan-94	7.5	0.0	0.0	21.0	0.0	0.0	23.4	0.0	0.0
21-Jan-94	7.5	0.0	0.0	21.0	0.0	0.0	23.4	0.0	0.0
26-Jan-94	7.5	0.0	0.0	21.0	0.0	0.0	23.4	0.0	0.0
28-Jan-94	7.5	0.0	0.0	21.0	0.0	0.0	23.4	0.0	0.0
31-Jan-94	7.5	0.0	0.0	21.0	0.0	0.0	23.4	0.0	0.0
03-Feb-94	7.7	0.0	0.0	21.0	0.0	0.0	23.4	0.0	0.0
07-Feb-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
10-Feb-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
14-Feb-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
17-Feb-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
21-Feb-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
24-Feb-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
28-Feb-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
01-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
02-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
03-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
04-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
05-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
07-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
08-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0

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Table 13. Mortality and Hatching of Mountain Whitefish Eggs Incubated at 5 mg/l Dissolved Oxygen. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 3: (502 eggs)			Tank 12: (785 eggs)			Tank 13: (1118 eggs)		
	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25-Oct-93	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Oct-93	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Oct-93	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Nov-93	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Nov-93	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09-Nov-93	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Nov-93	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Nov-93	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Nov-93	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Nov-93	7.2	0.0	0.0	3.8	0.0	0.0	2.6	0.0	0.0
26-Nov-93	7.2	0.0	0.0	8.4	0.0	0.0	12.5	0.0	0.0
27-Nov-93	7.2	0.0	0.0	8.4	0.0	0.0	12.5	0.0	0.0
29-Nov-93	7.2	0.0	0.0	10.9	0.0	0.0	15.7	0.0	0.0
30-Nov-93	7.2	0.0	0.0	11.4	0.0	0.0	15.7	0.0	0.0
01-Dec-93	7.2	0.0	0.0	11.4	0.0	0.0	15.7	0.0	0.0
02-Dec-93	7.2	0.0	0.0	13.0	0.0	0.0	17.7	0.0	0.0
03-Dec-93	7.2	0.0	0.0	13.0	0.0	0.0	17.7	0.0	0.0
04-Dec-93	7.2	0.0	0.0	13.0	0.0	0.0	17.7	0.0	0.0
05-Dec-93	7.2	0.0	0.0	13.0	0.0	0.0	17.7	0.0	0.0
07-Dec-93	7.2	0.0	0.0	13.4	0.0	0.0	18.2	0.0	0.0
10-Dec-93	7.2	0.0	0.0	13.6	0.0	0.0	19.1	0.0	0.0
14-Dec-93	7.2	0.0	0.0	13.7	0.0	0.0	19.5	0.0	0.0
16-Dec-93	7.2	0.0	0.0	13.8	0.0	0.0	19.5	0.0	0.0
20-Dec-93	7.2	0.0	0.0	13.8	0.0	0.0	20.0	0.0	0.0
23-Dec-93	7.2	0.0	0.0	14.0	0.0	0.0	20.1	0.0	0.0
27-Dec-93	7.2	0.0	0.0	14.3	0.0	0.0	20.1	0.0	0.0
30-Dec-93	7.2	0.0	0.0	14.4	0.0	0.0	20.1	0.0	0.0
03-Jan-94	7.2	0.0	0.0	14.4	0.0	0.0	20.2	0.0	0.0
06-Jan-94	7.2	0.0	0.0	14.4	0.0	0.0	20.2	0.0	0.0
11-Jan-94	7.2	0.0	0.0	14.4	0.0	0.0	20.2	0.0	0.0
18-Jan-94	7.2	0.0	0.0	14.6	0.0	0.0	20.3	0.0	0.0
21-Jan-94	7.2	0.0	0.0	14.7	0.0	0.0	20.3	0.0	0.0
26-Jan-94	7.2	0.0	0.0	14.7	0.0	0.0	20.3	0.1	0.0
28-Jan-94	7.2	0.0	0.0	14.7	0.0	0.0	20.9	0.1	0.0
31-Jan-94	7.2	0.0	0.0	14.7	0.0	0.0	21.0	0.1	0.0
03-Feb-94	7.2	0.0	0.0	14.8	0.0	0.0	22.5	0.1	0.0
07-Feb-94	7.2	0.0	0.0	14.8	0.0	0.0	22.8	0.1	0.0
10-Feb-94	7.2	0.0	0.0	14.8	0.0	0.0	23.1	0.1	0.0
14-Feb-94	7.2	0.0	0.0	14.8	0.1	0.0	23.5	0.1	0.0
16-Feb-94	7.2	0.0	0.0	14.8	0.1	0.0	23.5	0.1	0.0
17-Feb-94	7.2	0.0	0.0	14.8	0.1	0.0	23.5	0.1	0.0
21-Feb-94	7.2	0.0	0.0	15.0	0.1	0.0	23.6	0.1	0.0
24-Feb-94	7.2	0.0	0.0	15.0	0.1	0.0	23.6	0.1	0.0
28-Feb-94	7.2	0.0	0.0	15.0	0.1	0.0	23.6	0.2	0.0
01-Mar-94	7.2	0.0	0.0	15.0	0.1	0.0	23.6	0.2	0.0

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Table 14. Mortality and Hatching of Mountain Whitefish Eggs Incubated at 7 mg/l Dissolved Oxygen. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 4: (430 eggs)			Tank 10: (784 eggs)			Tank 11: (1062 eggs)		
	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25-Oct-93	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Oct-93	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Oct-93	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Nov-93	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Nov-93	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09-Nov-93	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Nov-93	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Nov-93	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Nov-93	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Nov-93	9.0	0.0	0.0	2.8	0.0	0.0	8.1	0.0	0.0
26-Nov-93	9.0	0.0	0.0	9.8	0.0	0.0	16.4	0.0	0.0
27-Nov-93	9.0	0.0	0.0	9.8	0.0	0.0	16.4	0.0	0.0
29-Nov-93	9.0	0.0	0.0	11.0	0.0	0.0	19.0	0.0	0.0
30-Nov-93	9.0	0.0	0.0	11.3	0.0	0.0	19.0	0.0	0.0
01-Dec-93	9.0	0.0	0.0	11.4	0.0	0.0	19.0	0.0	0.0
02-Dec-93	9.0	0.0	0.0	12.0	0.0	0.0	21.0	0.0	0.0
03-Dec-93	9.0	0.0	0.0	12.0	0.0	0.0	21.0	0.0	0.0
04-Dec-93	9.0	0.0	0.0	12.0	0.0	0.0	21.0	0.0	0.0
05-Dec-93	9.0	0.0	0.0	12.0	0.0	0.0	21.2	0.0	0.0
07-Dec-93	9.0	0.0	0.0	12.7	0.0	0.0	21.5	0.0	0.0
10-Dec-93	9.0	0.0	0.0	13.4	0.0	0.0	22.4	0.0	0.0
14-Dec-93	9.0	0.0	0.0	13.4	0.0	0.0	22.7	0.0	0.0
16-Dec-93	9.0	0.0	0.0	13.4	0.0	0.0	22.7	0.0	0.0
20-Dec-93	9.0	0.0	0.0	13.7	0.0	0.0	22.7	0.0	0.0
23-Dec-93	9.0	0.0	0.0	13.7	0.0	0.0	22.9	0.0	0.0
27-Dec-93	9.0	0.0	0.0	13.7	0.0	0.0	23.0	0.0	0.0
30-Dec-93	9.0	0.0	0.0	13.9	0.0	0.0	23.0	0.0	0.0
03-Jan-94	9.0	0.0	0.0	13.9	0.0	0.0	23.0	0.0	0.0
06-Jan-94	9.0	0.0	0.0	13.9	0.0	0.0	23.0	0.0	0.0
11-Jan-94	9.0	0.0	0.0	13.9	0.0	0.0	23.0	0.0	0.0
18-Jan-94	9.2	0.0	0.0	13.9	0.0	0.0	23.0	0.1	0.0
21-Jan-94	9.2	0.0	0.0	14.0	0.0	0.0	23.0	0.3	0.0
26-Jan-94	9.2	0.0	0.0	14.0	0.0	0.0	23.0	0.3	0.0
28-Jan-94	9.2	0.0	0.0	14.3	0.0	0.0	23.0	0.3	0.0
31-Jan-94	9.2	0.0	0.0	14.4	0.0	0.0	23.0	0.3	0.0
03-Feb-94	9.2	0.0	0.0	14.5	0.0	0.0	23.0	0.3	0.0
07-Feb-94	9.2	0.0	0.0	14.5	0.0	0.0	25.0	0.3	0.0
10-Feb-94	9.2	0.0	0.0	14.5	0.0	0.0	25.6	0.3	0.0
14-Feb-94	9.2	0.0	0.0	14.5	0.0	0.0	26.7	0.3	0.0
16-Feb-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.3	0.0
17-Feb-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.3	0.0
21-Feb-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.3	0.0
24-Feb-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.3	0.0
28-Feb-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.3	0.0
01-Mar-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.3	0.0

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Table 15. Mortality and Hatching of Mountain Whitefish Eggs Incubated at 9 mg/l Dissolved Oxygen. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 2: (501 eggs)			Tank 8: (1629 eggs)			Tank 9: (1147 eggs)		
	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25-Oct-93	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Oct-93	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Oct-93	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Nov-93	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Nov-93	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09-Nov-93	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Nov-93	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Nov-93	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Nov-93	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Nov-93	6.9	0.0	0.0	7.0	0.0	0.0	7.9	0.0	0.0
26-Nov-93	6.9	0.0	0.0	13.9	0.0	0.0	15.1	0.0	0.0
27-Nov-93	6.9	0.0	0.0	14.0	0.0	0.0	15.1	0.0	0.0
29-Nov-93	6.9	0.0	0.0	16.2	0.0	0.0	17.1	0.0	0.0
30-Nov-93	6.9	0.0	0.0	16.2	0.0	0.0	17.1	0.0	0.0
01-Dec-93	6.9	0.0	0.0	16.3	0.0	0.0	17.2	0.0	0.0
02-Dec-93	6.9	0.0	0.0	17.9	0.0	0.0	18.9	0.0	0.0
03-Dec-93	6.9	0.0	0.0	17.9	0.0	0.0	18.9	0.0	0.0
04-Dec-93	6.9	0.0	0.0	17.9	0.0	0.0	18.9	0.0	0.0
05-Dec-93	6.9	0.0	0.0	18.0	0.0	0.0	19.1	0.0	0.0
07-Dec-93	6.9	0.0	0.0	18.4	0.0	0.0	20.4	0.0	0.0
10-Dec-93	6.9	0.0	0.0	18.7	0.0	0.0	21.5	0.0	0.0
14-Dec-93	6.9	0.0	0.0	19.0	0.0	0.0	21.9	0.0	0.0
16-Dec-93	6.9	0.0	0.0	19.0	0.0	0.0	21.9	0.0	0.0
20-Dec-93	6.9	0.0	0.0	19.0	0.0	0.0	22.0	0.0	0.0
23-Dec-93	6.9	0.0	0.0	19.0	0.0	0.0	22.2	0.0	0.0
27-Dec-93	6.9	0.0	0.0	19.1	0.0	0.0	22.3	0.0	0.0
30-Dec-93	6.9	0.0	0.0	19.1	0.0	0.0	22.3	0.0	0.0
03-Jan-94	6.9	0.0	0.0	19.1	0.0	0.0	22.3	0.0	0.0
06-Jan-94	6.9	0.0	0.0	19.1	0.0	0.0	22.3	0.0	0.0
11-Jan-94	6.9	0.0	0.0	19.1	0.0	0.0	22.3	0.0	0.0
18-Jan-94	7.1	0.0	0.0	19.2	0.1	0.0	22.3	0.0	0.0
21-Jan-94	7.1	0.0	0.0	19.2	0.1	0.0	22.3	0.0	0.0
26-Jan-94	7.1	0.0	0.0	19.2	0.1	0.0	22.3	0.0	0.0
28-Jan-94	7.1	0.0	0.0	19.3	0.1	0.0	22.3	0.0	0.0
31-Jan-94	7.1	0.0	0.0	19.3	0.1	0.0	22.3	0.0	0.0
03-Feb-94	7.1	0.0	0.0	19.3	0.1	0.0	22.3	0.0	0.0
07-Feb-94	7.1	0.0	0.0	19.3	0.3	0.1	22.3	0.0	0.0
08-Feb-94	7.1	0.0	0.0	19.3	1.1	0.6	22.3	0.0	0.0
09-Feb-94	7.1	0.0	0.0	19.3	7.2	3.3	22.3	0.0	0.0
10-Feb-94	7.1	0.0	0.0	20.9	26.6	17.8	24.0	0.0	0.0
14-Feb-94	7.1	0.0	0.0	21.8	27.5	18.8	24.8	0.0	0.0
15-Feb-94	7.1	0.0	0.0	22.0	51.7	42.8	24.8	0.0	0.0
16-Feb-94	7.1	0.0	0.0	22.9	54.4	44.2	25.5	0.0	0.0
17-Feb-94	7.1	0.0	0.0	23.2	57.2	46.3	25.9	0.1	0.0
18-Feb-94	7.1	0.0	0.0	23.3	57.4	46.5	25.9	0.1	0.0

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Table 16. Mortality and Hatcjing of Mountain Whitefiish Eggs Incubated at 13.5 mg/l Dissolved Oxygen. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated.

	Tank 1: (509 eggs)			Tank 14: (795 eggs)			Tank 15: (851 eggs)		
	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.	Egg Mort.	Total Hatch	Larval Mort.
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25-Oct-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Oct-93	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29-Oct-93	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-Nov-93	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Nov-93	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09-Nov-93	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Nov-93	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Nov-93	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-Nov-93	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Nov-93	7.7	0.0	0.0	5.3	0.0	0.0	3.8	0.0	0.0
26-Nov-93	7.7	0.0	0.0	16.0	0.0	0.0	16.6	0.0	0.0
27-Nov-93	7.7	0.0	0.0	16.0	0.0	0.0	16.6	0.0	0.0
29-Nov-93	7.7	0.0	0.0	19.1	0.0	0.0	18.4	0.0	0.0
30-Nov-93	7.7	0.0	0.0	19.6	0.0	0.0	19.0	0.0	0.0
02-Dec-93	7.7	0.0	0.0	20.9	0.0	0.0	20.7	0.0	0.0
05-Dec-93	7.7	0.0	0.0	20.9	0.0	0.0	21.5	0.0	0.0
07-Dec-93	7.7	0.0	0.0	21.4	0.0	0.0	22.2	0.0	0.0
10-Dec-93	7.7	0.0	0.0	22.0	0.0	0.0	23.1	0.0	0.0
14-Dec-93	7.7	0.0	0.0	22.1	0.0	0.0	23.3	0.0	0.0
16-Dec-93	7.7	0.0	0.0	22.4	0.0	0.0	23.4	0.0	0.0
20-Dec-93	7.7	0.0	0.0	22.4	0.0	0.0	23.6	0.0	0.0
23-Dec-93	7.7	0.0	0.0	22.4	0.0	0.0	23.8	0.0	0.0
27-Dec-93	7.7	0.0	0.0	22.5	0.0	0.0	23.9	0.0	0.0
30-Dec-93	7.7	0.0	0.0	22.5	0.0	0.0	23.9	0.0	0.0
03-Jan-94	7.7	0.0	0.0	22.5	0.0	0.0	23.9	0.0	0.0
06-Jan-94	7.7	0.0	0.0	22.5	0.0	0.0	23.9	0.0	0.0
11-Jan-94	7.7	0.0	0.0	22.9	0.0	0.0	23.9	0.0	0.0
18-Jan-94	7.7	0.0	0.0	22.9	0.0	0.0	24.0	0.0	0.0
21-Jan-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.0	0.0
26-Jan-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.0	0.0
28-Jan-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.0	0.0
31-Jan-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.0	0.0
03-Feb-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.0	0.0
07-Feb-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.0	0.0
10-Feb-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.0	0.0
14-Feb-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.0	0.0
17-Feb-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.6	0.4
21-Feb-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.9	0.4
24-Feb-94	7.7	0.0	0.0	22.9	0.0	0.0	24.3	0.9	0.4
28-Feb-94	7.7	0.0	0.0	23.1	0.1	0.0	24.4	1.5	0.6
01-Mar-94	7.7	0.0	0.0	23.1	0.3	0.0	24.4	1.9	0.6
02-Mar-94	7.7	0.0	0.0	23.1	0.3	0.0	24.4	2.3	0.6
03-Mar-94	7.7	0.0	0.0	23.1	0.3	0.0	24.4	2.3	0.6
04-Mar-94	7.7	0.0	0.0	23.1	0.4	0.0	24.4	2.3	0.6
05-Mar-94	7.7	0.0	0.0	23.1	0.4	0.0	24.4	2.3	0.6

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Table 17. Mortality and Hatching of Mountain Whitefish Eggs Incubated at Various Levels of Dissolved Oxygen and Transferred to Different Oxygen Concentrations on March 28, 1994. The percent hatching was calculated from the number of live eggs remaining when hatching was initiated. Egg mortality is given for each group of eggs from the time of fertilization.

	OXYGEN TREATMENT TRANSFER											
	3 to 5 mg/l (564 eggs)		5 to 3 mg/l (261 eggs)		3 to 7 mg/l (489 eggs)		7 to 3 mg/l (261 eggs)		3 to 9 mg/l (542 eggs)		3 to 13.5 mg/l (533 eggs)	
	Egg Mort.	Total Hatch	Egg Mort.	Total Hatch	Egg Mort.	Total Hatch	Egg Mort.	Total Hatch	Egg Mort.	Total Hatch	Egg Mort.	Total Hatch
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
23-Nov-93	5.5	0.0	3.5	0.0	7.6	0.0	6.2	0.0	6.0	0.0	5.5	0.0
26-Nov-93	17.1	0.0	10.1	0.0	18.3	0.0	11.4	0.0	14.3	0.0	20.9	0.0
27-Nov-93	17.1	0.0	10.1	0.0	18.5	0.0	11.4	0.0	14.3	0.0	20.9	0.0
29-Nov-93	20.3	0.0	14.9	0.0	21.3	0.0	14.0	0.0	18.0	0.0	24.2	0.0
02-Dec-93	21.5	0.0	17.0	0.0	22.9	0.0	15.5	0.0	19.1	0.0	25.9	0.0
03-Dec-93	21.5	0.0	17.0	0.0	22.9	0.0	15.5	0.0	19.1	0.0	ND	ND
04-Dec-93	21.5	0.0	17.0	0.0	22.9	0.0	15.5	0.0	19.1	0.0	ND	ND
05-Dec-93	21.5	0.0	17.0	0.0	22.9	0.0	15.5	0.0	19.1	0.0	25.9	0.0
07-Dec-93	21.8	0.0	18.0	0.0	24.1	0.0	16.2	0.0	19.6	0.0	26.6	0.0
10-Dec-93	22.5	0.0	19.1	0.0	24.3	0.0	16.2	0.0	19.7	0.0	26.8	0.0
14-Dec-93	22.7	0.0	19.1	0.0	24.6	0.0	16.2	0.0	20.1	0.0	27.0	0.0
16-Dec-93	22.7	0.0	19.6	0.0	25.3	0.0	16.2	0.0	20.3	0.0	27.5	0.0
20-Dec-93	23.1	0.0	20.5	0.0	26.0	0.0	16.2	0.0	21.9	0.0	27.8	0.0
23-Dec-93	23.1	0.0	20.5	0.0	26.0	0.0	16.2	0.0	21.9	0.0	27.8	0.0
27-Dec-93	23.1	0.0	20.5	0.0	26.0	0.0	16.2	0.0	21.9	0.0	27.8	0.0
30-Dec-93	23.3	0.0	20.5	0.0	26.0	0.0	16.2	0.0	21.9	0.0	28.0	0.0
03-Jan-94	23.3	0.0	20.5	0.0	26.0	0.0	16.2	0.0	21.9	0.0	28.0	0.0
06-Jan-94	23.3	0.0	20.5	0.0	26.0	0.0	16.2	0.0	21.9	0.0	28.0	0.0
11-Jan-94	23.3	0.0	20.5	0.0	26.0	0.0	16.2	0.0	21.9	0.0	28.0	0.0
18-Jan-94	23.6	0.0	20.8	0.0	26.0	0.0	16.2	0.0	21.9	0.0	28.0	0.0
21-Jan-94	23.6	0.0	20.8	0.0	26.0	0.0	16.2	0.0	22.5	0.0	28.0	0.0
26-Jan-94	23.6	0.0	20.8	0.0	26.0	0.0	16.2	0.0	22.5	0.0	28.0	0.2
28-Jan-94	23.6	0.0	20.8	0.0	26.0	0.0	16.2	0.0	22.5	0.0	28.2	0.2
31-Jan-94	23.8	0.0	20.8	0.0	26.0	0.0	16.2	0.0	22.7	0.3	29.2	0.2
03-Feb-94	23.8	0.0	20.8	0.0	26.0	0.0	16.2	0.0	22.7	0.6	29.2	0.2
07-Feb-94	23.8	0.0	20.8	0.0	26.2	0.0	16.2	0.0	22.9	0.6	29.2	0.2
10-Feb-94	23.8	0.0	20.8	0.0	26.2	0.0	16.5	0.0	22.9	0.6	29.2	0.2
14-Feb-94	24.0	0.0	20.8	0.0	26.6	0.0	18.1	0.0	23.2	0.6	29.3	0.2
16-Feb-94	24.0	0.0	20.8	0.0	26.6	0.0	19.2	0.0	23.2	0.6	ND	ND
17-Feb-94	24.0	0.0	20.8	0.0	26.8	0.0	19.2	0.0	23.4	0.6	29.5	0.2
21-Feb-94	24.0	0.0	20.8	0.0	26.8	0.0	19.2	0.0	23.4	0.6	29.5	0.2
24-Feb-94	24.0	0.0	20.8	0.0	26.8	0.0	19.2	0.0	23.6	0.6	29.5	0.2
28-Feb-94	24.0	0.0	20.8	0.0	26.8	0.0	19.2	0.0	23.8	0.6	29.5	0.2
01-Mar-94	24.0	0.0	20.8	0.0	26.8	0.0	19.2	0.0	23.8	0.6	29.5	0.2
02-Mar-94	24.0	0.0	20.8	0.0	26.8	0.0	19.2	0.0	23.8	0.6	29.5	0.2
03-Mar-94	24.2	0.0	20.8	0.0	26.8	0.0	19.2	0.0	24.0	0.6	29.5	0.2
04-Mar-94	24.2	0.0	20.8	0.0	26.8	0.0	19.2	0.0	24.0	0.6	29.5	0.2
05-Mar-94	24.2	0.0	20.8	0.0	26.8	0.0	19.2	0.9	24.0	0.6	29.5	0.2
07-Mar-94	24.2	0.0	20.8	0.0	26.8	0.0	19.2	0.9	24.0	0.6	29.5	0.2
08-Mar-94	24.2	0.0	20.8	0.0	26.8	0.0	19.2	0.9	24.0	0.6	29.5	0.2
10-Mar-94	24.2	0.0	20.8	0.0	26.8	0.0	19.2	0.9	24.0	0.6	29.5	0.2
11-Mar-94	25.2	0.0	20.8	0.0	27.8	0.0	19.2	1.9	24.1	0.6	29.9	0.2

continued...

APPENDIX C:

OXYGEN CONSUMPTION OF BULL TROUT AND MOUNTAIN WHITEFISH EGGS INCUBATED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN

Table 18. Oxygen Consumption (Q) of Bull Trout Eggs and Alevins Incubated at Various Levels of Hypoxia. Tests were conducted by closed vessel respirometry at 2°C with (N) organisms per vessel. Q is given as μg O_2 consumed per hour per individual organism at each oxygen partial pressure (Po_2).

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (μg/h/egg)
25-Jan-94	3 eggs	9	replic1	148.0	1.366
25-Jan-94	3 eggs	9	replic1	132.7	0.427
25-Jan-94	3 eggs	9	replic1	95.7	0.905
25-Jan-94	3 eggs	9	replic1	80.2	0.513
25-Jan-94	3 eggs	9	replic1	55.9	0.499
25-Jan-94	3 eggs	9	replic1	41.9	0.549
25-Jan-94	3 eggs	9	replic1	30.9	0.246
25-Jan-94	3 eggs	9	replic1	27.3	0.178
25-Jan-94	3 eggs	9	replic1	25.3	0.131
25-Jan-94	3 eggs	9	replic1	14.4	0.050
25-Jan-94	3 eggs	9	replic1	10.0	0.025
25-Jan-94	3 eggs	9	replic2	148.1	1.467
25-Jan-94	3 eggs	9	replic2	131.2	0.599
25-Jan-94	3 eggs	9	replic2	94.6	1.130
25-Jan-94	3 eggs	9	replic2	75.7	0.674
25-Jan-94	3 eggs	9	replic2	56.5	0.539
25-Jan-94	3 eggs	9	replic2	43.5	0.434
25-Jan-94	3 eggs	9	replic2	27.1	0.199
25-Jan-94	3 eggs	9	replic2	26.4	0.270
25-Jan-94	3 eggs	9	replic2	20.3	0.158
25-Jan-94	3 eggs	9	replic2	11.7	0.116
25-Jan-94	3 eggs	9	replic2	6.5	0.020
25-Jan-94	3 eggs	9	replic3	149.1	1.123
25-Jan-94	3 eggs	9	replic3	132.6	0.703
25-Jan-94	3 eggs	9	replic3	95.6	0.903
25-Jan-94	3 eggs	9	replic3	78.6	0.588
25-Jan-94	3 eggs	9	replic3	57.1	0.509
25-Jan-94	3 eggs	9	replic3	40.6	0.400
25-Jan-94	3 eggs	9	replic3	30.3	0.136
25-Jan-94	3 eggs	9	replic3	25.3	0.207
25-Jan-94	3 eggs	9	replic3	24.3	0.146
25-Jan-94	3 eggs	9	replic3	11.3	0.016
25-Jan-94	3 eggs	9	replic3	9.4	0.012
25-Jan-94	3 eggs	7	replic1	150.3	1.250
25-Jan-94	3 eggs	7	replic1	134.5	0.783
25-Jan-94	3 eggs	7	replic1	95.4	0.855

continued...

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (μg/h/egg)
25-Jan-94	3 eggs	5	replic2	153.0	1.040
25-Jan-94	3 eggs	5	replic2	137.7	0.695
25-Jan-94	3 eggs	5	replic2	96.7	0.721
25-Jan-94	3 eggs	5	replic2	81.3	0.658
25-Jan-94	3 eggs	5	replic2	63.7	0.502
25-Jan-94	3 eggs	5	replic2	50.7	0.416
25-Jan-94	3 eggs	5	replic2	30.5	0.157
25-Jan-94	3 eggs	5	replic2	30.0	0.201
25-Jan-94	3 eggs	5	replic2	25.8	0.079
25-Jan-94	3 eggs	5	replic2	18.3	0.094
25-Jan-94	3 eggs	5	replic2	7.9	0.071
25-Jan-94	3 eggs	5	replic3	151.1	1.226
25-Jan-94	3 eggs	5	replic3	132.8	0.738
25-Jan-94	3 eggs	5	replic3	94.7	0.959
25-Jan-94	3 eggs	5	replic3	77.5	0.601
25-Jan-94	3 eggs	5	replic3	56.8	0.718
25-Jan-94	3 eggs	5	replic3	41.6	0.376
25-Jan-94	3 eggs	5	replic3	27.9	0.109
25-Jan-94	3 eggs	5	replic3	26.2	0.295
25-Jan-94	3 eggs	5	replic3	21.4	0.036
25-Jan-94	3 eggs	5	replic3	13.1	0.038
25-Jan-94	3 eggs	5	replic3	5.4	0.011
25-Jan-94	3 eggs	3	replic1	153.6	0.658
25-Jan-94	3 eggs	3	replic1	142.0	0.530
25-Jan-94	3 eggs	3	replic1	97.0	0.679
25-Jan-94	3 eggs	3	replic1	84.4	0.454
25-Jan-94	3 eggs	3	replic1	58.3	0.483
25-Jan-94	3 eggs	3	replic1	46.1	0.369
25-Jan-94	3 eggs	3	replic1	31.6	0.221
25-Jan-94	3 eggs	3	replic1	30.0	0.148
25-Jan-94	3 eggs	3	replic1	24.7	0.182
25-Jan-94	3 eggs	3	replic1	18.8	0.056
25-Jan-94	3 eggs	3	replic1	14.0	0.026
25-Jan-94	3 eggs	3	replic2	153.1	0.623
25-Jan-94	3 eggs	3	replic2	143.1	0.429
25-Jan-94	3 eggs	3	replic2	99.4	0.358
25-Jan-94	3 eggs	3	replic2	88.2	0.458
25-Jan-94	3 eggs	3	replic2	59.2	0.450
25-Jan-94	3 eggs	3	replic2	45.4	0.319
25-Jan-94	3 eggs	3	replic2	30.3	0.160
25-Jan-94	3 eggs	3	replic2	29.8	0.165

continued...

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (μg/h/egg)
25-Jan-94	3 eggs	13.5	replic3	40.3	0.287
25-Jan-94	3 eggs	13.5	replic3	28.0	0.203
25-Jan-94	3 eggs	13.5	replic3	27.9	0.177
25-Jan-94	3 eggs	13.5	replic3	20.3	0.192
25-Jan-94	3 eggs	13.5	replic3	15.8	0.020
25-Jan-94	3 eggs	13.5	replic3	10.1	0.042
02-Mar-94	2 eggs	13.5	replic1	149.5	2.896
02-Mar-94	2 eggs	13.5	replic1	136.1	2.267
02-Mar-94	2 eggs	13.5	replic1	124.9	1.399
02-Mar-94	2 eggs	13.5	replic1	115.1	1.596
02-Mar-94	2 eggs	13.5	replic1	97.4	1.519
02-Mar-94	2 eggs	13.5	replic1	83.5	0.972
02-Mar-94	2 eggs	13.5	replic1	71.1	0.870
02-Mar-94	2 eggs	13.5	replic1	58.7	0.738
02-Mar-94	2 eggs	13.5	replic2	149.4	3.600
02-Mar-94	2 eggs	13.5	replic2	134.0	2.416
02-Mar-94	2 eggs	13.5	replic2	121.8	1.577
02-Mar-94	2 eggs	13.5	replic2	111.6	1.528
02-Mar-94	2 eggs	13.5	replic2	95.7	1.459
02-Mar-94	2 eggs	13.5	replic2	82.3	0.976
02-Mar-94	2 eggs	13.5	replic2	68.9	1.013
02-Mar-94	2 eggs	13.5	replic2	55.3	0.763
02-Mar-94	2 eggs	13.5	replic3	148.6	3.760
02-Mar-94	2 eggs	13.5	replic3	134.6	1.731
02-Mar-94	2 eggs	13.5	replic3	123.3	1.796
02-Mar-94	2 eggs	13.5	replic3	112.2	1.565
02-Mar-94	2 eggs	13.5	replic3	97.5	1.190
02-Mar-94	2 eggs	13.5	replic3	85.4	0.992
02-Mar-94	2 eggs	13.5	replic3	73.7	0.768
02-Mar-94	2 eggs	13.5	replic3	62.2	0.733
02-Mar-94	2 eggs	7	replic1	149.1	3.022
02-Mar-94	2 eggs	7	replic1	136.4	1.713
02-Mar-94	2 eggs	7	replic1	125.8	1.469
02-Mar-94	2 eggs	7	replic1	115.5	1.446
02-Mar-94	2 eggs	7	replic1	99.1	0.733
02-Mar-94	2 eggs	7	replic1	89.8	0.855
02-Mar-94	2 eggs	7	replic1	78.4	0.756
02-Mar-94	2 eggs	7	replic1	66.7	0.642
02-Mar-94	2 eggs	7	replic2	149.2	1.929
02-Mar-94	2 eggs	7	replic2	139.2	1.728
02-Mar-94	2 eggs	7	replic2	127.9	1.632

continued...

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (μg/h/egg)
02-Mar-94	2 eggs	5	replic2	154.2	2.142
02-Mar-94	2 eggs	5	replic2	145.3	1.242
02-Mar-94	2 eggs	5	replic2	136.6	1.411
02-Mar-94	2 eggs	5	replic2	126.5	1.607
02-Mar-94	2 eggs	5	replic2	101.5	0.846
02-Mar-94	2 eggs	5	replic2	90.0	1.162
02-Mar-94	2 eggs	5	replic2	77.5	0.735
02-Mar-94	2 eggs	5	replic2	65.2	0.808
02-Mar-94	2 eggs	5	replic3	154.1	1.620
02-Mar-94	2 eggs	5	replic3	145.3	1.621
02-Mar-94	2 eggs	5	replic3	135.1	1.459
02-Mar-94	2 eggs	5	replic3	124.7	1.514
02-Mar-94	2 eggs	5	replic3	100.4	0.996
02-Mar-94	2 eggs	5	replic3	88.4	1.065
02-Mar-94	2 eggs	3	replic1	151.6	1.180
02-Mar-94	2 eggs	3	replic1	144.9	1.307
02-Mar-94	2 eggs	3	replic1	138.1	0.805
02-Mar-94	2 eggs	3	replic1	131.4	1.169
02-Mar-94	2 eggs	3	replic1	100.0	0.824
02-Mar-94	2 eggs	3	replic1	89.6	0.968
02-Mar-94	2 eggs	3	replic1	77.2	0.831
02-Mar-94	2 eggs	3	replic1	65.2	0.636
02-Mar-94	2 eggs	3	replic2	155.5	0.956
02-Mar-94	2 eggs	3	replic2	149.6	1.147
02-Mar-94	2 eggs	3	replic2	142.2	1.108
02-Mar-94	2 eggs	3	replic2	135.0	1.020
02-Mar-94	2 eggs	3	replic2	102.4	0.832
02-Mar-94	2 eggs	3	replic2	92.9	0.794
02-Mar-94	2 eggs	3	replic2	82.1	0.760
02-Mar-94	2 eggs	3	replic2	69.9	0.718
02-Mar-94	2 eggs	3	replic3	153.1	2.057
02-Mar-94	2 eggs	3	replic3	145.3	1.034
02-Mar-94	2 eggs	3	replic3	139.0	0.977
02-Mar-94	2 eggs	3	replic3	132.7	0.942
02-Mar-94	2 eggs	3	replic3	98.8	1.011
02-Mar-94	2 eggs	3	replic3	87.6	0.998
02-Mar-94	2 eggs	3	replic3	75.3	0.891
02-Mar-94	2 eggs	3	replic3	62.3	0.834
22-Apr-94	1 alevin	9	replic1	141.7	7.562
22-Apr-94	1 alevin	9	replic1	130.1	7.351
22-Apr-94	1 alevin	9	replic1	110.8	8.065

continued...

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (μg/h/egg)
22-Apr-94	1 alevin	7	replic2	21.9	3.1
22-Apr-94	1 alevin	7	replic3	139.0	7.127
22-Apr-94	1 alevin	7	replic3	127.2	7.684
22-Apr-94	1 alevin	7	replic3	108.6	7.228
22-Apr-94	1 alevin	7	replic3	86.7	6.000
22-Apr-94	1 alevin	7	replic3	73.3	7.186
22-Apr-94	1 alevin	7	replic3	56.4	5.936
22-Apr-94	1 alevin	7	replic3	40.8	6.244
22-Apr-94	1 alevin	7	replic3	24.9	4.581
22-Apr-94	1 alevin	7	replic3	13.4	2.6
22-Apr-94	1 alevin	5	replic1	142.4	4.493
22-Apr-94	1 alevin	5	replic1	134.1	5.718
22-Apr-94	1 alevin	5	replic1	120.2	5.315
22-Apr-94	1 alevin	5	replic1	103.7	4.429
22-Apr-94	1 alevin	5	replic1	80.5	4.603
22-Apr-94	1 alevin	5	replic1	66.7	5.501
22-Apr-94	1 alevin	5	replic1	48.7	5.187
22-Apr-94	1 alevin	5	replic1	32.2	5.556
22-Apr-94	1 alevin	5	replic1	17.1	3.4
22-Apr-94	1 alevin	5	replic2	142.9	6.557
22-Apr-94	1 alevin	5	replic2	132.7	6.392
22-Apr-94	1 alevin	5	replic2	117.2	6.041
22-Apr-94	1 alevin	5	replic2	97.4	6.003
22-Apr-94	1 alevin	5	replic2	78.9	5.037
22-Apr-94	1 alevin	5	replic2	63.3	6.551
22-Apr-94	1 alevin	5	replic2	45.5	6.088
22-Apr-94	1 alevin	5	replic2	29.0	4.861
22-Apr-94	1 alevin	5	replic2	16.6	2.7
22-Apr-94	1 alevin	5	replic3	140.4	8.266
22-Apr-94	1 alevin	5	replic3	128.2	7.385
22-Apr-94	1 alevin	5	replic3	110.1	7.294
22-Apr-94	1 alevin	5	replic3	87.1	6.983
22-Apr-94	1 alevin	5	replic3	75.9	7.847
22-Apr-94	1 alevin	5	replic3	56.5	7.287
22-Apr-94	1 alevin	5	replic3	41.7	7.137
22-Apr-94	1 alevin	5	replic3	24.1	4.749
22-Apr-94	1 alevin	5	replic3	12.8	2.2
22-Apr-94	1 alevin	3	replic1	146.0	4.007
22-Apr-94	1 alevin	3	replic1	140.2	3.313
22-Apr-94	1 alevin	3	replic1	131.6	3.498
22-Apr-94	1 alevin	3	replic1	119.6	3.721

continued...

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (μg/h/egg)
22-Apr-94	1 alevin	13.5	replic3	136.4	9.493
22-Apr-94	1 alevin	13.5	replic3	122.5	8.102
22-Apr-94	1 alevin	13.5	replic3	102.7	7.608
22-Apr-94	1 alevin	13.5	replic3	77.2	7.681
22-Apr-94	1 alevin	13.5	replic3	69.2	8.868
22-Apr-94	1 alevin	13.5	replic3	49.6	6.133
22-Apr-94	1 alevin	13.5	replic3	38.4	6.093
22-Apr-94	1 alevin	13.5	replic3	22.0	4.715
22-Apr-94	1 alevin	13.5	replic3	10.7	2.2
28-Apr-94	1 alevin	9	replic1	141.5	7.898
28-Apr-94	1 alevin	9	replic1	130.3	5.723
28-Apr-94	1 alevin	9	replic1	115.1	6.965
28-Apr-94	1 alevin	9	replic1	94.2	6.527
28-Apr-94	1 alevin	9	replic1	71.7	9.844
28-Apr-94	1 alevin	9	replic1	58.0	8.212
28-Apr-94	1 alevin	9	replic1	44.6	6.348
28-Apr-94	1 alevin	9	replic1	30.1	5.822
28-Apr-94	1 alevin	9	replic1	26.6	3.517
28-Apr-94	1 alevin	9	replic2	137.4	12.144
28-Apr-94	1 alevin	9	replic2	120.4	9.355
28-Apr-94	1 alevin	9	replic2	97.4	10.794
28-Apr-94	1 alevin	9	replic2	65.5	11.159
28-Apr-94	1 alevin	9	replic2	63.4	12.799
28-Apr-94	1 alevin	9	replic2	48.2	8.255
28-Apr-94	1 alevin	9	replic2	34.1	7.826
28-Apr-94	1 alevin	9	replic2	24.7	5.154
28-Apr-94	1 alevin	9	replic2	20.5	4.762
28-Apr-94	1 alevin	9	replic3	135.7	12.414
28-Apr-94	1 alevin	9	replic3	116.7	10.690
28-Apr-94	1 alevin	9	replic3	94.0	9.124
28-Apr-94	1 alevin	9	replic3	69.7	6.603
28-Apr-94	1 alevin	9	replic3	63.4	10.949
28-Apr-94	1 alevin	9	replic3	49.7	7.225
28-Apr-94	1 alevin	9	replic3	36.6	6.949
28-Apr-94	1 alevin	9	replic3	24.2	4.391
28-Apr-94	1 alevin	9	replic3	23.3	4.375
28-Apr-94	1 alevin	7	replic1	140.8	7.817
28-Apr-94	1 alevin	7	replic1	128.8	6.833
28-Apr-94	1 alevin	7	replic1	112.8	6.951
28-Apr-94	1 alevin	7	replic1	92.5	6.335
28-Apr-94	1 alevin	7	replic1	71.5	7.076

continued...

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (μg/h/egg)
28-Apr-94	1 alevin	5	replic3	129.7	7.220
28-Apr-94	1 alevin	5	replic3	112.7	7.617
28-Apr-94	1 alevin	5	replic3	90.5	7.261
28-Apr-94	1 alevin	5	replic3	71.2	7.565
28-Apr-94	1 alevin	5	replic3	60.7	6.324
28-Apr-94	1 alevin	5	replic3	48.5	7.307
28-Apr-94	1 alevin	5	replic3	32.9	6.132
28-Apr-94	1 alevin	5	replic3	24.6	4.752
28-Apr-94	1 alevin	3	replic1	146.0	4.520
28-Apr-94	1 alevin	3	replic1	138.8	4.475
28-Apr-94	1 alevin	3	replic1	129.1	4.001
28-Apr-94	1 alevin	3	replic1	117.3	3.756
28-Apr-94	1 alevin	3	replic1	76.7	4.896
28-Apr-94	1 alevin	3	replic1	69.2	4.777
28-Apr-94	1 alevin	3	replic1	60.8	4.353
28-Apr-94	1 alevin	3	replic1	51.1	3.829
28-Apr-94	1 alevin	3	replic1	24.6	3.403
28-Apr-94	1 alevin	3	replic2	146.8	4.227
28-Apr-94	1 alevin	3	replic2	140.7	3.649
28-Apr-94	1 alevin	3	replic2	131.4	4.513
28-Apr-94	1 alevin	3	replic2	118.4	4.583
28-Apr-94	1 alevin	3	replic2	76.8	4.214
28-Apr-94	1 alevin	3	replic2	70.2	4.636
28-Apr-94	1 alevin	3	replic2	62.0	4.714
28-Apr-94	1 alevin	3	replic2	52.4	3.817
28-Apr-94	1 alevin	3	replic2	32.1	3.735
28-Apr-94	1 alevin	3	replic3	145.9	4.577
28-Apr-94	1 alevin	3	replic3	138.9	4.177
28-Apr-94	1 alevin	3	replic3	129.1	4.239
28-Apr-94	1 alevin	3	replic3	116.8	3.714
28-Apr-94	1 alevin	3	replic3	77.4	3.912
28-Apr-94	1 alevin	3	replic3	71.0	4.265
28-Apr-94	1 alevin	3	replic3	63.6	3.814
28-Apr-94	1 alevin	3	replic3	53.4	4.413
28-Apr-94	1 alevin	3	replic3	34.6	3.829
28-Apr-94	1 alevin	13.5	replic1	141.0	13.517
28-Apr-94	1 alevin	13.5	replic1	126.2	5.378
28-Apr-94	1 alevin	13.5	replic1	113.0	6.464
28-Apr-94	1 alevin	13.5	replic1	96.2	5.381
28-Apr-94	1 alevin	13.5	replic1	73.3	9.520
28-Apr-94	1 alevin	13.5	replic1	62.2	6.071

continued...

Table 19. Oxygen Consumption (Q) of Mountain Whitefish Eggs Incubated at Various Levels of Hypoxia. Oxygen consumption was measured by closed vessel respirometry at 2°C with (N) eggs per vessel. Q is given as $\mu g\ O_2$ consumed per hour per egg at each oxygen partial pressure (Po_2).

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (ug/h//egg)
20-Jan-94	20	13.5mg	replic1	133.3	0.4002
20-Jan-94	20	13.5mg	replic1	107.2	0.1970
20-Jan-94	20	13.5mg	replic1	78.2	0.3342
20-Jan-94	20	13.5mg	replic1	51.5	0.1996
20-Jan-94	20	13.5mg	replic1	44.8	0.1255
20-Jan-94	20	13.5mg	replic1	31.1	0.0778
20-Jan-94	20	13.5mg	replic2	136.4	0.4524
20-Jan-94	20	13.5mg	replic2	111.9	0.1288
20-Jan-94	20	13.5mg	replic2	84.6	0.3223
20-Jan-94	20	13.5mg	replic2	55.4	0.2511
20-Jan-94	20	13.5mg	replic2	41.6	0.1780
20-Jan-94	20	13.5mg	replic2	25.9	0.0682
20-Jan-94	20	13.5mg	replic3	134.2	0.3988
20-Jan-94	20	13.5mg	replic3	108.5	0.0959
20-Jan-94	20	13.5mg	replic3	85.3	0.2937
20-Jan-94	20	13.5mg	replic3	55.2	0.2042
20-Jan-94	20	13.5mg	replic3	42.0	0.1755
20-Jan-94	20	13.5mg	replic3	24.9	0.0795
20-Jan-94	20	3mg	replic1	139.5	0.3522
20-Jan-94	20	3mg	replic1	120.8	0.1151
20-Jan-94	20	3mg	replic1	87.1	0.2621
20-Jan-94	20	3mg	replic1	66.4	0.2054
20-Jan-94	20	3mg	replic1	45.7	0.1226
20-Jan-94	20	3mg	replic1	31.0	0.0870
20-Jan-94	20	3mg	replic2	140.1	0.3531
20-Jan-94	20	3mg	replic2	121.9	0.1364
20-Jan-94	20	3mg	replic2	86.2	0.2989
20-Jan-94	20	3mg	replic2	62.4	0.2244
20-Jan-94	20	3mg	replic2	46.2	0.1061
20-Jan-94	20	3mg	replic2	32.7	0.0862
20-Jan-94	20	3mg	replic3	138.4	0.3408
20-Jan-94	20	3mg	replic3	121.7	0.0940
20-Jan-94	20	3mg	replic3	83.5	0.3140
20-Jan-94	20	3mg	replic3	57.9	0.1946
20-Jan-94	20	3mg	replic3	42.3	0.1361
20-Jan-94	20	3mg	replic3	25.4	0.0887
20-Jan-94	20	5mg	replic1	134.4	0.5699
20-Jan-94	20	5mg	replic1	109.5	0.1038
20-Jan-94	20	5mg	replic1	85.2	0.3552
20-Jan-94	20	5mg	replic1	63.2	0.1993
20-Jan-94	20	5mg	replic1	43.5	0.1537
20-Jan-94	20	5mg	replic1	24.4	0.1088
20-Jan-94	20	5mg	replic2	132.5	0.4169
20-Jan-94	20	5mg	replic2	112.5	0.1097
20-Jan-94	20	5mg	replic2	83.3	0.3486
20-Jan-94	20	5mg	replic2	60.2	0.2093

continued...

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po$_2$ (mm Hg)	Q (ug/h//egg)
09-Feb-94	10	13.45	replic1	48.9	0.2234
09-Feb-94	10	13.45	replic1	38.7	0.1075
09-Feb-94	10	13.45	replic1	31.4	0.0987
09-Feb-94	10	13.45	replic1	24.3	0.0742
09-Feb-94	10	13.45	replic2	145.2	0.6746
09-Feb-94	10	13.45	replic2	119.4	0.8233
09-Feb-94	10	13.45	replic2	96.5	0.4547
09-Feb-94	10	13.45	replic2	95.7	0.3805
09-Feb-94	10	13.45	replic2	78.7	0.3611
09-Feb-94	10	13.45	replic2	78.0	0.2992
09-Feb-94	10	13.45	replic2	61.6	0.2649
09-Feb-94	10	13.45	replic2	49.7	0.1748
09-Feb-94	10	13.45	replic2	41.0	0.1065
09-Feb-94	10	13.45	replic2	32.1	0.1466
09-Feb-94	10	13.45	replic2	23.5	0.0725
09-Feb-94	10	13.45	replic3	141.3	0.8080
09-Feb-94	10	13.45	replic3	115.9	0.6673
09-Feb-94	10	13.45	replic3	96.7	0.3845
09-Feb-94	10	13.45	replic3	91.6	0.4054
09-Feb-94	10	13.45	replic3	80.2	0.3610
09-Feb-94	10	13.45	replic3	74.5	0.2469
09-Feb-94	10	13.45	replic3	60.5	0.2288
09-Feb-94	10	13.45	replic3	48.5	0.1772
09-Feb-94	10	13.45	replic3	40.1	0.0948
09-Feb-94	10	13.45	replic3	32.4	0.1222
09-Feb-94	10	13.45	replic3	24.5	0.0727
09-Feb-94	10	3	replic1	147.1	0.4561
09-Feb-94	10	3	replic1	130.3	0.4242
09-Feb-94	10	3	replic1	115.0	0.3779
09-Feb-94	10	3	replic1	97.3	0.3645
09-Feb-94	10	3	replic1	94.3	0.2789
09-Feb-94	10	3	replic1	78.4	0.2991
09-Feb-94	10	3	replic1	62.8	0.2183
09-Feb-94	10	3	replic1	49.8	0.1583
09-Feb-94	10	3	replic1	39.8	0.1411
09-Feb-94	10	3	replic1	30.8	0.1023
09-Feb-94	10	3	replic1	23.9	0.0586
09-Feb-94	10	3	replic2	150.8	0.4665
09-Feb-94	10	3	replic2	135.0	0.5068
09-Feb-94	10	3	replic2	118.7	0.4086
09-Feb-94	10	3	replic2	102.5	0.3398
09-Feb-94	10	3	replic2	96.6	0.3947
09-Feb-94	10	3	replic2	78.8	0.2856
09-Feb-94	10	3	replic2	63.6	0.2456
09-Feb-94	10	3	replic2	51.4	0.1767
09-Feb-94	10	3	replic2	41.2	0.1440
09-Feb-94	10	3	replic2	32.1	0.1157
09-Feb-94	10	3	replic2	24.7	0.0686
09-Feb-94	10	3	replic3	146.6	0.4947
09-Feb-94	10	3	replic3	131.3	0.4308
09-Feb-94	10	3	replic3	115.7	0.3870

continued...

Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (ug/h//egg)
09-Feb-94	10	7mg	replic1	25.6	0.0487
09-Feb-94	10	7mg	replic2	146.1	0.5451
09-Feb-94	10	7mg	replic2	125.2	0.6033
09-Feb-94	10	7mg	replic2	103.7	0.4982
09-Feb-94	10	7mg	replic2	94.4	0.4718
09-Feb-94	10	7mg	replic2	82.7	0.3723
09-Feb-94	10	7mg	replic2	73.4	0.2996
09-Feb-94	10	7mg	replic2	57.0	0.2254
09-Feb-94	10	7mg	replic2	49.3	0.2055
09-Feb-94	10	7mg	replic2	37.4	0.1551
09-Feb-94	10	7mg	replic2	26.2	0.1426
09-Feb-94	10	7mg	replic2	16.7	0.0777
09-Feb-94	10	7mg	replic3	140.0	0.8529
09-Feb-94	10	7mg	replic3	113.7	0.7033
09-Feb-94	10	7mg	replic3	93.3	0.2812
09-Feb-94	10	7mg	replic3	93.0	0.4332
09-Feb-94	10	7mg	replic3	78.3	0.2864
09-Feb-94	10	7mg	replic3	75.5	0.3559
09-Feb-94	10	7mg	replic3	62.3	0.2529
09-Feb-94	10	7mg	replic3	49.9	0.1337
09-Feb-94	10	7mg	replic3	40.4	0.1564
09-Feb-94	10	7mg	replic3	30.8	0.1124
09-Feb-94	10	7mg	replic3	23.9	0.0571
09-Feb-94	10	9mg	replic1	141.2	0.7364
09-Feb-94	10	9mg	replic1	118.9	0.5601
09-Feb-94	10	9mg	replic1	99.3	0.5085
09-Feb-94	10	9mg	replic1	95.0	0.4722
09-Feb-94	10	9mg	replic1	80.3	0.3579
09-Feb-94	10	9mg	replic1	76.1	0.2499
09-Feb-94	10	9mg	replic1	60.4	0.2796
09-Feb-94	10	9mg	replic1	49.8	0.1448
09-Feb-94	10	9mg	replic1	40.7	0.1372
09-Feb-94	10	9mg	replic1	31.3	0.1284
09-Feb-94	10	9mg	replic1	23.2	0.0726
09-Feb-94	10	9mg	replic2	139.4	0.7878
09-Feb-94	10	9mg	replic2	112.9	0.6976
09-Feb-94	10	9mg	replic2	93.3	0.3043
09-Feb-94	10	9mg	replic2	92.7	0.3691
09-Feb-94	10	9mg	replic2	78.5	0.2435
09-Feb-94	10	9mg	replic2	75.3	0.3648
09-Feb-94	10	9mg	replic2	63.4	0.2430
09-Feb-94	10	9mg	replic2	49.2	0.1856
09-Feb-94	10	9mg	replic2	40.4	0.0915
09-Feb-94	10	9mg	replic2	31.9	0.1393
09-Feb-94	10	9mg	replic2	23.6	0.0621
09-Feb-94	10	9mg	replic3	144.6	0.5673
09-Feb-94	10	9mg	replic3	123.5	0.5949
09-Feb-94	10	9mg	replic3	103.4	0.4407
09-Feb-94	10	9mg	replic3	97.6	0.3363
09-Feb-94	10	9mg	replic3	86.0	0.3015
09-Feb-94	10	9mg	replic3	81.1	0.2681

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Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po, (mm Hg)	Q (ug/h//egg)
23-Feb-94	7	3mg	replic3	46.7	0.225
23-Feb-94	7	3mg	replic3	26.8	0.087
23-Feb-94	7	5mg	replic1	143.1	0.796
23-Feb-94	7	5mg	replic1	128.0	0.624
23-Feb-94	7	5mg	replic1	108.6	0.768
23-Feb-94	7	5mg	replic1	91.1	0.446
23-Feb-94	7	5mg	replic1	79.0	0.337
23-Feb-94	7	5mg	replic1	69.8	0.216
23-Feb-94	7	5mg	replic1	50.7	0.244
23-Feb-94	7	5mg	replic1	30.3	0.092
23-Feb-94	7	5mg	replic2	140.7	0.946
23-Feb-94	7	5mg	replic2	124.6	0.601
23-Feb-94	7	5mg	replic2	101.7	1.017
23-Feb-94	7	5mg	replic2	76.7	0.737
23-Feb-94	7	5mg	replic2	60.7	0.466
23-Feb-94	7	5mg	replic2	57.1	0.532
23-Feb-94	7	5mg	replic2	35.4	0.247
23-Feb-94	7	5mg	replic2	16.8	0.063
23-Feb-94	7	5mg	replic3	141.0	0.980
23-Feb-94	7	5mg	replic3	123.1	0.680
23-Feb-94	7	5mg	replic3	102.8	0.744
23-Feb-94	7	5mg	replic3	83.6	0.542
23-Feb-94	7	5mg	replic3	68.8	0.367
23-Feb-94	7	5mg	replic3	66.2	0.340
23-Feb-94	7	5mg	replic3	46.0	0.201
23-Feb-94	7	5mg	replic3	27.4	0.091
23-Feb-94	7	7mg	replic1	138.6	1.249
23-Feb-94	7	7mg	replic1	118.8	0.605
23-Feb-94	7	7mg	replic1	103.0	0.511
23-Feb-94	7	7mg	replic1	89.0	0.423
23-Feb-94	7	7mg	replic1	77.0	0.295
23-Feb-94	7	7mg	replic1	68.4	0.225
23-Feb-94	7	7mg	replic1	52.6	0.180
23-Feb-94	7	7mg	replic1	32.3	0.134
23-Feb-94	7	7mg	replic2	139.4	1.112
23-Feb-94	7	7mg	replic2	119.5	0.735
23-Feb-94	7	7mg	replic2	100.6	0.596
23-Feb-94	7	7mg	replic2	84.2	0.491
23-Feb-94	7	7mg	replic2	71.2	0.294
23-Feb-94	7	7mg	replic2	67.2	0.281
23-Feb-94	7	7mg	replic2	48.6	0.203
23-Feb-94	7	7mg	replic2	27.9	0.118
23-Feb-94	7	7mg	replic3	136.7	1.072
23-Feb-94	7	7mg	replic3	118.8	0.677
23-Feb-94	7	7mg	replic3	103.0	0.514
23-Feb-94	7	7mg	replic3	87.3	0.631
23-Feb-94	7	7mg	replic3	74.4	0.272
23-Feb-94	7	7mg	replic3	68.6	0.208
23-Feb-94	7	7mg	replic3	50.7	0.231
23-Feb-94	7	7mg	replic3	30.9	0.097
23-Feb-94	7	9mg	replic1	144.5	0.750

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Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (ug/h//egg)
24-Mar-94	8	T6-3mg	replic1	153.1	0.5571
24-Mar-94	8	T6-3mg	replic1	144.2	0.7772
24-Mar-94	8	T6-3mg	replic1	135.6	0.5284
24-Mar-94	8	T6-3mg	replic1	127.2	0.5154
24-Mar-94	8	T6-3mg	replic1	116.0	0.5685
24-Mar-94	8	T6-3mg	replic1	100.2	0.5562
24-Mar-94	8	T6-3mg	replic1	83.3	0.4488
24-Mar-94	8	T6-3mg	replic2	153.0	0.6103
24-Mar-94	8	T6-3mg	replic2	144.3	0.6878
24-Mar-94	8	T6-3mg	replic2	135.9	0.5503
24-Mar-94	8	T6-3mg	replic2	127.2	0.4992
24-Mar-94	8	T6-3mg	replic2	115.3	0.5934
24-Mar-94	8	T6-3mg	replic2	100.6	0.4310
24-Mar-94	8	T6-3mg	replic2	85.6	0.3974
24-Mar-94	8	T6-3mg	replic3	153.0	0.5409
24-Mar-94	8	T6-3mg	replic3	145.5	0.5804
24-Mar-94	8	T6-3mg	replic3	137.8	0.5492
24-Mar-94	8	T6-3mg	replic3	129.6	0.4498
24-Mar-94	8	T6-3mg	replic3	118.3	0.5683
24-Mar-94	8	T6-3mg	replic3	103.7	0.4351
24-Mar-94	8	T6-3mg	replic3	90.6	0.2697
24-Mar-94	8	T6-3mg	replic4	153.2	0.9590
24-Mar-94	8	T6-3mg	replic4	143.7	0.6131
24-Mar-94	8	T6-3mg	replic4	136.5	0.4713
24-Mar-94	8	T6-3mg	replic4	127.9	0.5437
24-Mar-94	8	T6-3mg	replic4	115.6	0.6023
24-Mar-94	8	T6-3mg	replic4	100.1	0.4980
24-Mar-94	8	T6-3mg	replic4	86.0	0.3041
24-Mar-94	8	T7-3mg	replic1	147.4	1.5809
24-Mar-94	8	T7-3mg	replic1	137.6	0.1629
24-Mar-94	8	T7-3mg	replic1	130.4	0.9426
24-Mar-94	8	T7-3mg	replic1	118.3	0.5742
24-Mar-94	8	T7-3mg	replic1	107.2	0.4199
24-Mar-94	8	T7-3mg	replic1	93.1	0.4849
24-Mar-94	8	T7-3mg	replic1	77.0	0.3675
24-Mar-94	8	T7-3mg	replic2	152.3	0.9630
24-Mar-94	8	T7-3mg	replic2	143.2	0.5208
24-Mar-94	8	T7-3mg	replic2	135.9	0.5526
24-Mar-94	8	T7-3mg	replic2	128.0	0.4039
24-Mar-94	8	T7-3mg	replic2	116.0	0.6610
24-Mar-94	8	T7-3mg	replic2	100.0	0.4407
24-Mar-94	8	T7-3mg	replic2	87.1	0.2414
24-Mar-94	8	T7-3mg	replic3	147.7	1.3750
24-Mar-94	8	T7-3mg	replic3	138.2	0.3457
24-Mar-94	8	T7-3mg	replic3	130.6	0.8463
24-Mar-94	8	T7-3mg	replic3	119.7	0.5617
24-Mar-94	8	T7-3mg	replic3	108.6	0.4997
24-Mar-94	8	T7-3mg	replic3	94.2	0.5156
24-Mar-94	8	T7-3mg	replic3	77.1	0.4945
24-Mar-94	8	T7-3mg	replic4	153.9	0.7677
24-Mar-94	8	T7-3mg	replic4	144.7	0.6907

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Date	N/test	Oxygen Treatment (mg/l O2)	Replicate	Po_2 (mm Hg)	Q (ug/h//egg)
11-Apr-94	4	3 to 7mg	replic1	144.0	0.665
11-Apr-94	4	3 to 7mg	replic1	133.0	0.860
11-Apr-94	4	3 to 7mg	replic1	119.3	0.703
11-Apr-94	4	3 to 7mg	replic1	105.3	0.607
11-Apr-94	4	3 to 7mg	replic2	151.6	0.485
11-Apr-94	4	3 to 7mg	replic2	146.8	0.433
11-Apr-94	4	3 to 7mg	replic2	136.3	0.789
11-Apr-94	4	3 to 7mg	replic2	120.8	0.629
11-Apr-94	4	3 to 7mg	replic2	105.9	0.482
11-Apr-94	4	3 to 7mg	replic3	152.3	0.255
11-Apr-94	4	3 to 7mg	replic3	146.4	0.814
11-Apr-94	4	3 to 7mg	replic3	133.3	1.100
11-Apr-94	4	3 to 7mg	replic3	118.7	0.667
11-Apr-94	4	3 to 7mg	replic3	104.5	0.719
11-Apr-94	4	3 to 9	replic1	149.9	0.486
11-Apr-94	4	3 to 9	replic1	142.5	0.915
11-Apr-94	4	3 to 9	replic1	129.3	1.006
11-Apr-94	4	3 to 9	replic1	114.2	0.821
11-Apr-94	4	3 to 9	replic1	99.8	0.628
11-Apr-94	4	3 to 9	replic2	150.6	0.340
11-Apr-94	4	3 to 9	replic2	145.2	0.666
11-Apr-94	4	3 to 9	replic2	132.8	1.099
11-Apr-94	4	3 to 9	replic2	120.3	0.477
11-Apr-94	4	3 to 9	replic2	108.4	0.689
11-Apr-94	4	3 to 9	replic3	150.8	0.205
11-Apr-94	4	3 to 9	replic3	146.3	0.579
11-Apr-94	4	3 to 9	replic3	135.7	0.880
11-Apr-94	4	3 to 9	replic3	123.7	0.526
11-Apr-94	4	3 to 9	replic3	112.2	0.543
13-Apr-94	6	3 to 13.4(t15)	replic1	144.8	0.470
13-Apr-94	6	3 to 13.4(t15)	replic1	135.0	0.896
13-Apr-94	6	3 to 13.4(t15)	replic1	120.8	0.810
13-Apr-94	6	3 to 13.4(t15)	replic2	147.4	1.056
13-Apr-94	6	3 to 13.4(t15)	replic2	134.7	0.908
13-Apr-94	6	3 to 13.4(t15)	replic2	121.1	0.751
13-Apr-94	6	3 to 13.4(t15)	replic3	148.1	1.212
13-Apr-94	6	3 to 13.4(t15)	replic3	134.9	0.856
13-Apr-94	6	3 to 13.4(t15)	replic3	121.7	0.752
13-Apr-94	6	3 to 3(t7)	replic1	149.1	0.737
13-Apr-94	6	3 to 3(t7)	replic1	139.2	0.720
13-Apr-94	6	3 to 3(t7)	replic1	127.4	0.669
13-Apr-94	6	3 to 3(t7)	replic2	152.0	0.618
13-Apr-94	6	3 to 3(t7)	replic2	142.6	0.744
13-Apr-94	6	3 to 3(t7)	replic2	129.6	0.783
13-Apr-94	6	3 to 3(t7)	replic3	150.3	0.763
13-Apr-94	6	3 to 3(t7)	replic3	140.0	0.750
13-Apr-94	6	3 to 3(t7)	replic3	127.7	0.687
13-Apr-94	6	3 to 5(t13)	replic1	145.6	0.561
13-Apr-94	6	3 to 5(t13)	replic1	136.2	0.751
13-Apr-94	6	3 to 5(t13)	replic1	123.7	0.717
13-Apr-94	6	3 to 5(t13)	replic2	152.3	0.827

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APPENDIX D:

CARDIAC RATES OF MOUNTAIN WHITEFISH EMBRYOS REARED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN

Table 20. Cardiac Rates of Mountain Whitefish Embryos. Values are beats/min and were derived from the mean of the times required for two sets of 30 contractions and one set of 60 contractions measured at 2 ±0.2°C. The columns with arrows (3→) indicate eggs which had been transferred from the 3 mg/l hypoxic treatment to less hypoxic conditions on March 28, 1994.

	OXYGEN TREATMENT (mg/l O_2)																		
	13.5	9	5	7	3	3	3	9	9	3→9	7	7	3→7	5	5	3→5	13.5	13.5	3→13.5
Date	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 9	Tank 10	Tank 11	Tank 11	Tank 12	Tank 13	Tank 13	Tank 14	Tank 15	Tank 15
O4-JAN-94	32.2	34.3	32.6	30.1	29.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
O4-JAN-94	26.3	30.6	28.3	26.3	26.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
O4-JAN-94	28.7	30.5	26.5	28.5	26.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
O4-JAN-94	30.1	34.3	23.3	27.3	22.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
O4-JAN-94	31.3	31.4	26.8	29.7	21.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
O4-JAN-94	29.6	29.1	26.4	28.2	24.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-JAN-94	26.4	33.4	28.5	31.0	27.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-JAN-94	26.1	34.2	28.3	29.3	28.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-JAN-94	27.2	29.2	28.9	29.2	28.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-JAN-94	27.0	28.5	27.8	27.9	28.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-JAN-94	27.6	28.7	28.6	28.4	27.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-JAN-94	27.2	29.1	27.6	28.1	27.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
21-JAN-94	29.7	32.3	30.8	30.9	29.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
21-JAN-94	29.0	30.8	31.1	30.3	25.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
21-JAN-94	28.1	29.2	28.3	29.3	25.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
21-JAN-94	28.8	30.3	29.7	29.0	26.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
21-JAN-94	27.2	29.0	30.3	30.1	26.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
21-JAN-94	30.1	31.1	28.7	27.8	25.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
27-JAN-94	31.2	33.1	28.9	29.6	28.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
27-JAN-94	32.7	32.4	29.6	26.9	25.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
27-JAN-94	31.8	30.1	30.2	29.0	28.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
27-JAN-94	30.8	30.7	29.7	32.2	24.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

continued...

	OXYGEN TREATMENT (mg/l O_2)																		
	13.5	9	5	7	3	3	3	9	9	3→9	7	7	3→7	5	5	3→5	13.5	13.5	3→⊓
Date	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 9	Tank 10	Tank 11	Tank 11	Tank 12	Tank 13	Tank 13	Tank 14	Tank 15	Tank 15
22-MAR-94	ND	ND	ND	ND	36.6	31.0	32.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22-MAR-94	ND	ND	ND	ND	34.3	28.8	31.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22-MAR-94	ND	ND	ND	ND	35.6	28.9	34.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22-MAR-94	ND	ND	ND	ND	32.6	26.8	31.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22-MAR-94	ND	ND	ND	ND	30.3	25.5	30.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
06-APR-94	31.8	30.9	32.9	36.2	32.3	30.2	33.2	38.7	36.5	36.0	38.3	35.9	35.0	33.3	37.5	31.0	47.4	40.0	34.2
06-APR-94	31.2	32.5	31.6	35.5	30.3	28.3	32.5	35.3	37.5	36.0	34.6	35.6	34.0	35.8	39.4	32.7	45.4	41.2	35.2
06-APR-94	34.8	33.9	32.1	31.2	31.9	28.1	27.8	41.2	36.6	34.8	37.9	35.3	34.0	36.0	32.9	35.2	44.6	44.1	36.7
06-APR-94	31.5	33.3	28.7	39.1	30.2	29.0	34.4	38.9	36.7	35.0	38.3	33.0	33.5	34.8	38.7	35.4	41.4	43.7	37.1
06-APR-94	32.4	33.8	31.8	35.3	31.8	32.1	32.6	39.0	40.3	32.9	34.7	32.5	32.4	32.9	33.1	34.3	43.7	44.6	34.8
06-APR-94	33.3	33.0	29.5	34.3	33.2	28.2	30.7	39.4	39.3	36.2	34.4	33.5	32.2	32.7	36.0	35.8	46.8	43.2	36.6
20-APR-94	40.3	40.3	34.0	40.8	30.5	34.1	33.4	43.7	38.3	40.7	39.1	38.9	40.8	42.0	40.9	33.3	ND	ND	38.6
20-APR-94	40.0	39.1	33.4	37.6	30.7	33.2	33.5	39.0	38.7	35.7	38.3	38.2	37.2	35.4	38.9	35.3	ND	ND	39.4
20-APR-94	37.3	39.7	35.0	37.5	33.1	32.9	32.9	36.1	38.6	35.0	35.8	35.8	35.8	36.5	39.7	37.1	ND	ND	42.2
20-APR-94	39.6	37.3	34.4	40.1	32.0	33.3	31.6	41.9	37.9	35.4	38.6	35.2	36.5	38.1	38.3	32.1	ND	ND	39.4
20-APR-94	34.6	38.1	35.1	37.2	32.1	30.6	32.5	39.1	39.4	39.7	36.2	36.3	37.4	38.3	39.7	34.4	ND	ND	39.7
20-APR-94	36.2	37.1	34.0	41.4	32.1	34.0	34.5	41.5	35.0	41.7	33.0	ND	37.8	37.8	38.3	36.9	ND	ND	40.0

Concluded

APPENDIX E:

FEEDING RATES OF MOUNTAIN WHITEFISH LARVAE AND FRY FROM EGGS INCUBATED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN

Table 21. Feeding Trials of Mountain Whitefish Larvae. Larvae were allowed to feed on Artemia cultures for 20 minutes. The nauplii were 6 to 12 hours old and water temperature was 11°C. The concentration of nauplii and eggs is given as mean (1 standard deviation). Larval length is total length.

	Artemia Concentration			Gut Contents		Larvae
	Nauplii	Eggs	Larval	Nauplii	Eggs	Length
Date	(N/l)	(N/l)	Treatment	N	N	(mm)
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	0	0	14.7
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	0	0	15
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	0	0	14.7
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	0	0	14.6
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	13	3	15.1
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	34	1	13.8
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	36	2	15
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	40	1	15
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	41	2	14.9
11-May-94	121 (19)	22 (8)	9 mg/l:(t8-9)	80	1	15.1
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	24	1	14.9
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	28	2	15.1
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	33	1	14.6
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	38	2	14.5
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	40	2	14.8
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	46	1	14.2
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	49	2	14.4
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	56	2	14.3
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	57	6	14.4
11-May-94	121 (19)	22 (8)	7 mg/l:(t10-11)	58	1	15.9
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	0	0	14.6
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	1	0	14.2
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	19	0	14.6
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	20	1	15
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	24	1	15.4
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	24	1	14.9
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	27	0	15
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	39	2	15.2
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	51	1	15.9
11-May-94	121 (19)	22 (8)	5 mg/l:(t12-13)	69	6	14.6
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	6	0	15.8
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	7	1	14.5
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	9	1	14.8
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	10	0	13.6
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	12	0	14.5
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	15	0	14.7
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	18	0	14.9
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	32	0	15.1
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	34	1	15.2
11-May-94	121 (19)	22 (8)	3 mg/l:(t6-7)	48	0	15.2
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	0	0	15.5
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	0	0	15.5
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	6	0	14.5
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	7	1	15.5
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	9	0	15

continued...

	Artemia Concentration			Gut Contents		Larvae
	Nauplii	Eggs	Larval	Nauplii	Eggs	Length
Date	(N/l)	(N/l)	Treatment	N	N	(mm)
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	47	5	17
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	24	5	17.5
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	52	1	18
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	48	2	17.5
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	73	0	17
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	21	0	17
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	28	0	17.5
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	63	3	16
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	68	5	17.5
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	11	0	17
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	44	1	17
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	71	4	18
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	24	4	18
29-Mar-94	182 (34)	62 (16)	7 mg//l:(t4)	38	2	17
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	51	8	16.5
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	47	9	17
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	5	4	16.5
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	27	1	16.5
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	35	6	17
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	29	4	17
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	29	4	17.5
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	26	0	17
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	26	5	17
29-Mar-94	182 (34)	62 (16)	5 mg/l:(t3)	29	0	16.5
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	22	2	16.6
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	18	1	16.8
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	17	3	17.5
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	33	4	16.5
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	20	13	17
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	15	5	17
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	36	7	17.3
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	20	20	17.1
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	3	7	16
29-Mar-94	123 (15)	42 (7)	13.5 mg/l:(t1)	35	2	17.2
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	14	5	17.4
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	24	6	16.9
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	35	6	17.4
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	31	8	16.4
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	12	9	16.9
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	30	3	17.6
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	35	2	17.9
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	8	0	16.8
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	42	9	17.8
29-Mar-94	123 (15)	42 (7)	9 mg/l:(t2)	25	2	17.8
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	0	2	17.1
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	1	5	17.1
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	16	1	15.9
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	20	2	16.5
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	21	9	16.4
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	25	1	18
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	26	7	16.4

continued...

	Artemia Concentration			Gut Contents		Larvae
	Nauplii	Eggs	Larval	Nauplii	Eggs	Length
Date	(N/l)	(N/l)	Treatment	N	N	(mm)
29-Mar-94	0	0	9	0	9	16.5
29-Mar-94	0	0	9	0	5	16.5
29-Mar-94	0	0	9	0	4	16.5
29-Mar-94	0	0	9	0	3	16.5
29-Mar-94	0	0	9	0	6	17.5
29-Mar-94	0	0	9	0	3	16
29-Mar-94	0	0	9	0	3	17
29-Mar-94	0	0	9	0	0	16.5
29-Mar-94	0	0	9	0	2	17
29-Mar-94	0	0	7	0	0	16
29-Mar-94	0	0	7	0	0	16.5
29-Mar-94	0	0	7	0	1	16
29-Mar-94	0	0	7	0	2	17
29-Mar-94	0	0	7	0	0	17
29-Mar-94	0	0	7	0	2	17
29-Mar-94	0	0	7	0	0	16
29-Mar-94	0	0	7	0	5	16
29-Mar-94	0	0	7	0	1	16
29-Mar-94	0	0	7	0	0	16
29-Mar-94	0	0	5	0	5	16.5
29-Mar-94	0	0	5	0	10	16.5
29-Mar-94	0	0	5	0	5	16.5
29-Mar-94	0	0	5	0	6	15.5
29-Mar-94	0	0	5	0	5	16
29-Mar-94	0	0	5	0	4	16
29-Mar-94	0	0	5	0	3	16
29-Mar-94	0	0	5	0	5	16
29-Mar-94	0	0	5	0	12	17
29-Mar-94	0	0	5	0	5	16

Concluded

APPENDIX F:

CRITICAL THERMAL MAXIMA OF BULL TROUT ALEVINS AND MOUNTAIN WHITEFISH LARVAE REARED AS EGGS AT DIFFERENT LEVELS OF HYPOXIA

Table 22. Critical Thermal Maxima (CTM) of Bull Trout Alevins and Mountain Whitefish Larvae from Eggs Reared at Different Levels of Hypoxia. The incubation tank (t#) used to rear each fish is indicated next to the acclimation date.

Species	Oxygen Treatment (mg/l)	Acclimation Date	Temperature (°C)	Wet Weight (g)
Whitefish	13.5	March 17:(t1)	22.84	nm
Whitefish	13.5	March 17:(t1)	27.44	nm
Whitefish	13.5	March 17:(t1)	28.16	nm
Whitefish	13.5	March 17:(t1)	28.16	nm
Whitefish	13.5	March 17:(t1)	28.34	nm
Whitefish	13.5	March 17:(t1)	28.46	nm
Whitefish	13.5	March 17:(t1)	28.47	nm
Whitefish	13.5	March 17:(t1)	28.54	nm
Whitefish	13.5	March 17:(t1)	28.55	nm
Whitefish	13.5	March 17:(t1)	28.72	nm
Whitefish	13.5	March 17:(t2)	24.60	nm
Whitefish	13.5	March 17:(t2)	26.78	nm
Whitefish	13.5	March 17:(t2)	27.65	nm
Whitefish	13.5	March 17:(t2)	27.81	nm
Whitefish	13.5	March 17:(t2)	27.89	nm
Whitefish	13.5	March 17:(t2)	28.69	nm
Whitefish	13.5	March 17:(t2)	28.69	nm
Whitefish	13.5	March 17:(t2)	28.69	nm
Whitefish	13.5	March 17:(t2)	28.81	nm
Whitefish	13.5	March 17:(t2)	28.85	nm
Whitefish	13.5	March 17:(t3)	26.03	0.352
Whitefish	13.5	March 17:(t3)	26.58	0.520
Whitefish	13.5	March 17:(t3)	27.15	0.318
Whitefish	13.5	March 17:(t3)	28.43	0.616
Whitefish	13.5	March 17:(t3)	28.74	0.152
Whitefish	13.5	March 17:(t3)	28.82	0.302
Whitefish	13.5	March 17:(t3)	28.78	0.316
Whitefish	13.5	March 17:(t3)	28.78	0.185
Whitefish	13.5	March 17:(t3)	28.78	0.261
Whitefish	13.5	March 17:(t3)	29.08	0.290
Whitefish	13.5	March 17:(t3)	29.14	0.637
Whitefish	13.5	March 17:(t3)	29.14	0.157
Whitefish	9	March 17:(t3)	28.67	0.155
Whitefish	9	March 17:(t3)	28.69	0.196
Whitefish	9	March 17:(t3)	28.69	0.279
Whitefish	9	March 17:(t3)	28.69	0.248
Whitefish	9	March 17:(t3)	28.69	0.211

continued...

Species	Oxygen Treatment (mg/l)	Acclimation Date	Temperature (°C)	Wet Weight (g)
Whitefish	5: (Tank 3)	May 5:(t4)	29.55	0.026
Whitefish	5: (Tank 12&13)	May 5:(t4)	27.54	0.018
Whitefish	5: (Tank 12&13)	May 5:(t4)	27.56	0.022
Whitefish	5: (Tank 12&13)	May 5:(t4)	27.65	0.027
Whitefish	5: (Tank 12&13)	May 5:(t4)	27.76	0.024
Whitefish	5: (Tank 12&13)	May 5:(t4)	28.01	0.018
Whitefish	5: (Tank 12&13)	May 5:(t4)	28.01	0.031
Whitefish	5: (Tank 12&13)	May 5:(t4)	28.01	0.024
Whitefish	5: (Tank 12&13)	May 5:(t4)	28.01	0.022
Whitefish	5: (Tank 12&13)	May 5:(t4)	28.01	0.027
Whitefish	5: (Tank 12&13)	May 5:(t4)	28.01	0.016
Whitefish	5: (Tank 12&13)	May 5:(t4)	28.01	nm
Whitefish	5: (Tank 12&13)	May 5:(t4)	28.29	nm
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	25.27	0.017
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	27.83	0.025
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	27.86	0.035
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	27.94	0.026
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	27.94	0.035
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	27.94	0.027
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	28.33	0.018
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	28.33	0.020
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	28.33	0.030
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	28.33	0.303
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	28.33	0.024
Whitefish	9: (Tank 8 & 9)	May 5:(t4)	28.36	0.013
Whitefish	3: (Tank 7)	May 26:(t5)	28.41	0.024
Whitefish	3: (Tank 7)	May 26:(t5)	28.60	0.019
Whitefish	3: (Tank 7)	May 26:(t5)	28.64	0.021
Whitefish	3: (Tank 7)	May 26:(t5)	28.64	0.016
Whitefish	3: (Tank 7)	May 26:(t5)	28.73	0.020
Whitefish	3: (Tank 7)	May 26:(t5)	28.73	0.018
Whitefish	3: (Tank 7)	May 26:(t5)	28.73	0.020
Whitefish	3: (Tank 7)	May 26:(t5)	28.78	0.022
Whitefish	3: (Tank 7)	May 26:(t5)	28.78	0.022
Whitefish	3: (Tank 7)	May 26:(t5)	28.78	0.020
Whitefish	3: (Tank 7)	May 26:(t5)	28.78	0.020
Whitefish	3: (Tank 7)	May 26:(t5)	28.78	0.018
Whitefish	3: (Tank 6)	May 26:(t5)	23.84	0.017
Whitefish	3: (Tank 6)	May 26:(t5)	25.18	0.018
Whitefish	3: (Tank 6)	May 26:(t5)	27.57	0.025
Whitefish	3: (Tank 6)	May 26:(t5)	27.91	0.019
Whitefish	3: (Tank 6)	May 26:(t5)	28.07	0.027

continued...

Species	Oxygen Treatment (mg/l)	Acclimation Date	Temperature (°C)	Wet Weight (g)
Bull Trout	3	May 26:(t6)	27.54	0.099
Bull Trout	3	May 26:(t6)	27.99	0.091
Bull Trout	3	May 26:(t6)	28.03	0.100
Bull Trout	3	May 26:(t6)	28.03	0.098
Bull Trout	3	May 26:(t6)	28.25	0.113
Bull Trout	3	May 26:(t6)	28.42	0.117
Bull Trout	3	May 26:(t6)	28.47	0.120
Bull Trout	9	May 26:(t6)	26.11	0.090
Bull Trout	9	May 26:(t6)	28.58	0.113
Bull Trout	9	May 26:(t6)	28.60	0.127
Bull Trout	9	May 26:(t6)	28.69	0.106
Bull Trout	9	May 26:(t6)	28.79	0.088
Bull Trout	9	May 26:(t6)	28.80	0.101
Bull Trout	9	May 26:(t6)	28.81	0.102
Bull Trout	9	May 26:(t6)	28.97	0.123
Bull Trout	9	May 26:(t6)	29.17	0.093
Bull Trout	9	May 26:(t6)	29.17	0.130
Bull Trout	9	May 26:(t6)	nm	0.113
Bull Trout	7	May 26:(t6)	27.65	0.109
Bull Trout	7	May 26:(t6)	28.14	0.108
Bull Trout	7	May 26:(t6)	28.26	0.104
Bull Trout	7	May 26:(t6)	28.27	0.102
Bull Trout	7	May 26:(t6)	28.45	0.106
Bull Trout	7	May 26:(t6)	28.75	0.105
Bull Trout	7	May 26:(t6)	29.00	0.121
Bull Trout	7	May 26:(t6)	29.04	0.155
Bull Trout	7	May 26:(t6)	29.09	0.104
Bull Trout	7	May 26:(t6)	29.22	nm

Concluded

APPENDIX G:

LENGTH AND WEIGHT MEASUREMENTS OF BULL TROUT AND MOUNTAIN WHITEFISH JUVENILES REARED AS EGGS AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN

Table 23. Total Length of Bull Trout Alevins Reared at Different Levels of Hypoxia.

Date	TREATMENT (mg/l O_2)	Length (mm)
25-Apr-94	13.5	22.68
25-Apr-94	13.5	23.28
25-Apr-94	13.5	24.80
25-Apr-94	13.5	23.16
25-Apr-94	13.5	25.10
25-Apr-94	13.5	24.61
25-Apr-94	13.5	24.98
25-Apr-94	13.5	23.59
25-Apr-94	9	23.15
25-Apr-94	9	25.44
25-Apr-94	9	25.17
25-Apr-94	9	24.63
25-Apr-94	9	24.39
25-Apr-94	9	24.03
25-Apr-94	9	24.82
25-Apr-94	9	24.21
25-Apr-94	9	25.51
25-Apr-94	9	25.19
25-Apr-94	7	24.21
25-Apr-94	7	24.01
25-Apr-94	7	24.25
25-Apr-94	7	24.27
25-Apr-94	7	24.95
25-Apr-94	7	24.95
25-Apr-94	7	23.76
25-Apr-94	7	25.04
25-Apr-94	7	24.48
25-Apr-94	7	24.56
25-Apr-94	5	22.49
25-Apr-94	5	21.07
25-Apr-94	5	21.54
25-Apr-94	5	20.58
25-Apr-94	5	23.07
25-Apr-94	5	22.83
25-Apr-94	5	22.49
25-Apr-94	5	23.62
25-Apr-94	5	21.92
06-May-94	13.5	24.79
06-May-94	13.5	25.56
06-May-94	13.5	26.76
06-May-94	13.5	24.75
06-May-94	13.5	24.29
06-May-94	13.5	25.25
06-May-94	13.5	25.78
06-May-94	13.5	25.44
06-May-94	13.5	26.65
06-May-94	13.5	24.84
06-May-94	13.5	26.08
06-May-94	13.5	25.10

continued...

Table 24. Weights of Individual Bull Trout Eggs and Alevins Reared at Different Levels of Hypoxia. The stage refers to eggs (E) or alevins (L).

DATE	OXYGEN TREATMENT (mg/l)	STAGE	WET WT. (mg)	DRY WT. (mg)	DRY WT. BODY (mg)	DRY WT. YOLK (mg)	YOLK (%)
03-Feb	13.5	E	80.3	26.8	ND	ND	ND
28-Jan	13.5	E	82.8	27.8	ND	ND	ND
28-Jan	13.5	E	82.1	27.1	ND	ND	ND
03-Feb	9	E	91.3	30.0	ND	ND	ND
28-Jan	9	E	90.1	29.2	ND	ND	ND
28-Jan	9	E	88.8	29.9	ND	ND	ND
03-Feb	7	E	95.2	30.9	ND	ND	ND
28-Jan	7	E	94.6	30.8	ND	ND	ND
28-Jan	7	E	90.9	29.7	ND	ND	ND
03-Feb	5	E	88.0	29.6	ND	ND	ND
28-Jan	5	E	84.9	28.7	ND	ND	ND
28-Jan	5	E	98.7	30.5	ND	ND	ND
03-Feb	3	E	93.0	30.8	ND	ND	ND
28-Jan	3	E	90.7	30.7	ND	ND	ND
28-Jan	3	E	78.6	27.0	ND	ND	ND
04-Mar	13.5	L	69.2	26.4	5.4	21.0	79.5
04-Mar	13.5	L	70.9	26.6	5.0	21.6	81.3
04-Mar	13.5	L	77.1	28.4	4.7	23.7	83.6
04-Mar	13.5	L	72.1	27.0	4.7	22.3	82.7
04-Mar	13.5	L	71.9	26.8	6.6	20.2	75.4
04-Mar	13.5	L	64.1	23.6	1.7	21.9	92.8
04-Mar	9	L	76.2	28.0	7.0	21.0	75.0
04-Mar	9	L	75.9	28.0	7.4	20.6	73.5
04-Mar	9	L	71.3	26.4	5.3	21.1	79.9
04-Mar	9	L	73.8	27.7	5.1	22.7	81.8
04-Mar	9	L	68.5	25.0	4.8	20.3	81.0
04-Mar	9	L	64.8	23.8	4.8	19.0	79.8
04-Mar	7	L	70.8	27.9	3.5	24.4	87.6
04-Mar	7	L	73.2	28.6	2.9	25.7	89.8
04-Mar	7	L	60.8	23.5	3.5	20.1	85.3
04-Mar	7	L	69.9	27.5	3.2	24.3	88.3
04-Mar	7	L	72.5	28.1	15.0	13.1	46.6
04-Mar	7	L	65.8	24.8	6.2	18.6	74.9
04-Mar	5	L	57.4	21.7	4.5	17.2	79.1
04-Mar	5	L	64.8	24.9	4.8	20.1	80.8
04-Mar	5	L	73.5	28.4	3.6	24.8	87.2
04-Mar	5	L	73.7	29.0	5.1	23.9	82.4
04-Mar	5	L	57.3	23.0	3.1	19.9	86.7
04-Mar	5	L	70.8	28.1	1.7	26.4	93.9
04-Mar	3	L	72.5	23.7	4.9	18.8	79.2
04-Mar	3	L	73.7	27.4	0.6	26.8	97.8
04-Mar	3	L	76.0	28.7	2.7	26.0	90.7
04-Mar	3	L	67.5	25.5	4.6	20.9	81.9
04-Mar	3	L	69.8	26.7	2.5	24.2	90.5
04-Mar	3	L	83.0	27.6	7.6	20.0	72.5
13-Apr	13.5	L	ND	25.3	10.9	14.4	56.9
13-Apr	13.5	L	ND	24.7	10.7	14.0	56.7

continued...

DATE	OXYGEN TREATMENT (mg/l)	STAGE	WET WT. (mg)	DRY WT. (mg)	DRY WT. BODY (mg)	DRY WT. YOLK (mg)	YOLK (%)
03-May	3	L	ND	24.0	8.9	15.1	62.9
03-May	3	L	ND	28.3	8.8	19.5	68.9

Concluded

APPENDIX H:

MEASUREMENTS OF EMBRYOLOGICAL DEVELOPMENT IN EGGS OF MOUNTAIN WHITEFISH INCUBATED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN

Table 26. Summary of Measurements on Embryonic Development From Individual Mountain Whitefish Eggs.

Date	Oxygen Treatment (mg/l)	Tank	Egg Diameter (mm)	Yolk Area (mm^2)	Eye Length (mm)	Interorbital Distance ((mm)
22-Dec-93	13.5	1	4.09	9.65	0.88	0.52
22-Dec-93	13.5	1	4.18	9.12	0.95	NM
22-Dec-93	13.5	1	4.05	10.22	0.94	0.44
22-Dec-93	13.5	1	4.04	6.72	1.00	0.42
22-Dec-93	13.5	1	3.03	6.36	0.97	0.45
22-Dec-93	3	5	4.07	8.40	0.92	NM
22-Dec-93	3	5	3.91	7.02	0.82	0.58
22-Dec-93	3	5	4.21	8.96	0.83	0.56
22-Dec-93	3	5	4.59	11.10	0.83	NM
22-Dec-93	3	5	4.46	10.31	NM	0.55
22-Dec-93	5	3	4.07	6.57	0.87	0.39
22-Dec-93	5	3	4.50	9.11	1.01	NM
22-Dec-93	5	3	4.38	8.74	0.89	0.51
22-Dec-93	5	3	4.11	8.12	0.96	NM
22-Dec-93	5	3	4.03	6.14	0.92	0.35
22-Dec-93	7	4	4.25	7.32	0.81	NM
22-Dec-93	7	4	4.10	7.33	0.98	NM
22-Dec-93	7	4	4.20	8.82	0.94	0.44
22-Dec-93	7	4	4.01	6.65	NM	0.54
22-Dec-93	7	4	4.02	7.34	0.94	0.32
22-Dec-93	7	4	4.13	8.77	0.99	0.49
22-Dec-93	7	4	3.94	8.17	0.84	0.44
22-Dec-93	7	4	4.20	9.17	0.87	0.57
22-Dec-93	7	4	4.03	8.19	0.93	0.43
22-Dec-93	7	4	4.10	8.20	0.94	0.42
22-Dec-93	9	2	4.23	9.70	0.95	0.34
22-Dec-93	9	2	4.23	8.15	0.99	0.33
22-Dec-93	9	2	4.24	9.31	0.93	0.48
22-Dec-93	9	2	4.06	7.37	0.90	0.38
22-Dec-93	9	2	3.89	7.41	0.90	0.33
22-Dec-93	13.5	15	4.10	8.55	0.89	0.51
22-Dec-93	13.5	15	4.03	7.14	NM	NM
22-Dec-93	13.5	15	4.02	8.72	0.91	0.44
22-Dec-93	13.5	15	3.80	6.84	0.84	0.48
22-Dec-93	13.5	15	4.05	8.39	NM	NM
22-Dec-93	3	7	3.89	7.89	0.89	0.32
22-Dec-93	3	7	4.00	8.23	0.85	0.33
22-Dec-93	3	7	3.95	8.28	NM	NM
22-Dec-93	3	7	3.84	7.52	0.80	0.33
22-Dec-93	3	7	3.78	8.56	0.79	0.51
22-Dec-93	5	13	4.12	7.02	0.76	0.49
22-Dec-93	5	13	3.85	6.46	0.81	0.39
22-Dec-93	5	13	3.96	8.03	0.82	0.39
22-Dec-93	5	13	3.97	7.30	0.87	NM
22-Dec-93	5	13	3.74	7.65	0.77	0.46
22-Dec-93	7	11	4.00	7.60	0.92	0.57
22-Dec-93	7	11	4.00	7.17	0.84	NM

continued...

Date	Oxygen Treatment (mg/l)	Tank	Egg Diameter (mm)	Yolk Area (mm²)	Eye Length (mm)	Interorbital Distance ((mm)
12-Jan-94	5	3	3.96	9.20	0.99	0.60
12-Jan-94	5	3	3.95	NM	1.03	NM
12-Jan-94	7	4	4.17	12.60	1.15	NM
12-Jan-94	7	4	3.97	10.48	1.01	NM
12-Jan-94	7	4	3.95	9.99	0.99	0.76
12-Jan-94	7	4	3.93	NM	NM	NM
12-Jan-94	7	4	4.01	8.97	1.10	0.77
12-Jan-94	7	4	3.96	10.05	NM	NM
12-Jan-94	7	4	3.91	10.15	1.03	0.63
12-Jan-94	7	4	3.96	10.86	NM	NM
12-Jan-94	7	4	4.06	10.32	1.05	NM
12-Jan-94	7	4	3.88	9.67	NM	NM
12-Jan-94	9	2	4.08	11.56	1.11	NM
12-Jan-94	9	2	4.05	5.98	1.00	NM
12-Jan-94	9	2	4.18	11.46	1.10	NM
12-Jan-94	9	2	4.05	8.76	NM	NM
12-Jan-94	9	2	4.00	11.20	1.01	0.57
12-Jan-94	9	2	4.06	10.05	1.04	0.44
12-Jan-94	9	2	4.22	10.74	1.06	0.70
12-Jan-94	9	2	3.99	10.09	1.08	NM
12-Jan-94	9	2	4.06	11.15	1.08	0.67
12-Jan-94	9	2	3.86	8.47	1.00	0.72
12-Jan-94	5	3	3.80	9.71	0.91	NM
12-Jan-94	5	3	2.79	9.83	NM	NM
12-Jan-94	5	3	3.84	10.42	0.85	NM
12-Jan-94	5	3	4.19	11.16	0.89	NM
12-Jan-94	5	3	3.77	7.56	0.86	0.65
12-Jan-94	5	3	3.53	7.80	NM	NM
12-Jan-94	5	3	3.67	9.16	0.93	NM
12-Jan-94	5	3	3.88	9.05	NM	NM
12-Jan-94	5	3	3.73	8.63	0.88	NM
12-Jan-94	5	3	3.71	9.63	0.95	NM
12-Jan-94	7	4	4.01	8.76	1.11	NM
12-Jan-94	7	4	3.93	8.56	1.12	NM
12-Jan-94	7	4	4.03	NM	1.14	NM
12-Jan-94	7	4	3.92	NM	1.14	NM
12-Jan-94	7	4	3.94	10.06	1.07	NM
12-Jan-94	7	4	3.93	NM	NM	0.66
12-Jan-94	7	4	3.82	NM	NM	NM
12-Jan-94	7	4	3.80	10.52	NM	NM
12-Jan-94	7	4	3.91	10.30	1.12	NM
12-Jan-94	7	4	3.79	9.80	1.06	NM
12-Jan-94	13.5	15	4.20	11.49	NM	NM
12-Jan-94	13.5	15	4.21	10.27	1.02	0.71
12-Jan-94	13.5	15	4.07	6.84	0.76	0.63
12-Jan-94	13.5	15	4.01	9.28	NM	NM
12-Jan-94	13.5	15	4.06	10.01	NM	0.64
12-Jan-94	13.5	15	4.06	7.81	0.99	0.63
12-Jan-94	13.5	15	3.84	6.83	0.95	NM
12-Jan-94	13.5	15	3.84	8.81	NM	NM
12-Jan-94	13.5	15	3.76	4.08	NM	NM

continued…

Date	Oxygen Treatment (mg/l)	Tank	Egg Diameter (mm)	Yolk Area (mm^2)	Eye Length (mm)	Interorbital Distance ((mm)
12-Jan-94	3	6	4.67	11.60	0.99	0.66
12-Jan-94	3	6	4.38	10.74	0.99	NM
12-Jan-94	3	6	4.37	9.52	0.91	0.66
12-Jan-94	3	6	4.24	8.24	0.92	NM
12-Jan-94	3	6	4.13	8.12	0.93	NM
12-Jan-94	3	6	4.28	8.23	NM	NM
12-Jan-94	3	6	4.22	10.11	0.97	NM
12-Jan-94	3	6	4.22	9.59	NM	NM
12-Jan-94	3	6	4.08	10.00	1.00	NM
12-Jan-94	5	12	4.10	7.10	0.92	NM
12-Jan-94	5	12	3.94	6.00	0.85	NM
12-Jan-94	5	12	4.21	8.64	0.85	0.60
12-Jan-94	5	12	4.25	7.03	0.90	NM
12-Jan-94	5	12	4.19	5.85	NM	NM
12-Jan-94	5	12	4.53	9.25	0.96	NM
12-Jan-94	5	12	4.14	6.97	0.99	NM
12-Jan-94	5	12	4.12	7.14	NM	NM
12-Jan-94	7	10	3.95	8.19	0.94	0.64
12-Jan-94	7	10	4.18	9.22	NM	NM
12-Jan-94	7	10	4.15	7.13	0.99	NM
12-Jan-94	7	10	3.92	8.63	0.95	NM
12-Jan-94	7	10	4.02	8.74	0.95	0.64
12-Jan-94	7	10	3.65	5.06	NM	0.59
12-Jan-94	7	10	3.71	6.50	0.92	NM
12-Jan-94	7	10	4.00	9.64	0.98	0.67
12-Jan-94	7	10	3.87	8.52	0.95	0.57
12-Jan-94	7	10	3.83	9.53	NM	NM
12-Jan-94	9	8	4.35	6.90	NM	NM
12-Jan-94	9	8	4.37	10.50	1.09	NM
12-Jan-94	9	8	4.29	10.75	1.15	0.71
12-Jan-94	9	8	4.45	10.56	NM	NM
12-Jan-94	9	8	4.24	8.62	1.14	0.77
12-Jan-94	9	8	4.56	11.00	1.13	0.61
12-Jan-94	9	8	4.64	10.77	1.22	NM
12-Jan-94	9	8	4.00	7.22	1.12	0.31
12-Jan-94	9	8	4.34	9.16	1.23	0.75
03-Feb-94	13.5	1	3.98	4.33	NM	NM
03-Feb-94	13.5	1	4.07	4.79	NM	NM
03-Feb-94	13.5	1	4.28	3.91	1.23	NM
03-Feb-94	13.5	1	4.14	2.87	1.09	NM
03-Feb-94	13.5	1	4.92	5.08	NM	NM
03-Feb-94	13.5	1	4.07	5.17	1.07	0.34
03-Feb-94	13.5	1	4.15	5.85	1.00	0.40
03-Feb-94	13.5	1	3.99	3.74	0.98	0.47
03-Feb-94	13.5	1	3.96	5.04	0.98	0.47
03-Feb-94	13.5	1	4.07	4.57	1.10	NM
03-Feb-94	3	5	4.27	7.60	0.96	NM
03-Feb-94	3	5	4.41	8.66	0.87	NM
03-Feb-94	3	5	4.74	8.22	NM	NM
03-Feb-94	3	5	4.80	10.31	NM	NM
03-Feb-94	3	5	4.21	5.99	NM	NM

continued...

Date	Oxygen Treatment (mg/l)	Tank	Egg Diameter (mm)	Yolk Area (mm^2)	Eye Length (mm)	Interorbital Distance ((mm)
03-Feb-94	5	13	3.77	3.33	NM	NM
03-Feb-94	5	13	3.69	2.97	NM	NM
03-Feb-94	5	13	3.86	3.23	NM	NM
03-Feb-94	5	13	3.67	NM	NM	NM
03-Feb-94	9	9	3.83	3.51	NM	NM
03-Feb-94	9	9	3.86	4.22	1.08	0.53
03-Feb-94	9	9	4.00	NM	NM	NM
03-Feb-94	9	9	3.96	3.69	1.00	NM
03-Feb-94	9	9	4.15	6.68	1.00	0.53
03-Feb-94	9	9	3.68	3.09	NM	0.40
03-Feb-94	9	9	3.73	3.23	NM	0.53
03-Feb-94	9	9	3.83	4.16	1.12	NM
03-Feb-94	9	9	3.69	NM	NM	NM
03-Feb-94	9	9	3.73	3.30	NM	NM
03-Feb-94	13.5	14	3.98	3.01	NM	NM
03-Feb-94	13.5	14	3.98	2.68	NM	NM
03-Feb-94	13.5	14	4.16	4.10	NM	NM
03-Feb-94	13.5	14	4.08	2.88	1.24	NM
03-Feb-94	13.5	14	3.94	3.28	1.02	NM
03-Feb-94	13.5	14	3.92	4.17	1.00	NM
03-Feb-94	13.5	14	4.12	4.49	NM	0.70
03-Feb-94	13.5	14	4.00	3.59	1.23	0.55
03-Feb-94	13.5	14	3.91	3.95	1.13	NM
03-Feb-94	13.5	14	4.22	4.62	NM	NM
03-Feb-94	3	6	4.12	7.16	0.82	0.64
03-Feb-94	3	6	4.31	8.34	0.98	NM
03-Feb-94	3	6	4.03	6.82	0.94	NM
03-Feb-94	3	6	4.37	7.77	0.83	0.69
03-Feb-94	3	6	3.83	5.39	0.84	NM
03-Feb-94	3	6	3.91	5.50	0.86	NM
03-Feb-94	3	6	3.89	3.95	NM	NM
03-Feb-94	3	6	3.95	NM	NM	NM
03-Feb-94	3	6	3.74	6.10	0.92	0.48
03-Feb-94	3	6	3.93	7.00	0.91	NM
03-Feb-94	5	12	4.39	4.94	1.48	NM
03-Feb-94	5	12	4.41	4.99	0.95	NM
03-Feb-94	5	12	3.92	4.75	0.85	0.35
03-Feb-94	5	12	4.13	6.42	0.88	0.31
03-Feb-94	5	12	3.74	3.68	0.88	0.60
03-Feb-94	5	12	3.83	3.72	0.66	NM
03-Feb-94	5	12	3.95	5.10	0.92	NM
03-Feb-94	5	12	3.96	3.05	NM	NM
03-Feb-94	5	12	4.27	5.13	0.91	0.65
03-Feb-94	5	12	4.20	5.56	0.88	0.58
03-Feb-94	7	10	4.07	4.29	NM	NM
03-Feb-94	7	10	4.21	5.01	NM	NM
03-Feb-94	7	10	3.90	2.89	NM	NM
03-Feb-94	7	10	4.07	5.48	0.99	0.51
03-Feb-94	7	10	3.87	3.57	NM	NM
03-Feb-94	7	10	3.93	4.86	1.06	0.64
03-Feb-94	7	10	4.19	4.56	NM	NM

continued...

Date	Oxygen Treatment (mg/l)	Tank	Egg Diameter (mm)	Yolk Area (mm^2)	Eye Length (mm)	Interorbital Distance ((mm)
23-Mar-94	9	9	3.79	1.04	0.56	NM
23-Mar-94	9	9	3.54	4.39	NM	NM
23-Mar-94	9	9	3.50	3.89	NM	NM
23-Mar-94	9	9	3.88	3.32	0.97	0.73
23-Mar-94	9	9	4.20	3.63	1.04	0.57
23-Mar-94	9	9	3.74	2.11	0.92	0.51
23-Mar-94	9	9	3.66	2.94	1.00	0.63
23-Mar-94	9	9	3.88	2.11	1.14	0.62
23-Mar-94	13.5	14	4.90	2.53	1.17	0.63
23-Mar-94	13.5	14	4.34	4.10	1.19	0.67
23-Mar-94	13.5	14	4.03	1.87	1.27	0.65
23-Mar-94	13.5	14	3.74	2.40	NM	NM
23-Mar-94	13.5	14	3.88	1.86	1.12	0.57
23-Mar-94	13.5	14	3.60	1.19	1.30	0.57
23-Mar-94	13.5	14	3.72	1.85	1.08	0.63
23-Mar-94	13.5	14	4.02	1.78	1.14	NM
23-Mar-94	13.5	14	4.28	1.94	NM	NM
23-Mar-94	13.5	14	3.72	1.33	NM	NM
23-Mar-94	3	6	4.04	4.25	NM	NM
23-Mar-94	3	6	3.60	3.47	NM	NM
23-Mar-94	3	6	3.95	5.37	NM	NM
23-Mar-94	3	6	3.95	3.83	NM	NM
23-Mar-94	3	6	3.75	3.78	0.69	0.49
23-Mar-94	3	6	4.21	4.50	NM	NM
23-Mar-94	3	6	3.92	5.57	0.95	0.31
23-Mar-94	3	6	4.05	4.92	NM	NM
23-Mar-94	3	6	3.65	3.60	NM	NM
23-Mar-94	3	6	3.69	2.38	1.05	0.81
23-Mar-94	5	12	4.32	3.24	1.06	0.59
23-Mar-94	5	12	4.22	2.31	1.14	0.66
23-Mar-94	5	12	3.81	2.21	1.07	0.48
23-Mar-94	5	12	3.91	4.64	0.90	NM
23-Mar-94	5	12	3.75	3.21	1.01	0.67
23-Mar-94	5	12	3.69	2.04	0.99	NM
23-Mar-94	5	12	4.18	3.81	1.17	0.42
23-Mar-94	5	12	3.79	3.68	1.15	NM
23-Mar-94	5	12	3.74	3.41	0.95	0.60
23-Mar-94	5	12	3.70	4.08	1.05	0.98
23-Mar-94	7	10	3.96	2.35	1.21	0.54
23-Mar-94	7	10	3.82	3.36	0.99	0.72
23-Mar-94	7	10	3.64	2.00	1.04	NM
23-Mar-94	7	10	3.70	2.12	1.09	0.60
23-Mar-94	7	10	3.63	2.38	1.16	0.60
23-Mar-94	7	10	3.91	2.76	NM	NM
23-Mar-94	7	10	3.84	2.66	1.05	0.61
23-Mar-94	7	10	4.11	1.93	1.14	0.71
23-Mar-94	7	10	3.66	2.14	NM	NM
23-Mar-94	9	8	4.11	2.22	1.16	0.54
23-Mar-94	9	8	3.86	1.60	1.04	0.59
23-Mar-94	9	8	3.84	1.98	1.09	0.54
23-Mar-94	9	8	3.85	1.82	NM	NM

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Date	Oxygen Treatment (mg/l)	Tank	Egg Diameter (mm)	Yolk Area (mm^2)	Eye Length (mm)	Interorbital Distance ((mm)
23-Mar-94	9	8	4.29	2.14	1.05	0.53
23-Mar-94	9	8	3.67	3.98	1.02	0.46
23-Mar-94	9	8	3.75	1.71	1.15	0.58
23-Mar-94	9	8	3.79	1.95	1.06	0.51
23-Mar-94	9	8	3.72	2.14	1.11	NM

Concluded