

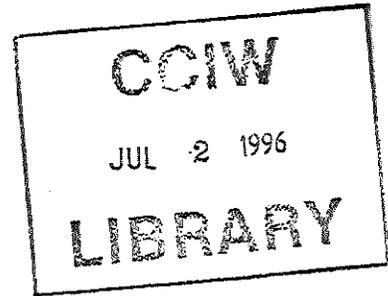
120

Canada

Alberta



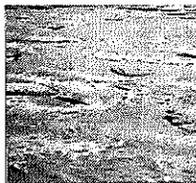
# Northern River Basins Study



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*)



QH  
540  
N67  
No. 120

Prepared for the  
Northern River Basins Study  
under Project 3221-C1

by

M. A. Giles and M. Van der Zweep  
Department of Fisheries and Oceans, Freshwater Institute

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*)**

Published by the  
Northern River Basins Study  
Edmonton, Alberta  
February, 1996

## CANADIAN CATALOGUING IN PUBLICATION DATA

Giles, M. A. (Michael Arthur), 1943-

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*)

(Northern River Basins Study project report,  
ISSN 1192-3571 ; no. 120)  
Includes bibliographical references.  
ISBN 0-662-24501-6  
Cat. no. R71-49/3-120E

1. Bull trout -- Reproduction.
  2. Mountain whitefish -- Reproduction.
  3. Water -- Dissolved oxygen.
  4. Water quality -- Alberta -- Athabasca River Watershed.
  5. Water quality -- Peace River Watershed (B.C. and Alta.)
  6. Water quality -- Slave River Watershed (Alta. and N.W.T.)
- I. Van der Zweep, M.
  - II. Northern River Basins Study (Canada)
  - III. Title.
  - IV. Title: A laboratory study of bull trout (*Salvelinus confluentus*) and mountain whitefish (*Prosopium williamsoni*).
  - V. Series.

QL638.S2G54 1996 597.55 C96-980177-7

Copyright © 1996 by the Northern River Basins Study.

All rights reserved. Permission is granted to reproduce all or any portion of this publication provided the reproduction includes a proper acknowledgement of the Study and a proper credit to the authors. The reproduction must be presented within its proper context and must not be used for profit. The views expressed in this publication are solely those of the authors.

## **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.

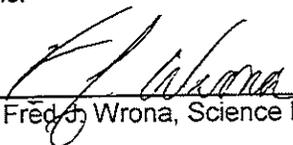
It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce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

**NORTHERN RIVER BASINS STUDY  
PROJECT REPORT RELEASE FORM**

This publication may be cited as:

**Giles, M. A. and van der Zweep, A. 1996. 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*), Northern River Basins Study, Edmonton, Alberta.**

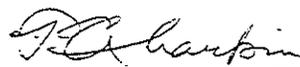
Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,  
**IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;**  
this publication be subjected to proper and responsible review and be considered for release to the public.

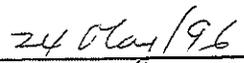
  
\_\_\_\_\_  
(Dr. Fred J. Wrona, Science Director)

  
\_\_\_\_\_  
(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.

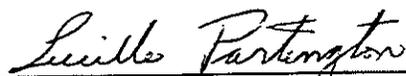
**SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No**

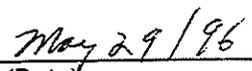
  
\_\_\_\_\_  
(Dr. P. A. Larkin, Ph.D., Chair)

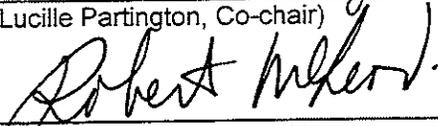
  
\_\_\_\_\_  
(Date)

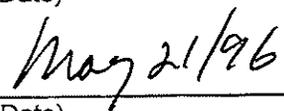
Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,

**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)

  
\_\_\_\_\_  
(Date)

  
\_\_\_\_\_  
(Robert McLeod, Co-chair)

  
\_\_\_\_\_  
(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 effects 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,-trichlorophenol), during periods of diminished DO, was abandoned due to the unavailability of certified contaminant during start-up of the laboratory studies.

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).

***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.*

## 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

at hatch. Analysis of the size of the yolk, however, demonstrated significant reductions in the rates of yolk utilization of whitefish eggs during later stages of development. This suggests that whitefish, as opposed to bull trout, do not hatch until development in the egg is completed. The thermal tolerances of both species was estimated using the critical thermal maxima test. No differences in thermal tolerance related to oxygen treatment were observed in the young of either species. The success of capture of live prey was also similar for whitefish from all oxygen treatments. Feeding trials with bull trout were unsuccessful since the alevins were still using endogenous food sources (yolk) at the termination of the study.

The results of this study would suggest that significant reductions in dissolved oxygen in rivers in the Northern River Basins Study Area would not cause the death of large numbers of bull trout or mountain whitefish eggs. It is highly probable, however, that reductions of dissolved oxygen which have already been recorded at various sites receiving effluent with a high oxygen demand would cause delays in the normal development of the embryos of both species.

## **ACKNOWLEDGEMENTS**

The senior author would like to thank the many people 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.

## TABLE OF CONTENTS

	Page
<b><u>REPORT SUMMARY</u></b>	i
<b><u>ACKNOWLEDGEMENTS</u></b>	iii
<b><u>TABLE OF CONTENTS</u></b>	iv
<b><u>LIST OF TABLES</u></b>	vii
<b><u>LIST OF FIGURES</u></b>	viii
<b>1.0      <u>INTRODUCTION</u></b>	<b>1</b>
<b>2.0      <u>MATERIAL AND METHODS</u></b>	<b>2</b>
<b>2.1      EGG COLLECTION</b>	<b>2</b>
<b>2.2      EGG INCUBATION</b>	
<b>2.2.1    Egg Incubation System</b>	<b>2</b>
<b>2.2.2    Incubation Protocol</b>	<b>7</b>
<b>2.3      MORTALITY AND HATCHING</b>	<b>8</b>
<b>2.4      WEIGHT AND LENGTH MEASUREMENTS</b>	<b>9</b>
<b>2.5      OXYGEN CONSUMPTION</b>	<b>10</b>
<b>2.6      CARDIAC RATES</b>	<b>10</b>
<b>2.7      CRITICAL THERMAL MAXIMA</b>	<b>11</b>
<b>2.8      LARVAL FEEDING TRIALS</b>	<b>11</b>
<b>2.9      EMBRYOLOGICAL DEVELOPMENT</b>	<b>12</b>
<b>3.0      <u>RESULTS</u></b>	<b>13</b>
<b>3.1      <u>INCUBATION CONDITIONS</u></b>	<b>13</b>
<b>3.1.1    Dissolved Oxygen and Water Temperature During Incubation</b>	<b>13</b>
<b>3.2      <u>EFFECT OF DISSOLVED OXYGEN UPON EGG MORTALITY AND HATCHING</u></b>	<b>13</b>
<b>3.2.1    Bull Trout</b>	<b>13</b>
<b>3.2.2    Mountain Whitefish</b>	<b>20</b>
<b>3.3      <u>OXYGEN CONSUMPTION</u></b>	<b>34</b>
<b>3.3.1    Bull Trout</b>	<b>34</b>
<b>3.3.2    Mountain Whitefish</b>	<b>34</b>
<b>3.3.3    Q<sub>02</sub> of Bull Trout and Mountain Whitefish Eggs at Incubation Conditions</b>	<b>43</b>
<b>3.3.4    Residual Oxygen Levels</b>	<b>43</b>
<b>3.4      <u>EFFECTS OF HYPOXIA UPON CARDIAC RATES</u></b>	<b>46</b>

<b>3.5</b>	<b>EFFECT OF HYPOXIA ON FEEDING SUCCESS OF WHITEFISH LARVAE</b>	<b>Page 46</b>
<b>3.6</b>	<b>CRITICAL THERMAL MAXIMA</b>	<b>46</b>
<b>3.7</b>	<b>EMBRYOLOGICAL DEVELOPMENT AND YOLK UTILIZATION</b>	<b>46</b>
<b>3.7.1</b>	<b>Mountain Whitefish</b>	<b>46</b>
<b>3.7.2</b>	<b>Bull Trout</b>	<b>48</b>
<b>4.0</b>	<b><u>DISCUSSION</u></b>	<b>54</b>
<b>4.1</b>	<b>EFFECTS OF HYPOXIA UPON EGG MORTALITY</b>	<b>54</b>
<b>4.2</b>	<b>EFFECTS OF HYPOXIA UPON EMBRYOLOGICAL DEVELOPMENT</b>	<b>54</b>
<b>4.3</b>	<b>RELEVANCE OF EXPERIMENTAL CONDITIONS TO NRB STUDY AREA</b>	<b>56</b>
<b>4.4</b>	<b>RATIONALE FOR BIOLOGICAL MEASUREMENTS EMPLOYED</b>	<b>57</b>
<b>4.5</b>	<b>POTENTIAL INTERACTIVE EFFECTS OF HYPOXIA AND TRICHLOROPHENOL</b>	<b>58</b>
<b>4.6</b>	<b>RELATION OF THE RESULTS OF THIS STUDY TO NRB STUDY AREA</b>	<b>58</b>
<b>5.0</b>	<b><u>CONCLUSIONS</u></b>	<b>59</b>
<b>6.0</b>	<b><u>RECOMMENDATIONS</u></b>	<b>60</b>
<b>7.0</b>	<b><u>REFERENCES</u></b>	<b>61</b>
<b><u>APPENDICES</u></b>		
<b>A</b>	<b>TERMS OF REFERENCE</b>	<b>65</b>
<b>B</b>	<b>MORTALITY AND HATCHING OF BULL TROUT AND MOUNTAIN WHITEFISH EGGS INCUBATED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN</b>	<b>69</b>
<b>C</b>	<b>OXYGEN CONSUMPTION OF BULL TROUT AND MOUNTAIN WHITEFISH EGGS INCUBATED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN</b>	<b>92</b>
<b>D</b>	<b>CARDIAC RATES OF MOUNTAIN WHITEFISH EMBRYOS REARED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN</b>	<b>117</b>
<b>E</b>	<b>FEEDING RATES OF MOUNTAIN WHITEFISH LARVAE AND FRY FROM EGGS INCUBATED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN</b>	<b>123</b>
<b>F</b>	<b>WATER TEMPERATURES AT WHICH INDIVIDUAL BULL TROUT AND MOUNTAIN WHITEFISH EXHIBITED LOSS OF EQUILIBRIUM IN TESTS OF CRITICAL THERMAL MAXIMA</b>	<b>129</b>
<b>G</b>	<b>LENGTH AND WEIGHT MEASUREMENTS OF BULL TROUT AND MOUNTAIN WHITEFISH JUVENILES REARED AS EGGS AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN</b>	<b>135</b>

<b>H</b>	<b>MEASUREMENTS OF EMBRYOLOGICAL DEVELOPMENT IN EGGS OF MOUNTAIN WHITEFISH INCUBATED AT DIFFERENT CONCENTRATIONS OF DISSOLVED OXYGEN</b>	<b>142</b>
----------	--	------------

**LIST OF TABLES**

		<b>Page</b>
<b>Table 1</b>	<b>Residual Oxygen Levels in Bull Trout and Mountain Whitefish Eggs Incubated at Different Concentrations of Dissolved Oxygen</b>	<b>44</b>
<b>Table 2</b>	<b>Effect of Hypoxia Upon Cardiac Rate in Mountain Whitefish Embryos</b>	<b>48</b>
<b>Table 3</b>	<b>Effect of Hypoxia During Embryonic Development Upon Feeding Success of Mountain Whitefish Larvae</b>	<b>49</b>
<b>Table 4</b>	<b>Critical Thermal Maxima of Bull Trout and Mountain Whitefish Fry Incubated as Eggs at Different Levels of Hypoxia</b>	<b>51</b>
<b>Table 5</b>	<b>Effect of Dissolved Oxygen Upon Embryological Development in Mountain Whitefish</b>	<b>52</b>
<b>Table 6</b>	<b>Effect of Dissolved Oxygen on Weight of Bull Trout Eggs and Alevins</b>	<b>53</b>
<b>Table 7</b>	<b>Mortality and Hatching of Bull Trout Eggs Incubated at 3 mg/l of Dissolved Oxygen</b>	<b>70</b>
<b>Table 8</b>	<b>Mortality and Hatching of Bull Trout Eggs Incubated at 5 mg/l of Dissolved Oxygen</b>	<b>72</b>
<b>Table 9</b>	<b>Mortality and Hatching of Bull Trout Eggs Incubated at 7 mg/l of Dissolved Oxygen</b>	<b>74</b>
<b>Table 10</b>	<b>Mortality and Hatching of Bull Trout Eggs Incubated at 9 mg/l of Dissolved Oxygen</b>	<b>76</b>
<b>Table 11</b>	<b>Mortality and Hatching of Bull Trout Eggs Incubated at 13.5 mg/l of Dissolved Oxygen</b>	<b>78</b>
<b>Table 12</b>	<b>Mortality and Hatching of Mountain Whitefish Eggs Incubated at 3 mg/l of Dissolved Oxygen</b>	<b>80</b>

<b>Table 13</b>	<b>Mortality and Hatching of Mountain Whitefish Eggs Incubated at 5 mg/l of Dissolved Oxygen</b>	<b>82</b>
<b>Table 14</b>	<b>Mortality and Hatching of Mountain Whitefish Eggs Incubated at 7 mg/l of Dissolved Oxygen</b>	<b>84</b>
<b>Table 15</b>	<b>Mortality and Hatching of Mountain Whitefish Eggs Incubated at 9 mg/l of Dissolved Oxygen</b>	<b>86</b>
<b>Table 16</b>	<b>Mortality and Hatching of Mountain Whitefish Eggs Incubated at 13.5 mg/l of Dissolved Oxygen</b>	<b>88</b>
<b>Table 17</b>	<b>Mortality and Hatching of Mountain Whitefish Eggs Incubated at Various Levels of Dissolved Oxygen and Transferred to Different Oxygen Concentrations on March 28, 1994</b>	<b>90</b>
<b>Table 18</b>	<b>Oxygen Consumption Of Bull Trout Eggs and Alevins Incubated at Various Levels of Hypoxia</b>	<b>93</b>
<b>Table 19</b>	<b>Oxygen Consumption Of Mountain Whitefish Eggs Incubated at Various Levels of Hypoxia</b>	<b>107</b>
<b>Table 20</b>	<b>Cardiac Rates of Mountain Whitefish Embryos at Different Levels of Hypoxia</b>	<b>120</b>
<b>Table 21</b>	<b>Feeding Trials of Mountain Whitefish Larvae</b>	<b>124</b>
<b>Table 22</b>	<b>Critical Thermal Maxima of Bull Trout Alevins and Mountain Whitefish Larvae</b>	<b>130</b>
<b>Table 23</b>	<b>Total Length of Bull Trout Alevins at Different Levels of Hypoxia</b>	<b>136</b>
<b>Table 24</b>	<b>Wet and Dry Weights of Individual Bull Trout Eggs and Alevins Incubated at Different Levels of Hypoxia</b>	<b>138</b>
<b>Table 25</b>	<b>Mean Wet and Dry Weights of Mountain Whitefish Eggs and Larvae Incubated at Different Levels of Hypoxia</b>	<b>141</b>
<b>Table 26</b>	<b>Summary of Measurements of Embryological Development From Individual Mountain Whitefish Eggs</b>	<b>143</b>

## LIST OF FIGURES

	<b>Page</b>	
<b>Figure 1</b>	<b>Collection Site for Bull Trout Eggs</b>	<b>3</b>
<b>Figure 2</b>	<b>Collection Site for Mountain Whitefish Eggs</b>	<b>4</b>
<b>Figure 3</b>	<b>Schematic of an Incubation Unit</b>	<b>5</b>
<b>Figure 4</b>	<b>Schematic of an Egg Incubator</b>	<b>6</b>
<b>Figure 5</b>	<b>Arrangement of the 15 Incubation Units in Water Baths A and B</b>	<b>14</b>
<b>Figure 6</b>	<b>Daily Dissolved Oxygen Concentrations in Tanks 1 to 5</b>	<b>15</b>
<b>Figure 7</b>	<b>Daily Dissolved Oxygen Concentrations in Tanks 6, 8, 10, 12, and 14</b>	<b>16</b>
<b>Figure 8</b>	<b>Daily Dissolved Oxygen Concentrations in Tanks 7, 9, 11, 13, and 15</b>	<b>17</b>
<b>Figure 9</b>	<b>Daily Water Temperature Records for Tanks 1 to 7</b>	<b>18</b>
<b>Figure 10</b>	<b>Daily Water Temperature Records for Tanks 8 to 15</b>	<b>19</b>
<b>Figure 11</b>	<b>Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 3 mg/l</b>	<b>21</b>
<b>Figure 12</b>	<b>Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 5 mg/l</b>	<b>22</b>
<b>Figure 13</b>	<b>Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 7 mg/l</b>	<b>23</b>
<b>Figure 14</b>	<b>Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 9 mg/l</b>	<b>24</b>
<b>Figure 15</b>	<b>Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 13.5 mg/l</b>	<b>25</b>
<b>Figure 16</b>	<b>Hatching Patterns of Bull Trout Eggs Incubated at Different Concentrations of Dissolved Oxygen</b>	<b>26</b>

	<b>Page</b>
<b>Figure 17 Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 3 mg/l</b>	<b>28</b>
<b>Figure 18 Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 5 mg/l</b>	<b>29</b>
<b>Figure 19 Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 7mg/l</b>	<b>30</b>
<b>Figure 20 Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 9 mg/l</b>	<b>31</b>
<b>Figure 21 Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 13.5 mg/l</b>	<b>32</b>
<b>Figure 22 Hatching Patterns of Mountain Whitefish Eggs Incubated at Different Concentrations of Dissolved Oxygen</b>	<b>33</b>
<b>Figure 23 Oxygen Consumption of Bull Trout Eggs (January 25)</b>	<b>35</b>
<b>Figure 24 Oxygen Consumption of Bull Trout Eggs (March 2)</b>	<b>36</b>
<b>Figure 25 Oxygen Consumption Of Bull Trout Alevins (April 22)</b>	<b>37</b>
<b>Figure 26 Oxygen Consumption of Bull Trout Alevins (April 28)</b>	<b>38</b>
<b>Figure 27 Oxygen Consumption of Mountain Whitefish Eggs (January 20)</b>	<b>39</b>
<b>Figure 28 Oxygen Consumption of Mountain Whitefish Eggs (February 9)</b>	<b>40</b>
<b>Figure29 Oxygen Consumption of Mountain Whitefish Eggs (February 23)</b>	<b>41</b>
<b>Figure 30 Oxygen Consumption of Mountain Whitefish Eggs 14 Days After Transfer From [DO] of 3 mg/l to Less Hypoxic Water</b>	<b>42</b>
<b>Figure 31 Oxygen Consumption of Bull Trout and Mountain Whitefish Eggs at the Actual [DO] Conditions of Incubation</b>	<b>45</b>

## 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 populations 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 circumstances. 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.

## **2.0 MATERIALS AND METHODS**

### **2.1 EGG COLLECTION**

Approximately 1200 fertilized bull trout eggs were obtained from the spawn-taking of October 6, 1993 at the Hill Creek Hatchery on the Upper Arrow Lake, British Columbia (Figure 1). The adult fish had been collected from streams entering the lake and held in a pond at the hatchery until they were spawned. Water Temperature at the time of fertilization was 8.5°C. The eggs were water hardened for one hour, placed in 4 l plastic containers filled with hatchery water, and packed in ice in a cooler. The eggs were transported overnight to Calgary and shipped by air to the Freshwater Institute in Winnipeg. Water temperature in the egg container was 3°C upon arrival at the laboratory and the eggs were transferred to incubators containing dechlorinated Winnipeg municipal water at 3.5°C. On October 10, 1993 5 female and 5 male mountain whitefish were caught by electrofishing from the Athabasca River at a site immediately downstream from the junction of the Snaring River (Figure 2). Water temperature was approximately 3°C. Approximately 18000 fertilized eggs were collected, water hardened for one hour, packed in 4 l jars containing Athabasca River water and shipped by air to Winnipeg. Water temperature upon arrival at the Freshwater Institute was 2.5°C and the eggs were distributed among the incubators containing water at 3.5°C. Elapsed time between fertilization and placement of the eggs in the incubators was less than 24 hours. Both groups of eggs arrived at the laboratory without any visible signs of damage or mortality.

### **2.2 EGG INCUBATION**

#### **2.2.1 Egg Incubation System**

Fifteen incubation units (Figure 3) were constructed to hold the eggs of both species. Each unit consisted of a stainless steel tank (LxWxH: 55x42x29 cm) containing 28 individual incubators (Figure 4) connected to a 15 watt submersible pump (Rena; model C40-Turbo) and an in-line gas exchange column. The incubation units were suspended in water baths maintained at the desired temperature by 8 HP stainless steel refrigeration units. The submersible pump supplied gas-equilibrated water to each incubator at the rate of 115 ml/min. Average water velocity through the incubators was 10.7 cm/min which resulted in a mean water velocity of 2.5 and 2.7 mm/sec past the whitefish and bull trout eggs, respectively. Fresh unequilibrated, dechlorinated water was supplied to each stainless steel tank at 40 ml/min to provide a 95% replacement rate of 63 h (Sprague, 1973). The fifteen incubation units were distributed between two water baths. Nitrogen and air were mixed in various proportions using flowmeters (Gilmont Flowmeters; models 150 and 65) and the mixtures supplied to the appropriate gas exchange columns at a rate of approximately 100 ml/min. Dissolved oxygen control was initiated on November 23, 1993 and continued until May 5, 1994.

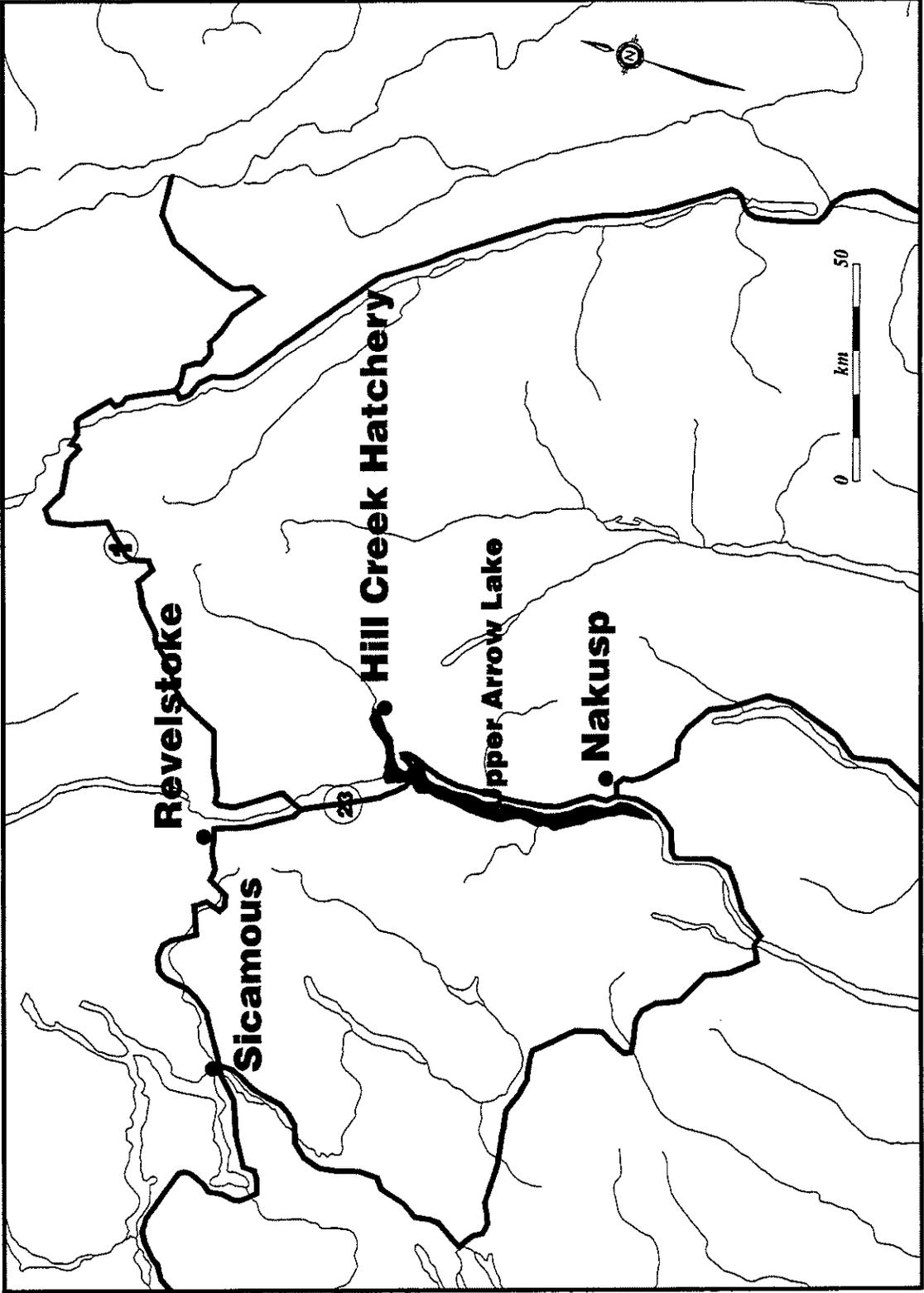


Figure 1. Collection Site for Bull Trout Eggs at the Hill Creek Hatchery, British Columbia.

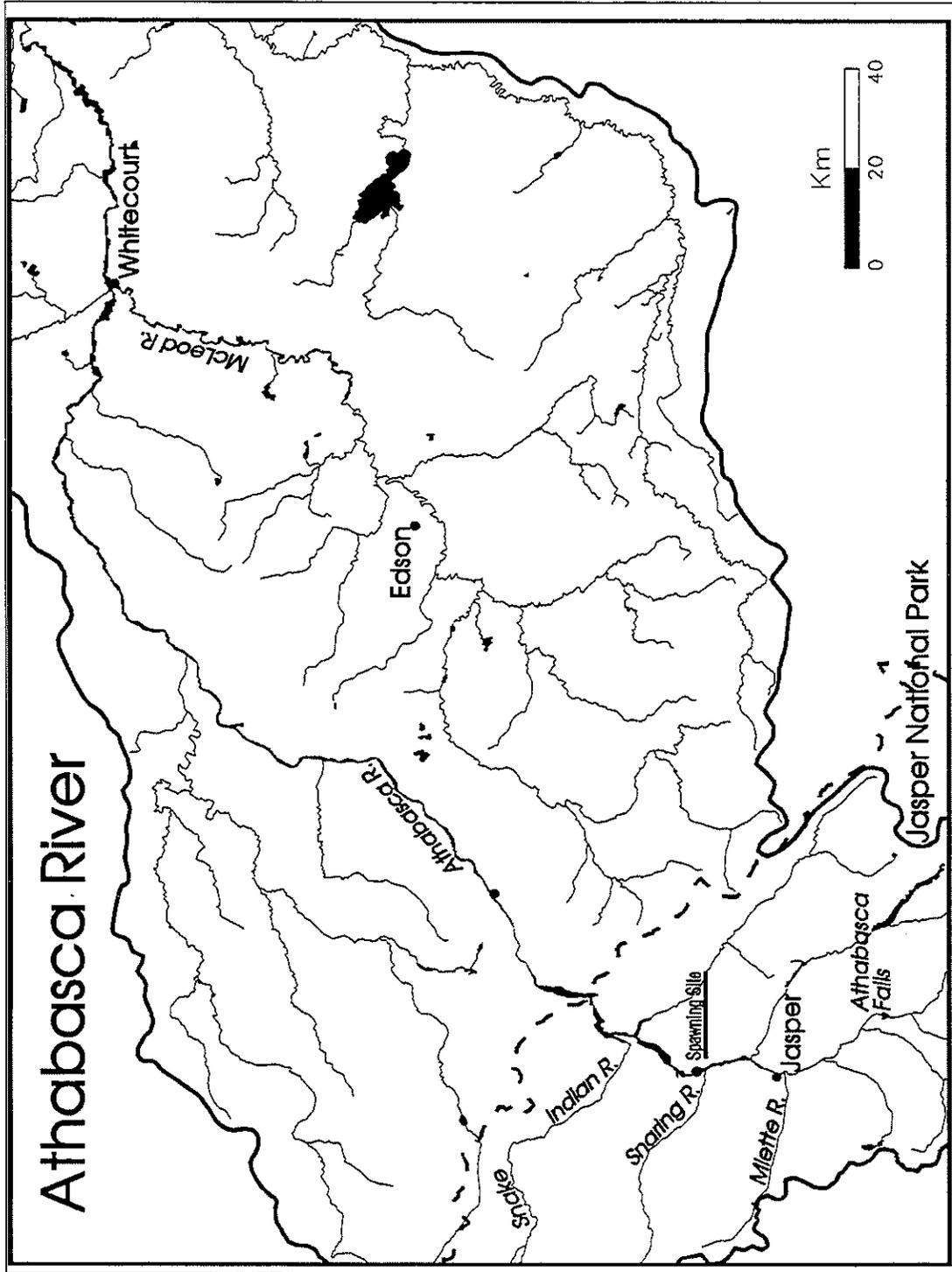


Figure 2. Collection Site for Mountain Whitefish Eggs on the Athabasca River in Jasper National Park, Alberta.

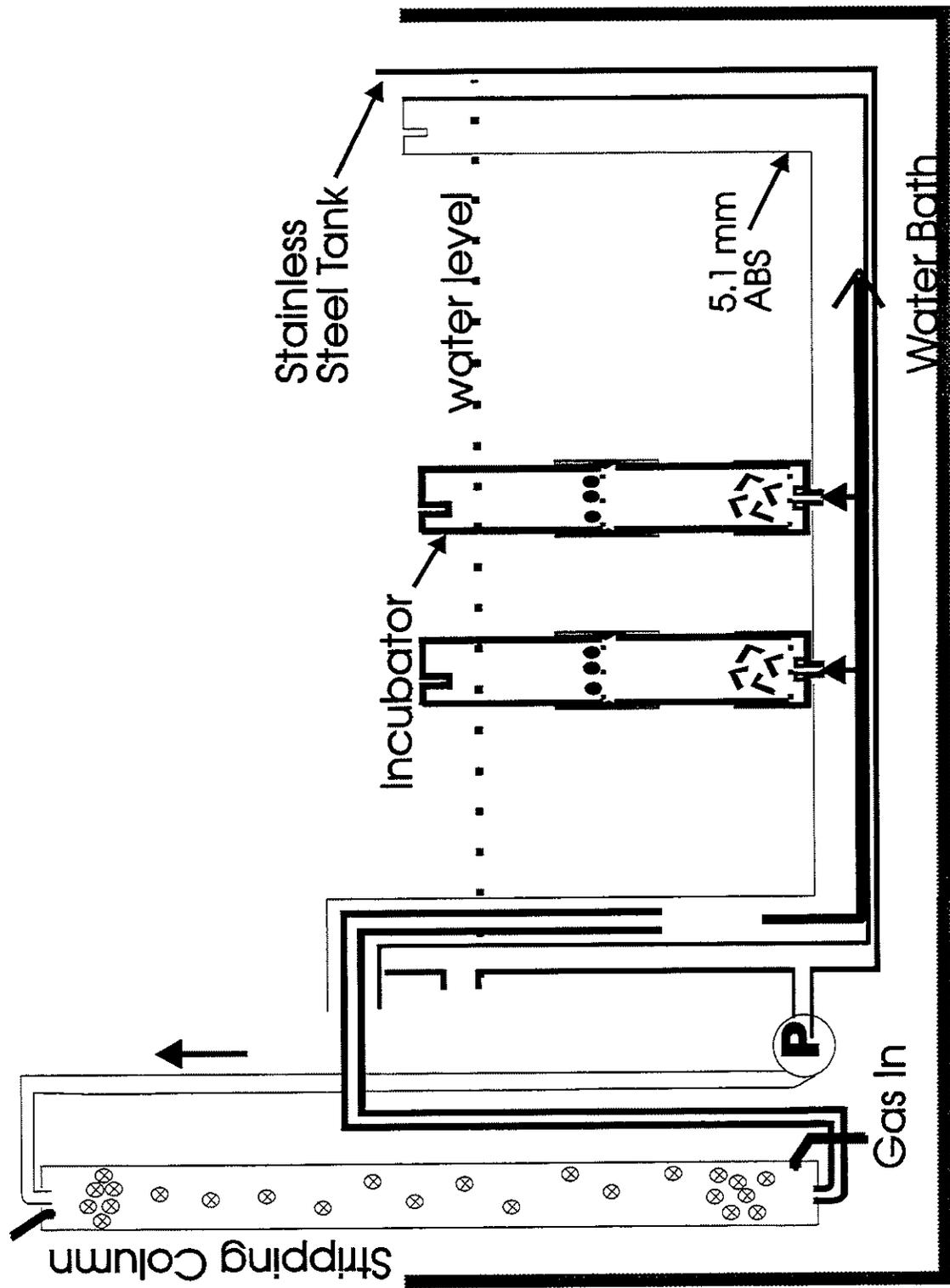


Figure 3. Side View of an Incubation Unit. Each unit held 28 incubators. P indicates a 15 watt submersible pump.

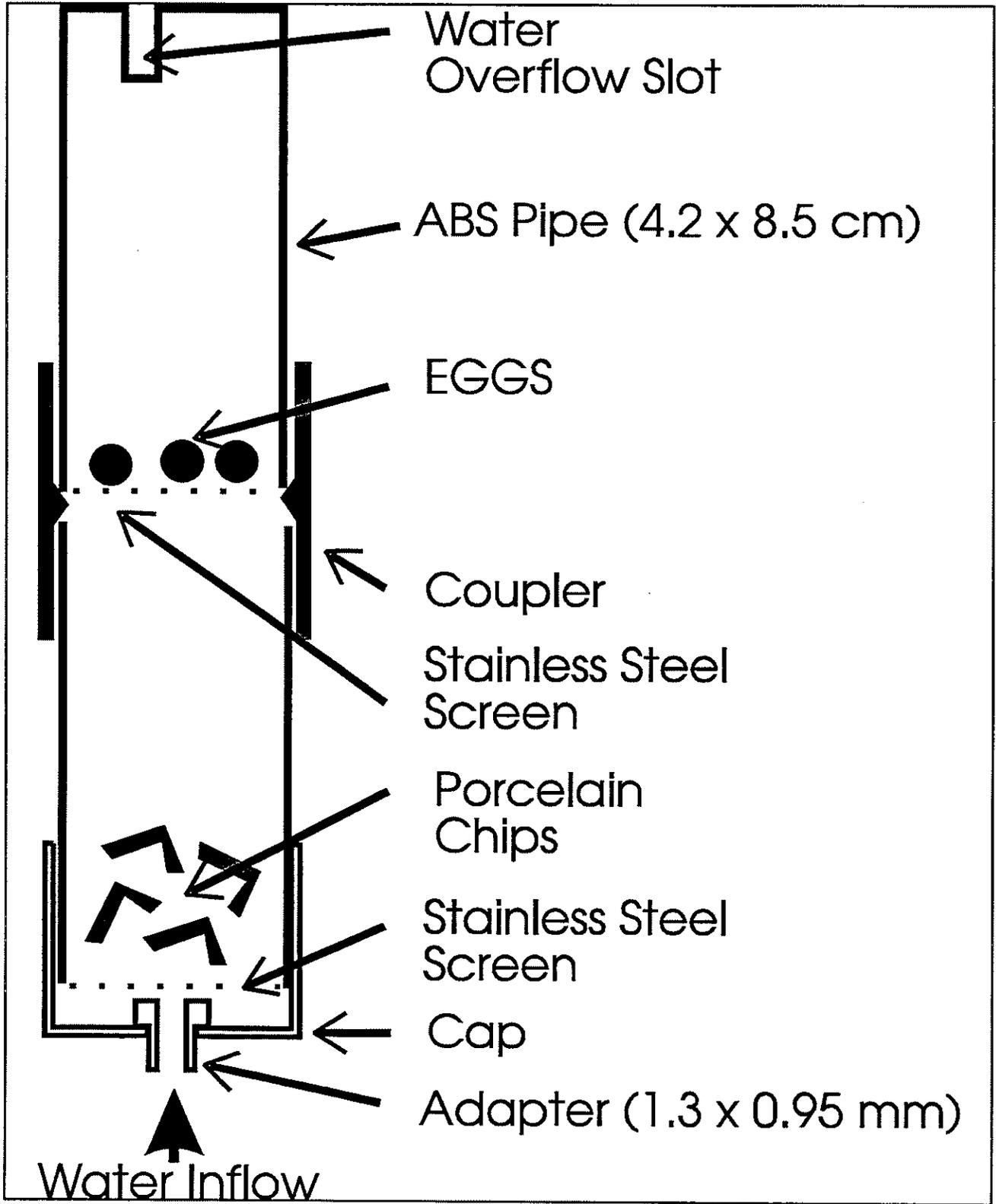


Figure 4. Side View of an Egg Incubator.

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, dechlorinated 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<sub>4</sub>-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 µg/l) and ammonia levels were 1.5 ± 2.5 µg/l (mean ± 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 ± 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:

$$[O_2] = \frac{P_i}{P_s} \alpha$$

where:  $[O_2]$  = dissolved oxygen concentration (mg/l);  
 $P_i$  = oxygen partial pressure of sample (mm Hg);  
 $P_s$  = oxygen partial pressure of air equilibrated water (mm Hg);  
 $\alpha$  = solubility coefficient of oxygen in water at test temperature (mg/l per mm Hg);

The solubility coefficient was 0.086 mg/l per mm Hg oxygen partial pressure (Colt, 1980).

### 2.3 MORTALITY and HATCHING

Egg mortality was recorded from each incubator at least three times weekly. Eggs which developed an opaque whitish color were considered dead and removed by aspiration. The time elapsed between the death of the embryos and the change in egg appearance was unknown but was likely several days at the low incubation temperatures. Daily mortality (percent),  $M_d$ , was calculated in the following manner:

$$M_d = 100 \frac{E_{dt}}{(N_i - \sum S)}$$

where:  $E_{dt}$  = number of dead eggs /day/incubator;  
 $\sum S$  = cumulative sampled eggs/incubator;  
 $N_i$  = original number of eggs in the incubator;

Cumulative mortality was calculated as the cumulative sum of daily mortality in each incubator. Hatching was recorded at least three times each week. During periods of heavy hatch the number of hatched eggs was recorded daily. Hatched mountain whitefish larvae were removed from the incubators by gentle aspiration and placed in holding baskets suspended in their appropriate incubation tank. Bull trout alevins were left in their incubators after hatching until required for tests of critical thermal maxima. Daily hatch,  $H_d$ , was calculated as:

$$H_d = 100 \frac{L}{(N - (\sum E_d + \sum S))}$$

where:  $L$  = number of hatched larvae/day;

N = original number of eggs in the incubator;  
 $\Sigma E_d$  = cumulative number of dead eggs to date;  
 $\Sigma S$  = 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 *Artemia* 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.

## 2.5 OXYGEN CONSUMPTION

The oxygen consumption of triplicate groups of mountain whitefish eggs and bull trout eggs and alevins was determined by closed vessel respirometry. Eggs or alevins were placed in water-filled 10 ml glass syringes attached to a three-way stopcock. The second port of the stopcock was fitted with a 5 ml glass syringe with all void spaces filled with water. Water could be moved gently back and forth between the two syringes without exposure to air to ensure mixing of the water in the 10 ml syringe. The syringe was initially filled with air-saturated water (13.5 mg/l of dissolved oxygen) and submerged in a water bath at 2°C. After a period of time the volume of water in the syringe was recorded and the oxygen partial pressure measured by expelling a portion of the water anaerobically into the Radiometer oxygen electrode chamber described previously. The syringes and eggs were returned to the water bath for another period of time and the process was repeated. When the water in the syringe was exhausted the syringe was refilled using water from the incubation tank with a dissolved oxygen level closest to the level recorded in the last oxygen consumption reading. In some tests the eggs or alevins were permitted to consume the oxygen to very low levels (6 to 10% of saturation), then were returned to saturation levels and the tests repeated. A single set of tests generally required 30 to 36 h to complete. In some tests the eggs or alevins were permitted to reduce the oxygen levels to lethal levels as determined by a lack of a heart beat. Dissolved oxygen concentrations measured under these circumstances were used to estimate residual oxygen levels (Giles and Klappart, 1979). Oxygen consumption ( $Q_{O_2}$ ) was measured as  $\mu\text{g/h}$ /individual egg or alevin and was calculated as:

$$Q = \frac{(\Delta P_{O_2} V)}{(P_s TN)} \alpha$$

where:  $\Delta P_{O_2}$  = change in oxygen partial pressure (mm Hg) during the test interval;  
 $P_s$  = oxygen partial pressure of air saturated water;  
 $T$  = test interval in hours;  
 $V$  = volume of water in respirometer (ml);  
 $N$  = number of eggs or alevins in respirometer;  
 $\alpha$  = solubility of oxygen in water at the test temperature (13.5  $\mu\text{g/ml}$  at 2°C);

## 2.6 CARDIAC RATES

Cardiac rates were measured on developing embryos of mountain whitefish. Six eggs from each treatment were removed from the incubators and maintained in water at their respective dissolved

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

is possible that exogenous feeding was unnecessary prior to that time.

## **2.9 EMBRYOLOGICAL DEVELOPMENT**

Bull trout and mountain whitefish eggs were sampled at intervals for embryological examination. The eggs were photographed using transmitted light on black and white film (Ilford FP4 ISO 125) at a magnification of approximately 11X using a Nikon dissecting microscope (model SMZ-10) fitted with a Microflex photomicrographic attachment. The eggs were then preserved in 3% formalin buffered with sodium borate (Steedman, 1977). The negatives were printed on contact sheets and all measurements were derived from these prints. All measurements were taken electronically using a BioScan Optimas image analysis system. The images were generated by an Ikegami CCD camera (model ICD-4220) with a zoom macro lens. Measurements were taken from the dorsal surface of the embryo. Egg diameter (ED) was taken along the sagittal axis of the embryo. Yolk area (YA) was computed directly by the BioScan software after tracing the yolk circumference. Yolk area was not a direct measure of yolk volume but was considered a relative measure of yolk utilization. Eye length was measured as the longest horizontal distance of the eye in a plane parallel to the center of the body. The inter-orbital distance (ID) was the shortest distance between the eyes.

## **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  $2.1 \pm 0.2^\circ\text{C}$  and  $2.3 \pm 0.2^\circ\text{C}$  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

Dissolved Oxygen (mg/l)	Bath B							
	T8	T9	T10	T11	T12	T13	T14	T15
Nominal	9	9	7	7	5	5	13.5	13.5
Actual	9.0 (0.8)	9.4 (1.0)	7.1 (0.4)	7.0 (0.7)	4.8 (0.5)	5.0 (0.7)	13.4 (0.3)	13.6 (0.3)

Dissolved Oxygen (mg/l)	Bath A						
	T1	T2	T3	T4	T5	T6	T7
Nominal	13.5	9	5	7	3	3	3
Actual	13.4 (0.2)	9.0 (0.6)	4.7 (0.5)	7.2 (0.9)	3.0 (0.6)	2.9 (0.4)	3.1 (0.6)

Figure 5. Arrangement and Dissolved Oxygen Concentrations of the 15 Incubation Units in Water Baths A and B. The nominal and actual mean dissolved oxygen concentrations ( $\pm 1$  standard deviation) are shown.

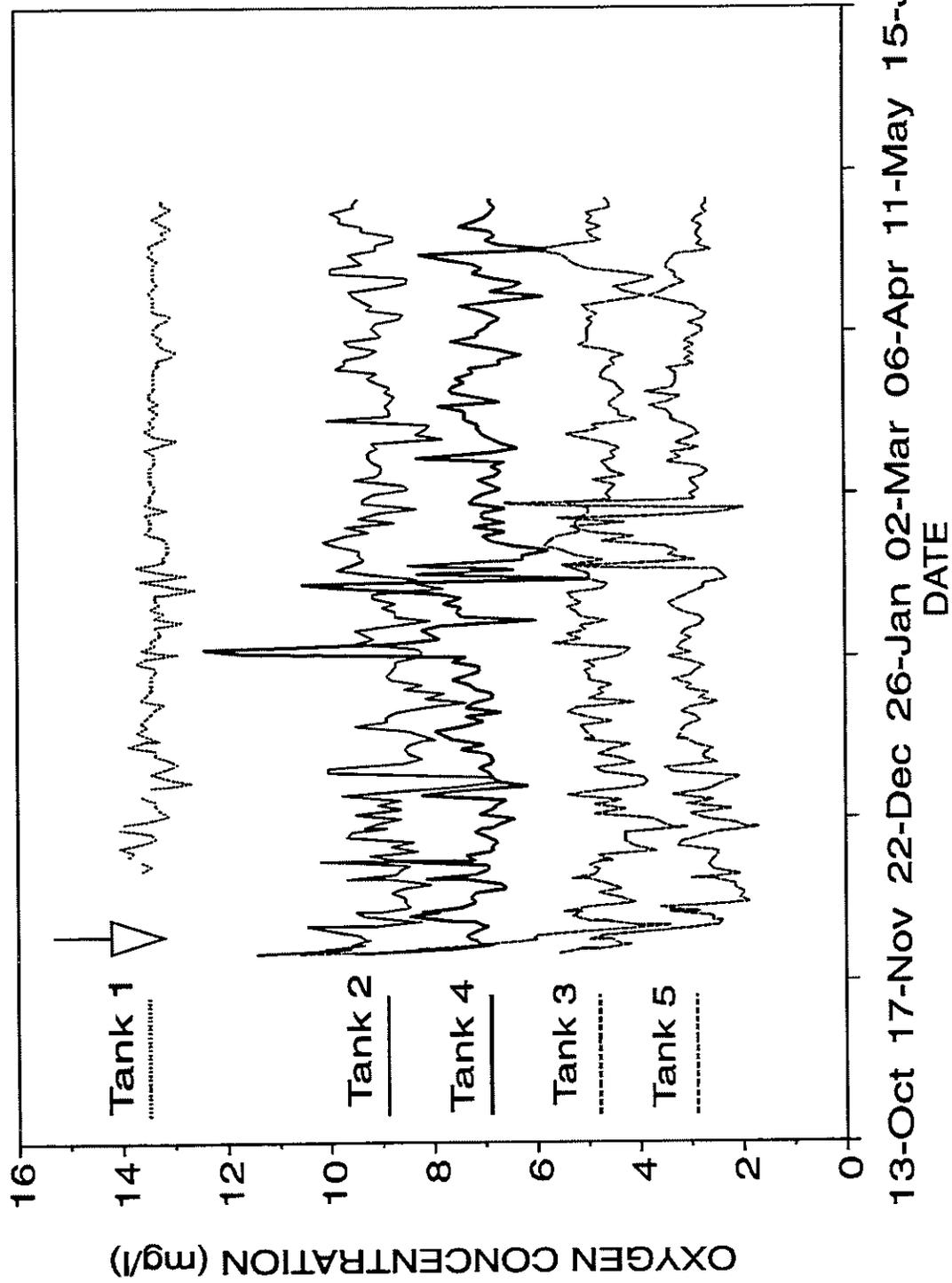


Figure 6. Daily Dissolved Oxygen Concentrations in Incubation Units 1 to 5. The arrow indicates the initiation of dissolved oxygen regulation.

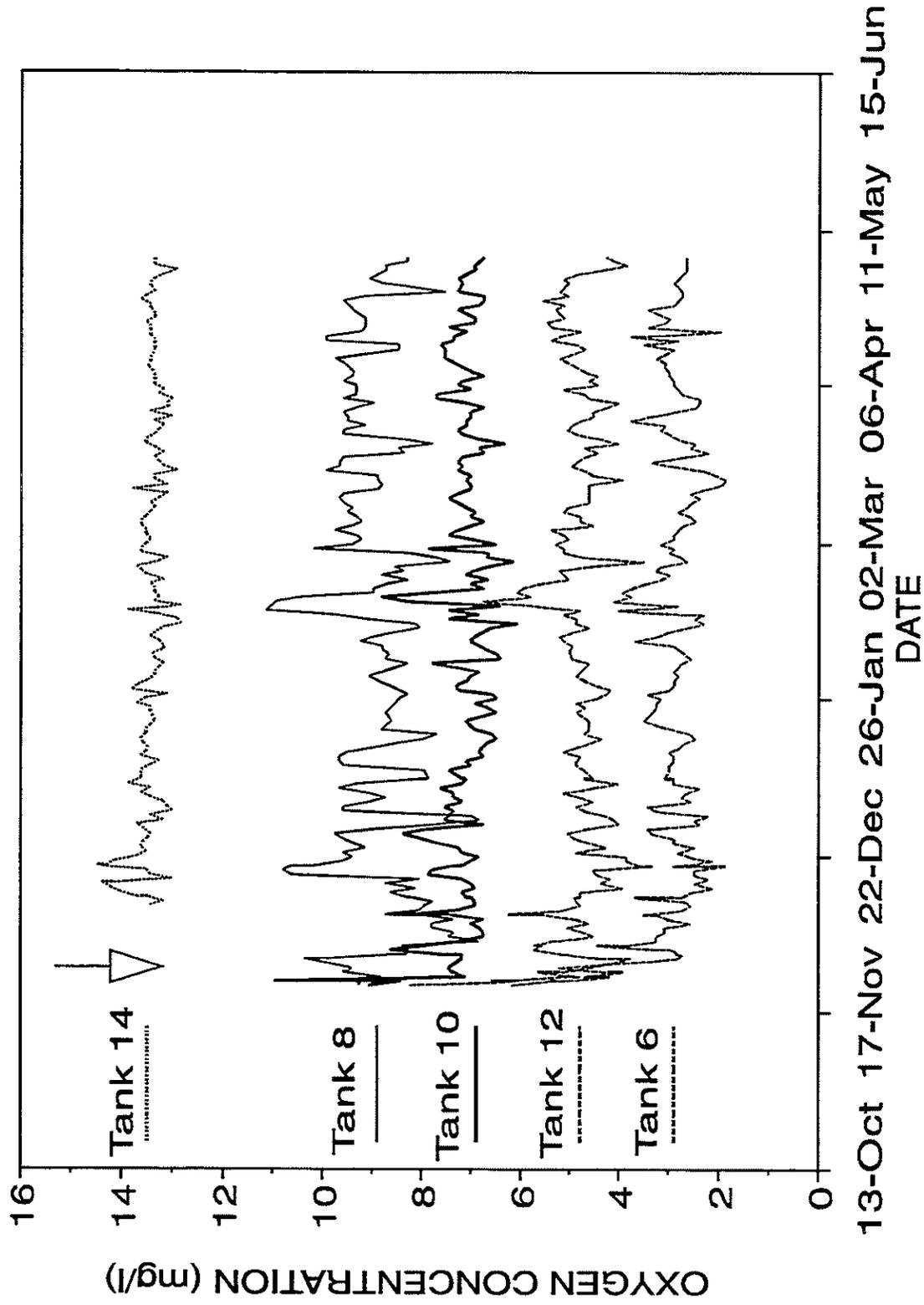


Figure 7. Daily Dissolved Oxygen Concentrations in Incubation Units 6, 8, 10, 12, and 14. The arrow indicates the initiation of dissolved oxygen regulation.

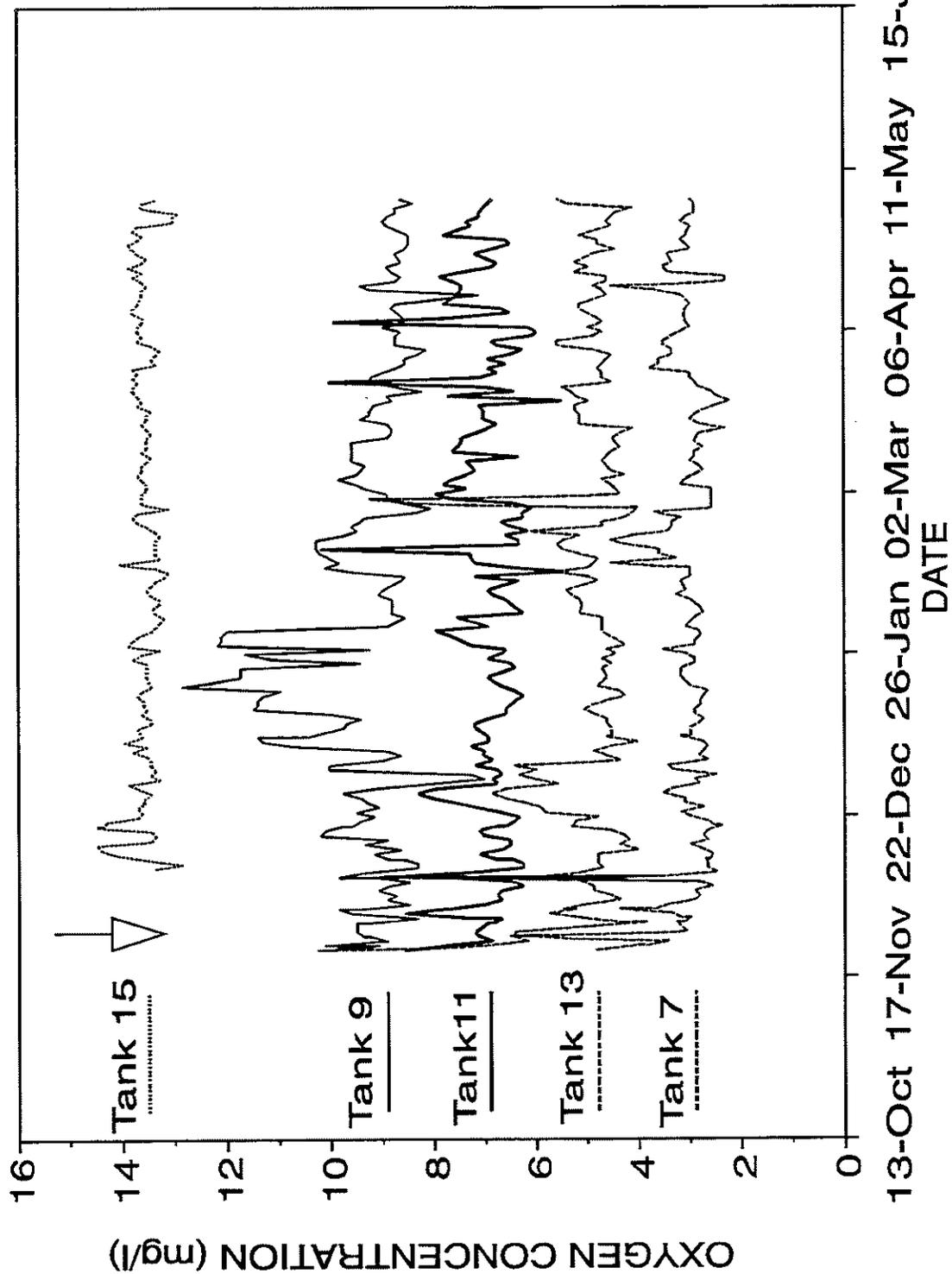


Figure 8. Daily Dissolved Oxygen Concentrations in Incubation Units 7, 9, 11, 13, and 15. The arrow indicates the initiation of dissolved oxygen regulation.

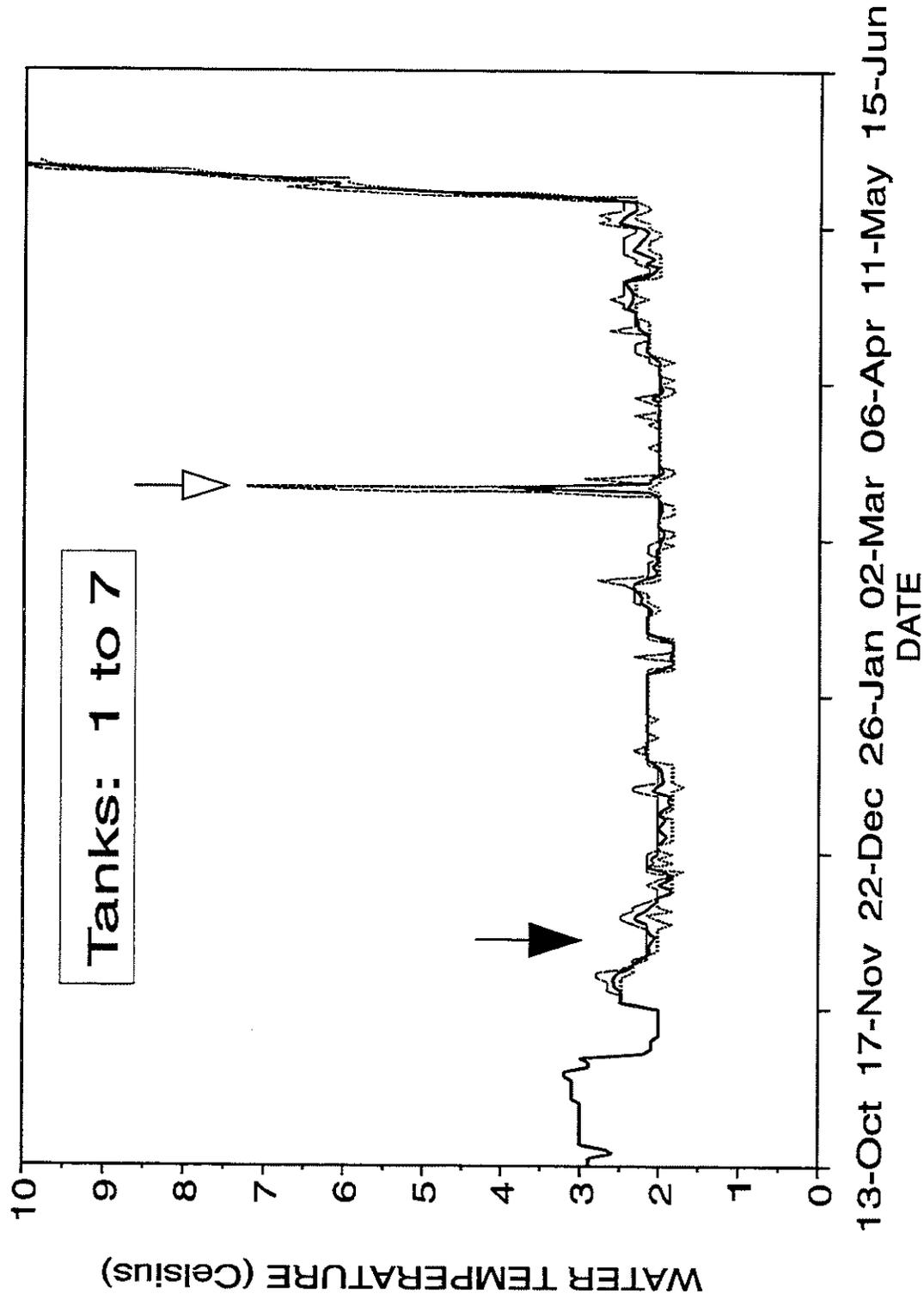


Figure 9. Daily Water Temperatures for Incubation Units 1 to 7 Showing Mean (solid), Minimum (dotted), and Maximum (dashed) Temperatures. The dates on which the nominal dissolved oxygen levels were attained (solid arrow) and the temperature regulation was temporarily lost (open arrow) are shown.

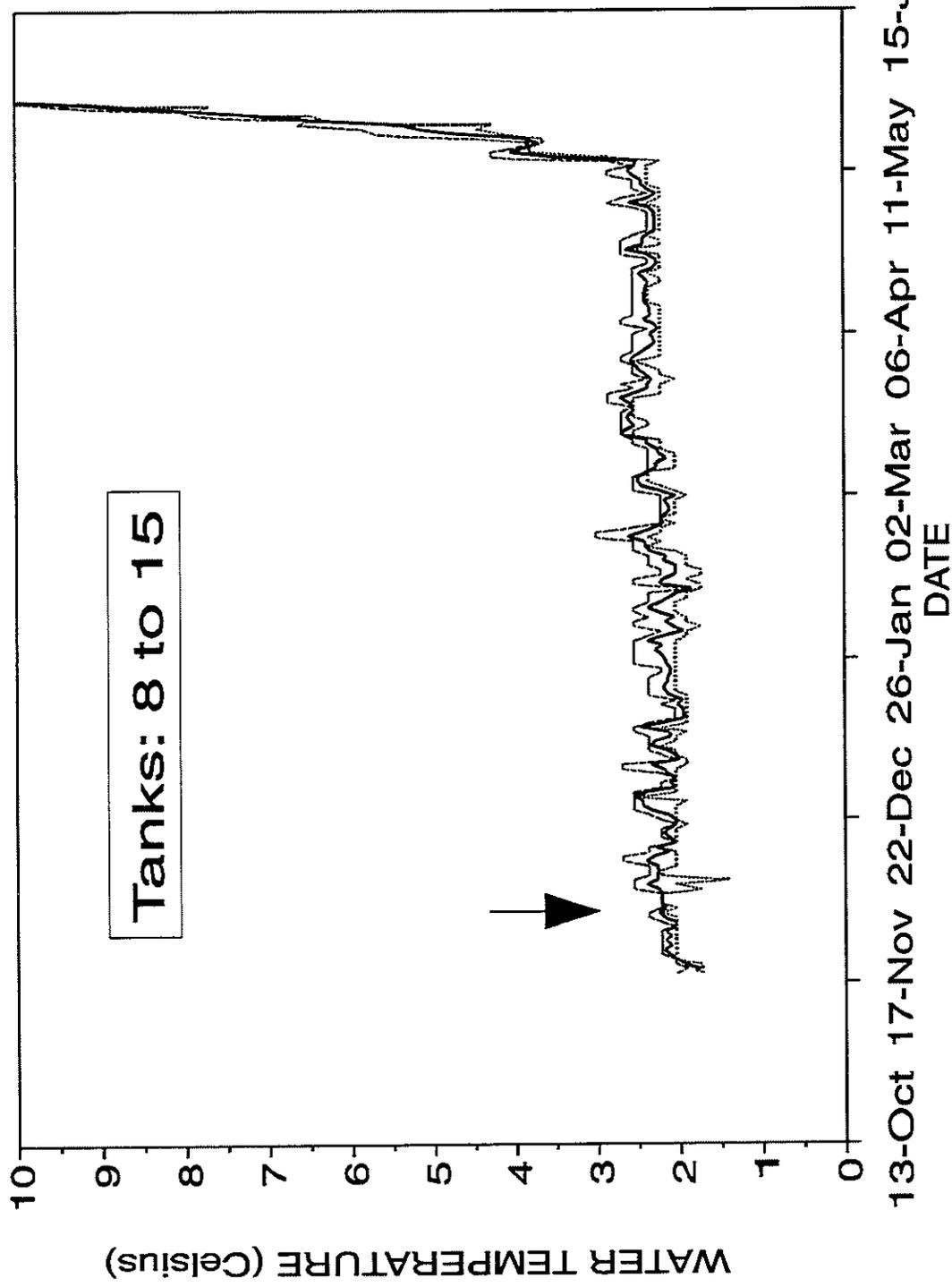


Figure 10. Daily Water Temperatures for Incubation Units 8 to 15 Showing Mean (solid), Minimum (dotted), and Maximum (dashed) Temperatures. The date on which the nominal dissolved oxygen levels were attained (solid arrow) are shown.

level of mortality was observed in eggs reared at the Hill Creek Hatchery (G. Thorp; personal communication). Less than 6% mortality occurred in the eggs during the period of December 22, 1993 to mid-April 1994, regardless of oxygen treatment. This represents less than 1 egg per incubator in tanks 1 to 5. The mortalities shown for tanks 6 to 15 must be viewed with caution since less than 45 eggs were present in each tank. Approximately 50% of the mortality experienced after December 22 occurred during the period of hatching in eggs held at dissolved oxygen concentrations  $\leq 7$  mg/l. Cumulative hatching was calculated from the number of live eggs present in the individual incubators when hatching was first observed. Hatching in tanks 1 to 5 immediately after the rise in water temperature was caused by the pump failure on March 14 (open arrow, Figures 11 to 15). Eggs held at [DO]  $\geq 5$  mg/l all hatched within 24 hours of the temperature rise. Approximately 15 to 70 percent of the eggs held at [DO] of 3 mg/l also hatched immediately after the temperature rise (Figure 11) while the remainder hatched during the subsequent 19 days. A comparison of the hatching time of bull trout incubated in water bath B which did not experience a temperature aberration and eggs from tanks 5, 6, and 7, ([DO] = 3 mg/l) which had experienced the temperature rise demonstrated that reduction of [DO] to 5 mg/l did not influence hatching (Figure 16). At 3 mg/l, however, hatching was delayed by approximately 7 d. Mortality of hatched bull trout alevins maintained under hypoxic conditions was recorded in tanks 1 to 5. Cumulative alevin mortality to May 26 was 4.1, 2.0, 0.6, 5.1, and 1.9 percent in eggs incubated at 3, 5, 7, 9, and 13.5 mg/l dissolved oxygen, respectively. This number included any alevins which may have been affected by the reduced oxygen between the time of hatch and May 5 when oxygen levels were returned to saturation.

### 3.2.2 Mountain Whitefish

Mortality and hatching patterns of mountain whitefish eggs (Figures 17 to 21) differed from those of bull trout. An initial mortality of 7 to 8 percent was observed in the whitefish eggs in tanks 1 to 5 prior to November 10. This occurred 2 weeks prior to the initiation of the reduction in dissolved oxygen and represents the loss of infertile or damaged eggs. Thereafter, less than 3% of the eggs died in any of these incubators. Eggs initially incubated in the Heath Incubator developed a substantial fungal infection by November 16. These eggs were treated with formaldehyde, and the dead eggs were discarded. Over the next 4 days these eggs were held in incubation jars with upwelling water flow and additional dead or damaged eggs were removed daily. On November 22 the eggs were transferred to incubators in tanks 6 to 15. Control of dissolved oxygen was initiated on November 23 in all tanks. Approximately 15 to 22 percent of the whitefish eggs in tanks 6 to 15 died prior to December 8. This mortality occurred across all treatments and was not related to oxygen treatment. From mid-December, 1993 to June 1, 1994 less than 5% of the eggs in any treatment died. The numbers of eggs in each tank remaining at the initiation of hatch after mortality and sampling losses is given in brackets in Figures 17 to 21. The temperature rise on March 14 stimulated a partial hatch in whitefish eggs reared at [DO] of 13.5, 9, 7, and 5 mg/l, (tanks 1, 2, 4, and 3, respectively), but not in eggs reared at 3 mg/l. Eggs which did not hatch in response to the temperature rise, however, tended to hatch within a few days of the eggs receiving the same oxygen treatment without the temperature rise. In all instances except tank 5 hatching success exceeded 95%. Hatching success

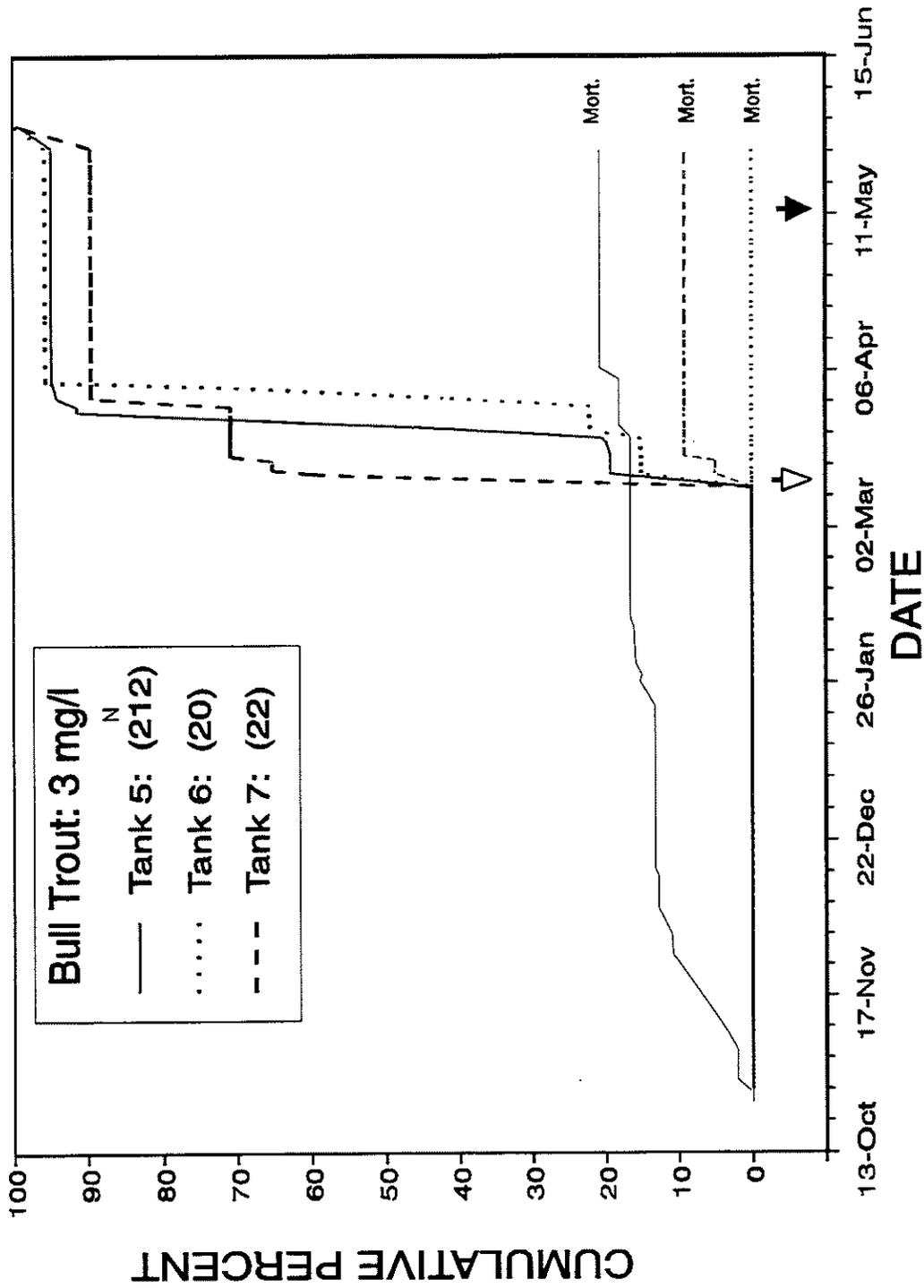


Figure 11. Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 3 mg/l. The tank numbers and total number of live alevins (N) are shown for each replicate. Water temperature rose to 7.2°C for a short period on March 14 (open arrow) and was purposely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

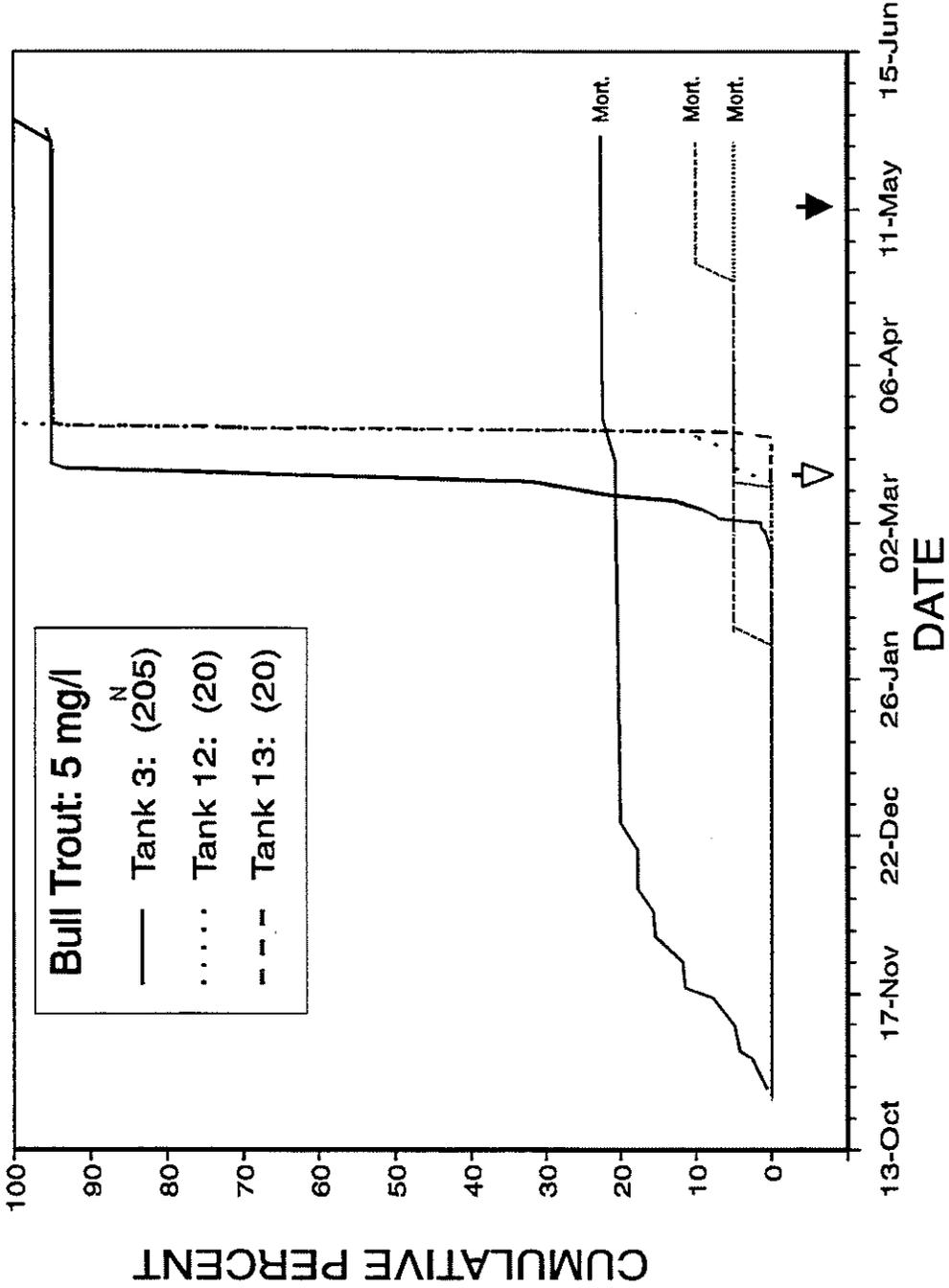
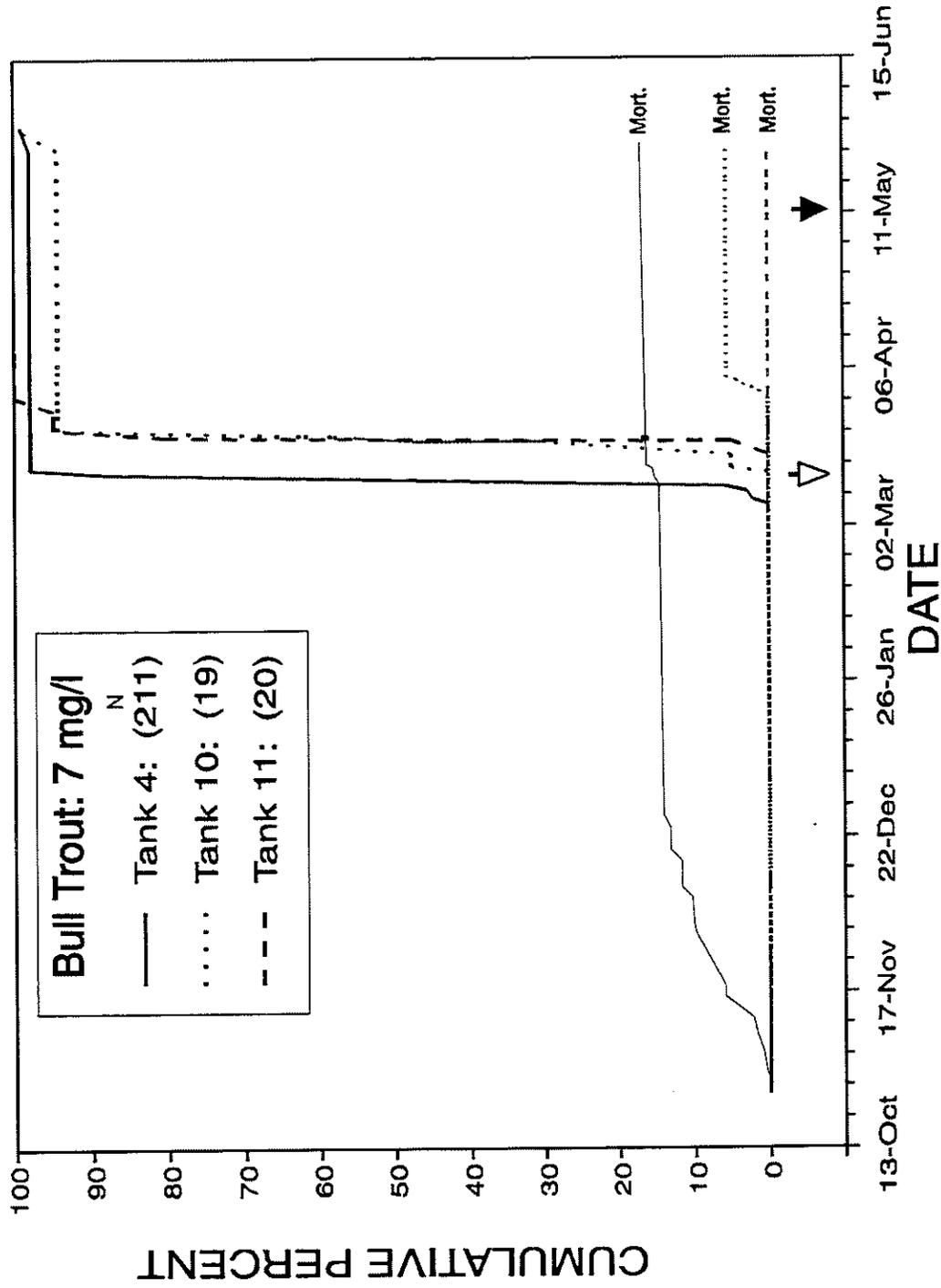
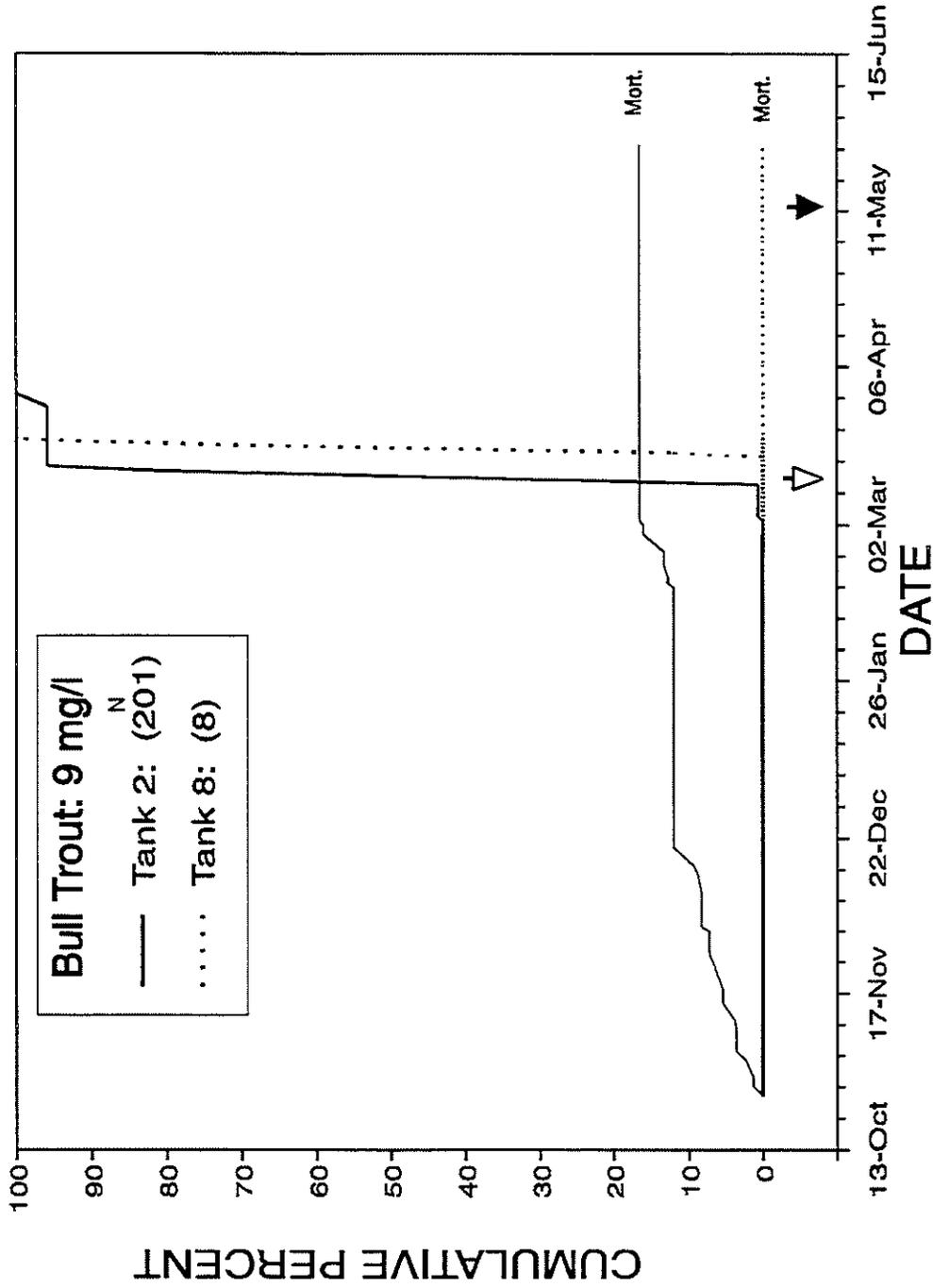


Figure 12. Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 5 mg/l. The tank numbers and total number of live alevins (N) are shown for each replicate. Water temperature rose to 7.2°C in tank 3 for a short period on March 14 (open arrow) and 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 14.** Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 9 mg/l. The tank numbers and total number of five alevins (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).

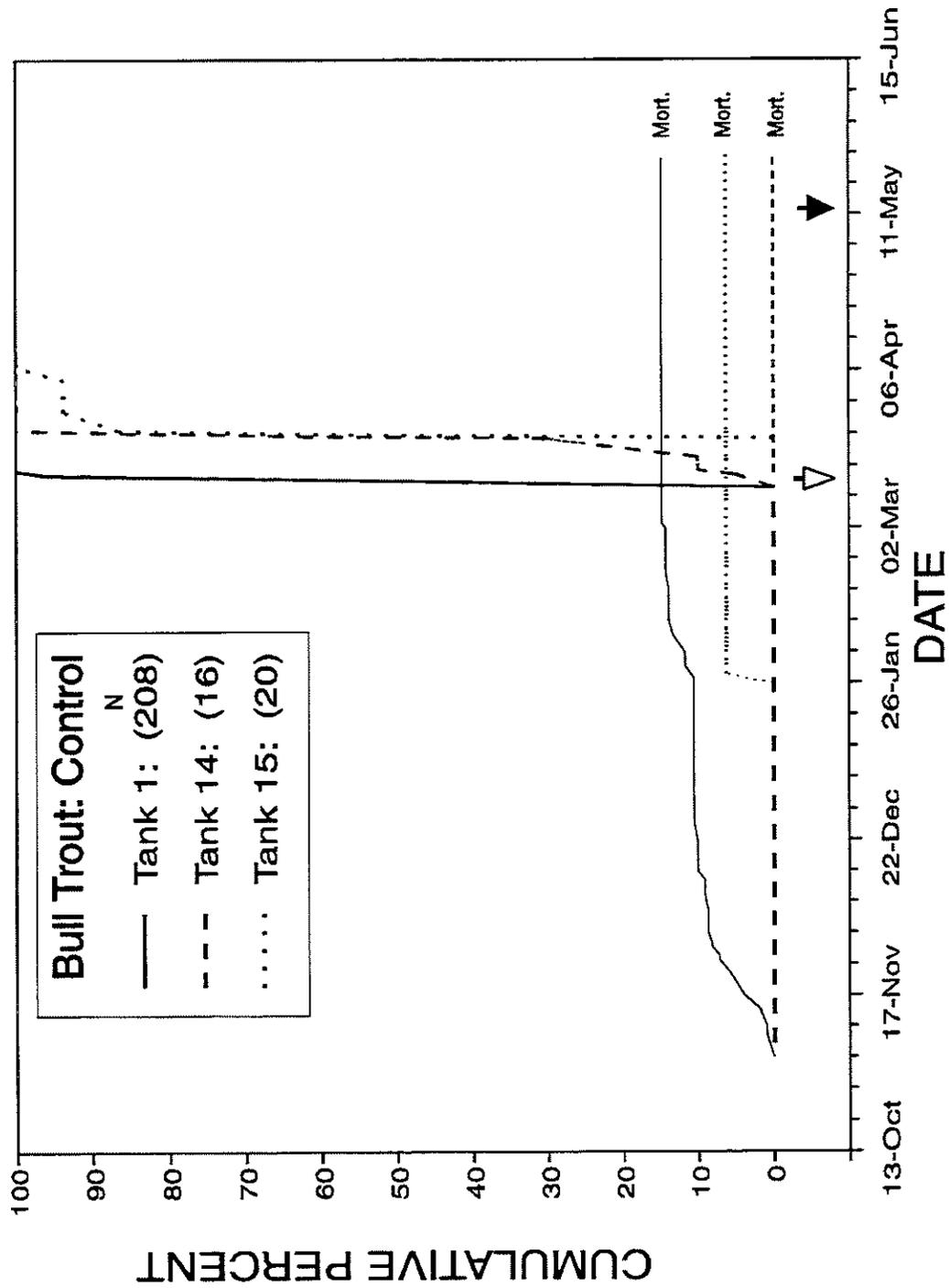


Figure 15. Mortality and Hatching Patterns of Bull Trout Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 13.5 mg/l. The tank numbers and total number of live alevins (N) are shown for each replicate. Water temperature rose to 7.2°C in tank 1 for a short period on March 14 (open arrow) and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

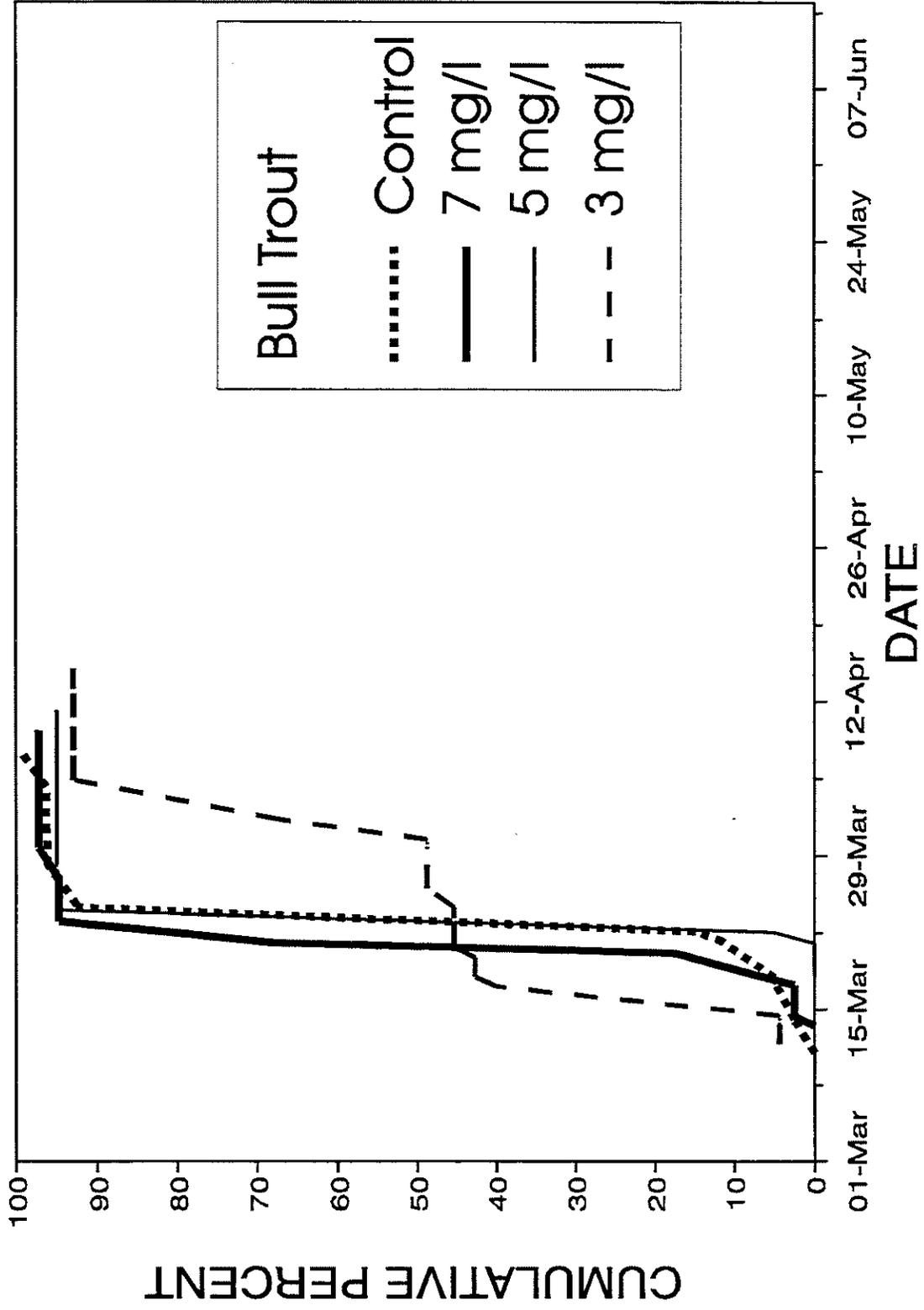


Figure 16. Comparison of Hatching Patterns of Bull Trout Eggs Incubated at Different Concentrations of Dissolved Oxygen.

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).

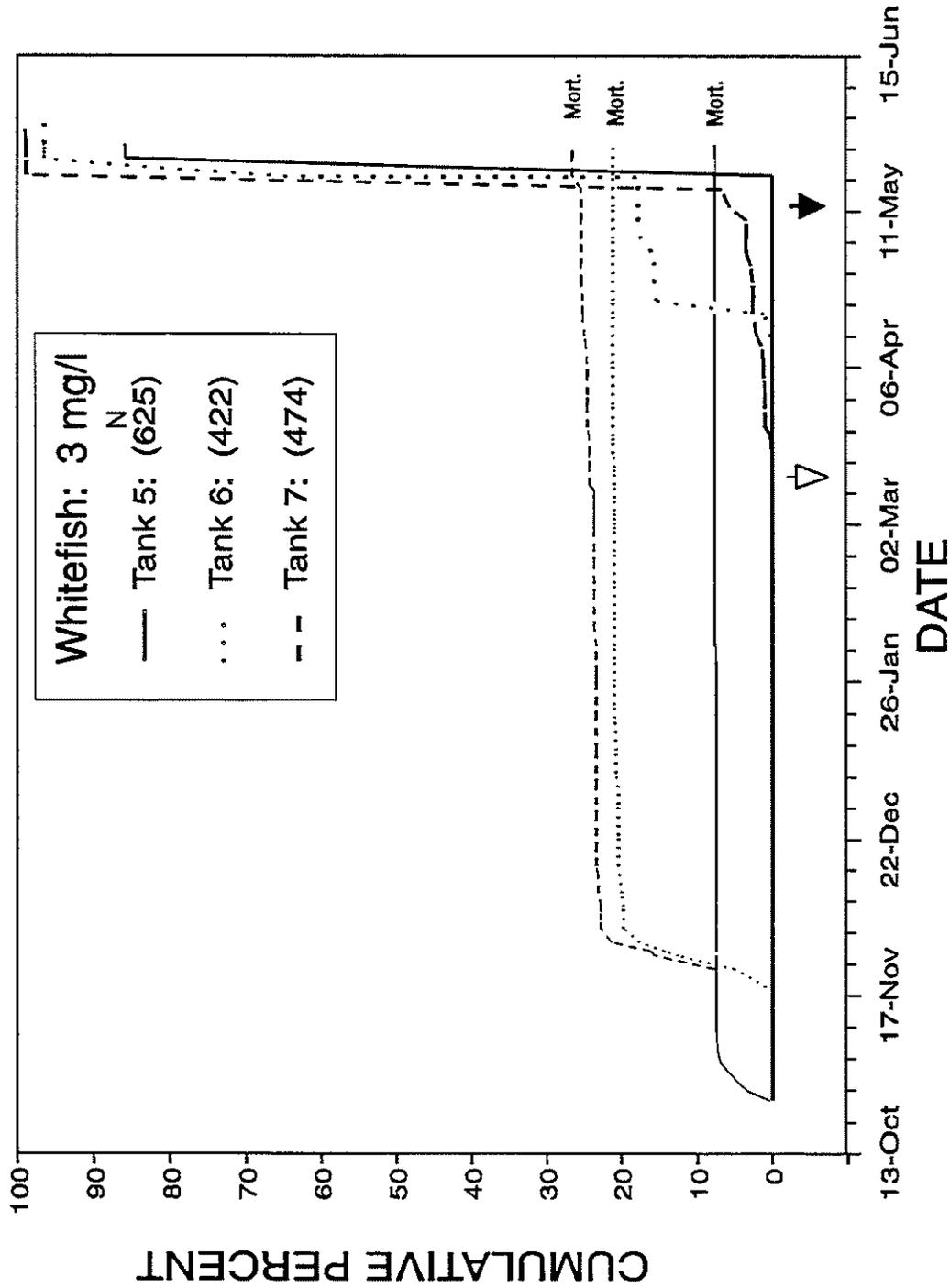


Figure 17. Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 3 mg/l. The tank numbers and total number of live larvae (N) are shown for each replicate. Water temperature rose to 7.2°C for a short period on March 14 (open arrow) and was raised purposely by 0.6 °C/day in all tanks beginning May 11 (solid arrow).

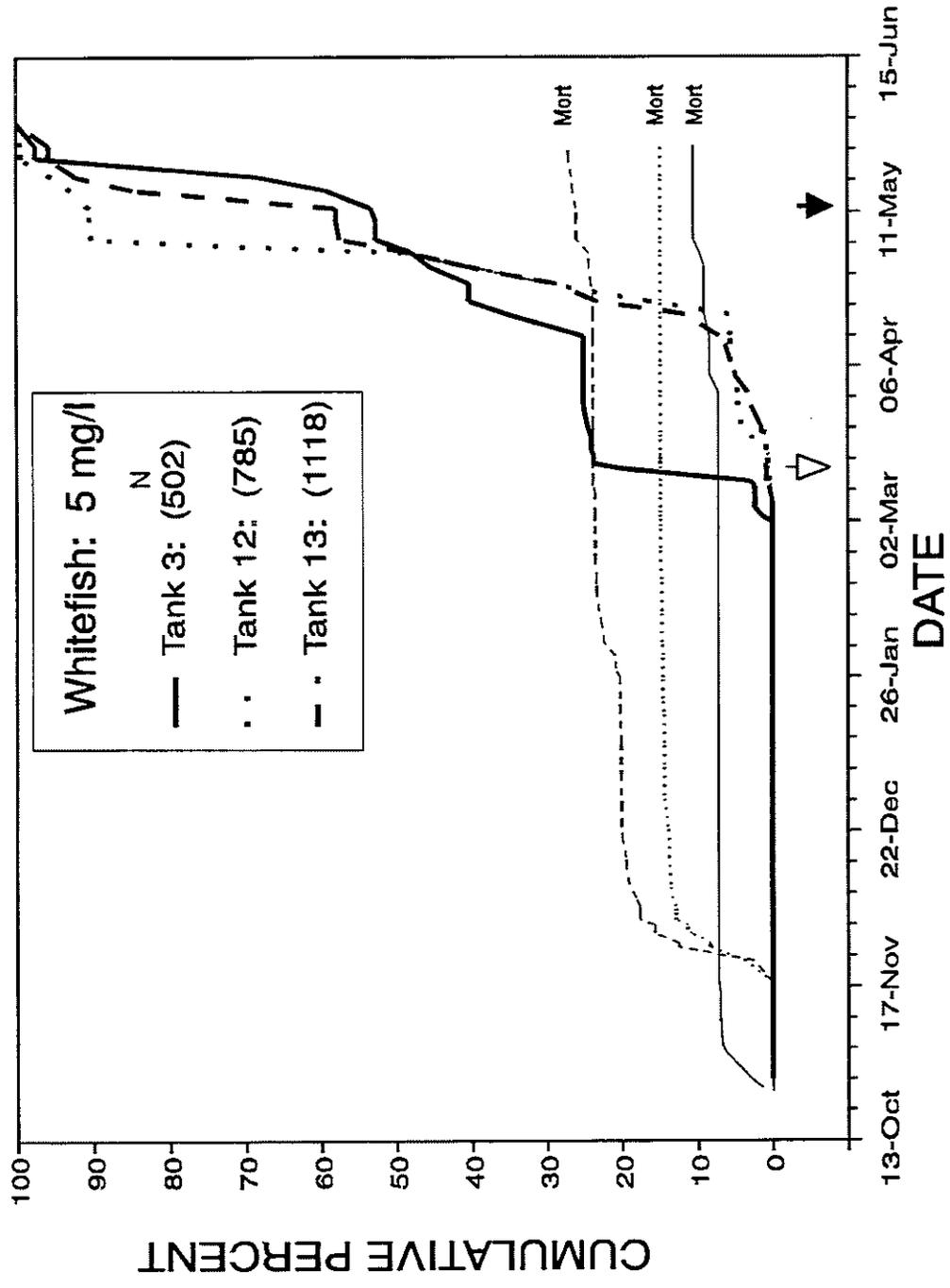


Figure 18. Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 5 mg/l. The tank numbers and total number of live larvae (N) are shown for each replicate. Water temperature rose to 7.2°C in tank 3 for a short period on March 14 (open arrow)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

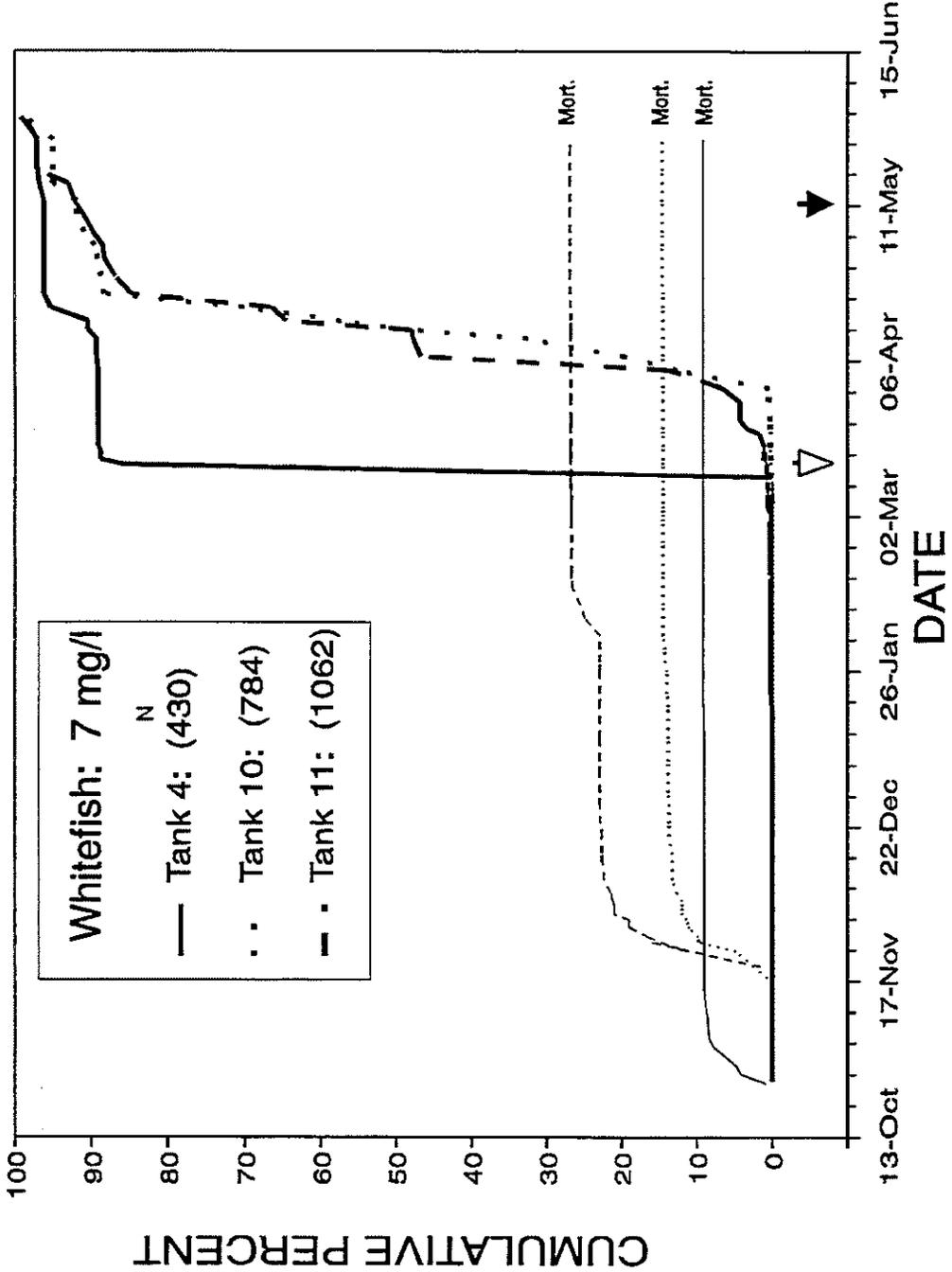


Figure 19. Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 7 mg/l. The tank numbers and total number of live larvae (N) are shown for each replicate. Water temperature rose to 7.2 °C in tank 4 for a short period on March 14 (open arrow) and was raised purposely by 0.6 °C/day in all tanks beginning May 11 (solid arrow).

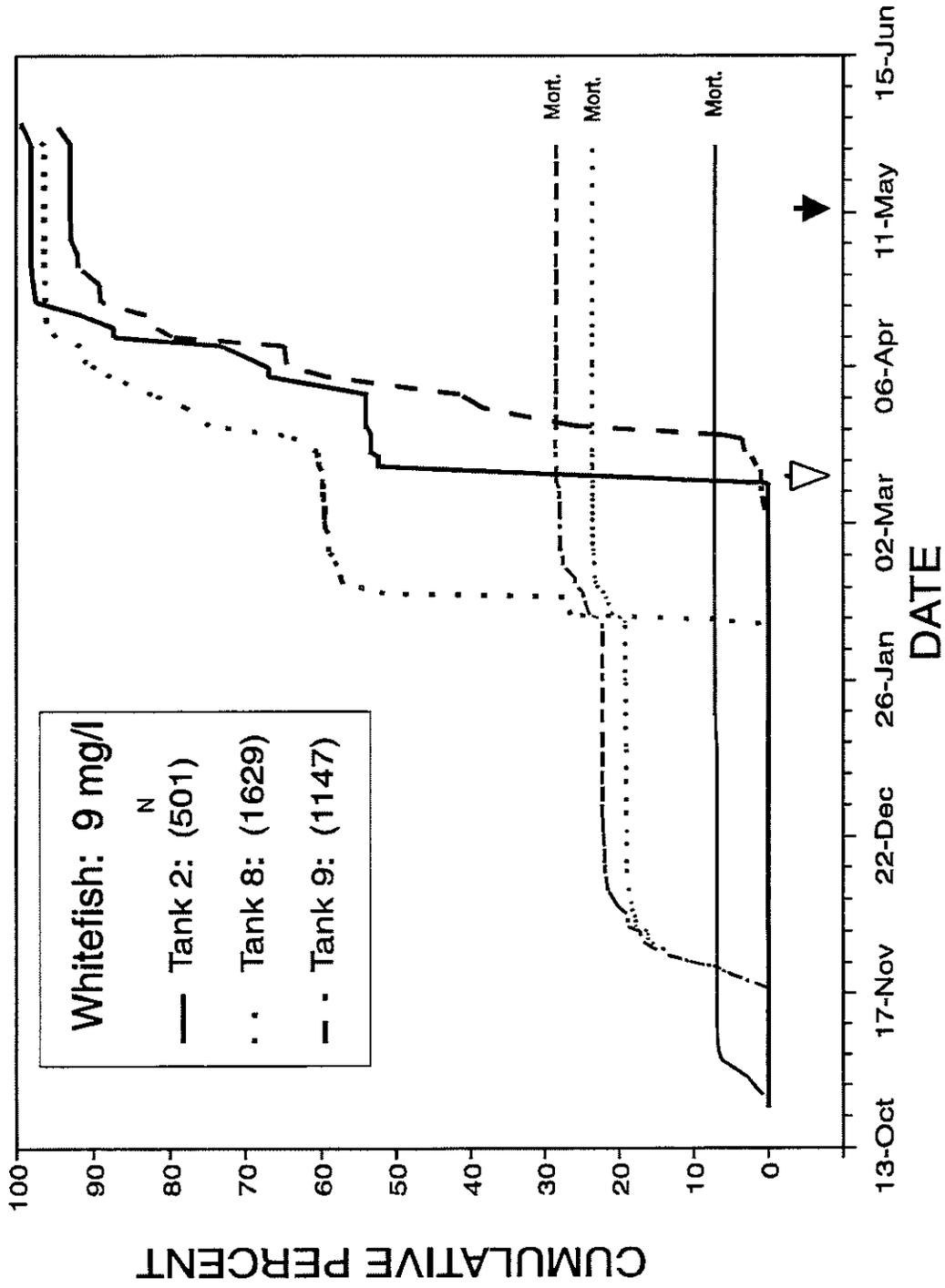
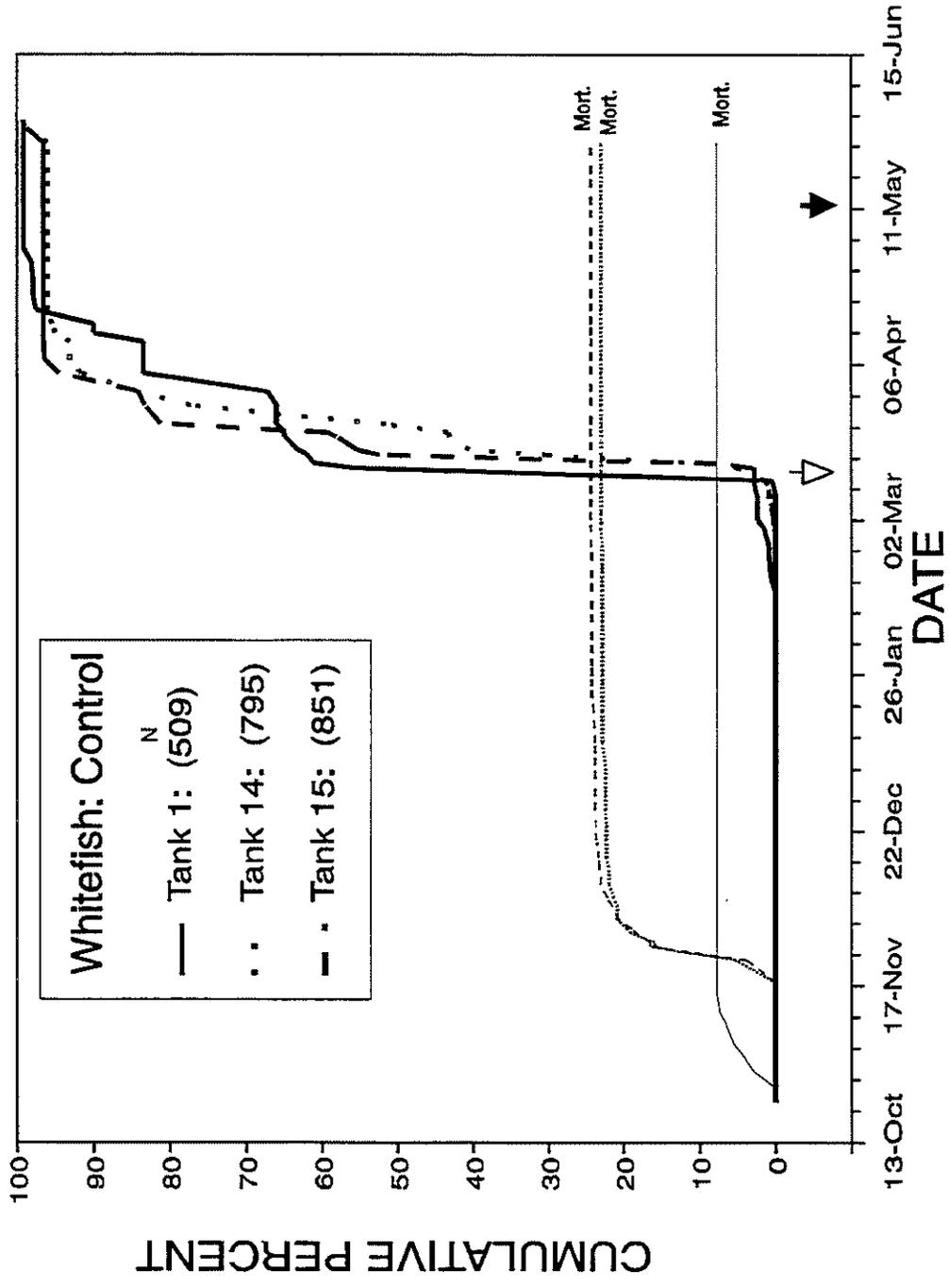


Figure 20. Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 9 mg/l. The tank numbers and total number of live larvae (N) are shown for each replicate. Water temperature rose to 7.2°C in tank 2 for a short period on March 14 (open arrow)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



**Figure 21.** Mortality and Hatching Patterns of Mountain Whitefish Eggs Incubated at a Nominal Dissolved Oxygen Concentration of 13.5 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 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).

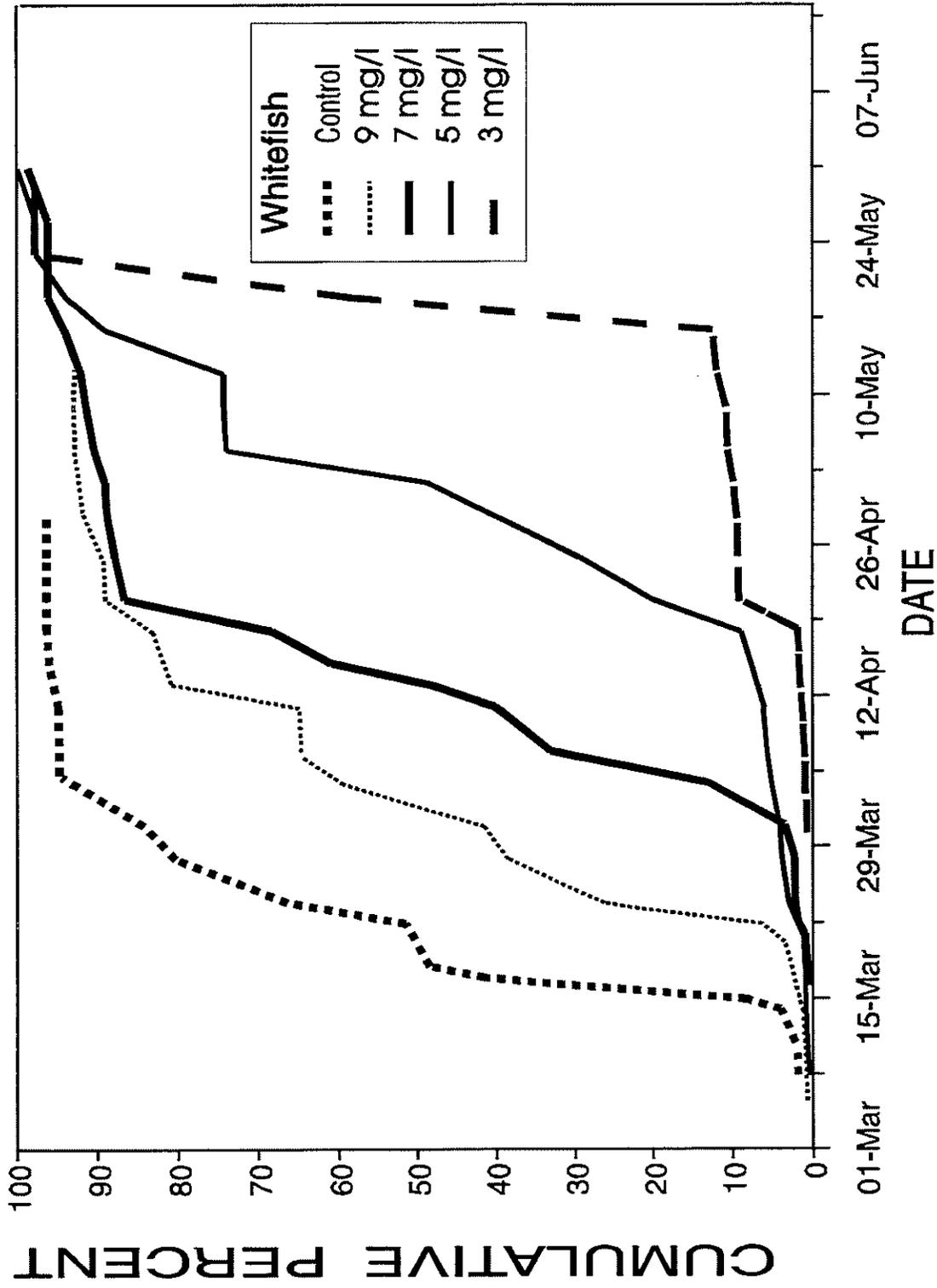


Figure 22. Comparison of Hatching Patterns of Mountain Whitefish Eggs Incubated at Different Concentrations of Dissolved Oxygen.

### 3.3 OXYGEN CONSUMPTION

#### 3.3.1 Bull Trout

Oxygen consumption ( $Q_{O_2}$ ) of bull trout over a wide range of dissolved oxygen tensions was determined for eyed eggs on January 25 and March 2, 1994 (Figures 23 and 24) and for hatched alevins on April 22 and April 28, 1994 (Figures 25 and 26) using closed vessel respirometry. In developing eggs reared at  $[DO] \geq 5$  mg/l,  $Q_{O_2}$  was oxygen-dependent in that consumption changed with decreasing oxygen tension over the entire range of oxygen partial pressure. Thus, these eggs were able to increase oxygen consumption in relation to oxygen availability. The large dip in  $Q_{O_2}$  observed in eggs reared at  $[DO]$  of 9 and 13.5 mg/l was unexplained but was also observed in whitefish eggs on January 20. Bull trout eggs incubated at 3 mg/l  $[DO]$  exhibited oxygen-independent respiration at oxygen tensions exceeding 60 and 75 mm Hg on January 25 and March 2, respectively. As a result  $Q_{O_2}$  was substantially reduced in these eggs relative to eggs reared at  $[DO] \geq 5$  mg/l at oxygen tensions  $\geq 70$  mm Hg or  $\geq 100$  mm Hg on January 25 and March 2, respectively. Maximum oxygen consumption increased by 2.5 times in all treatments between these two dates. At oxygen tensions  $< 60$  mm Hg,  $Q_{O_2}$  was the same for all eggs regardless of oxygen treatment. It is probable that physical diffusion of oxygen through the egg shell is the limiting factor for respiration at these levels. Oxygen consumption of bull trout alevins which hatched on March 14 in response to the rise in water temperature differed substantially from that of the eggs. Alevins from all oxygen treatments exhibited both oxygen-independent and oxygen-dependent respiration over oxygen tensions of 15 to 150 mm Hg. The change from independent to dependent respiration occurred at approximately 70 mm Hg for alevins in the 13.5, 9, and 7 mg/l  $[DO]$  treatments, at 45 mm Hg for alevins in the 5 mg/l treatment, and at 35 mm Hg for alevins in the 3 mg/l treatment. Furthermore,  $Q_{O_2}$  was reduced in alevins from the 5 mg/l treatment in relation to higher oxygen treatments, although the reduction was only 15 percent.  $Q_{O_2}$  in alevins from the 3 mg/l treatment were approximately 50% of those from alevins at  $[DO] \geq 7$  mg/l. The estimates of  $Q_{O_2}$  for alevins should be viewed with caution since it was not possible to control swimming activity during the measurements.

#### 3.3.2 Mountain Whitefish

The oxygen consumption of mountain whitefish eggs from all treatment groups was measured on January 20, February 9, and February 23. The relationship between oxygen consumption and oxygen tension (Figures 27 to 29) was unaffected by the oxygen concentration at which the whitefish eggs were incubated at oxygen tensions  $\geq 100$  mm Hg. All eggs exhibited oxygen-dependent respiration which was approximately linear from 150 to 20 mm Hg. On January 20 and February 9, at oxygen tensions above 100 mm Hg,  $Q_{O_2}$  was reduced by approximately 40% in eggs reared at  $[DO]$  of 3 mg/l compared to eggs reared at higher dissolved oxygen concentrations. Maximum oxygen consumption of eggs increased from approximately  $0.45 \mu\text{g/h/egg}$  on January 20 to 0.75 and  $1.4 \mu\text{g/h/egg}$  on

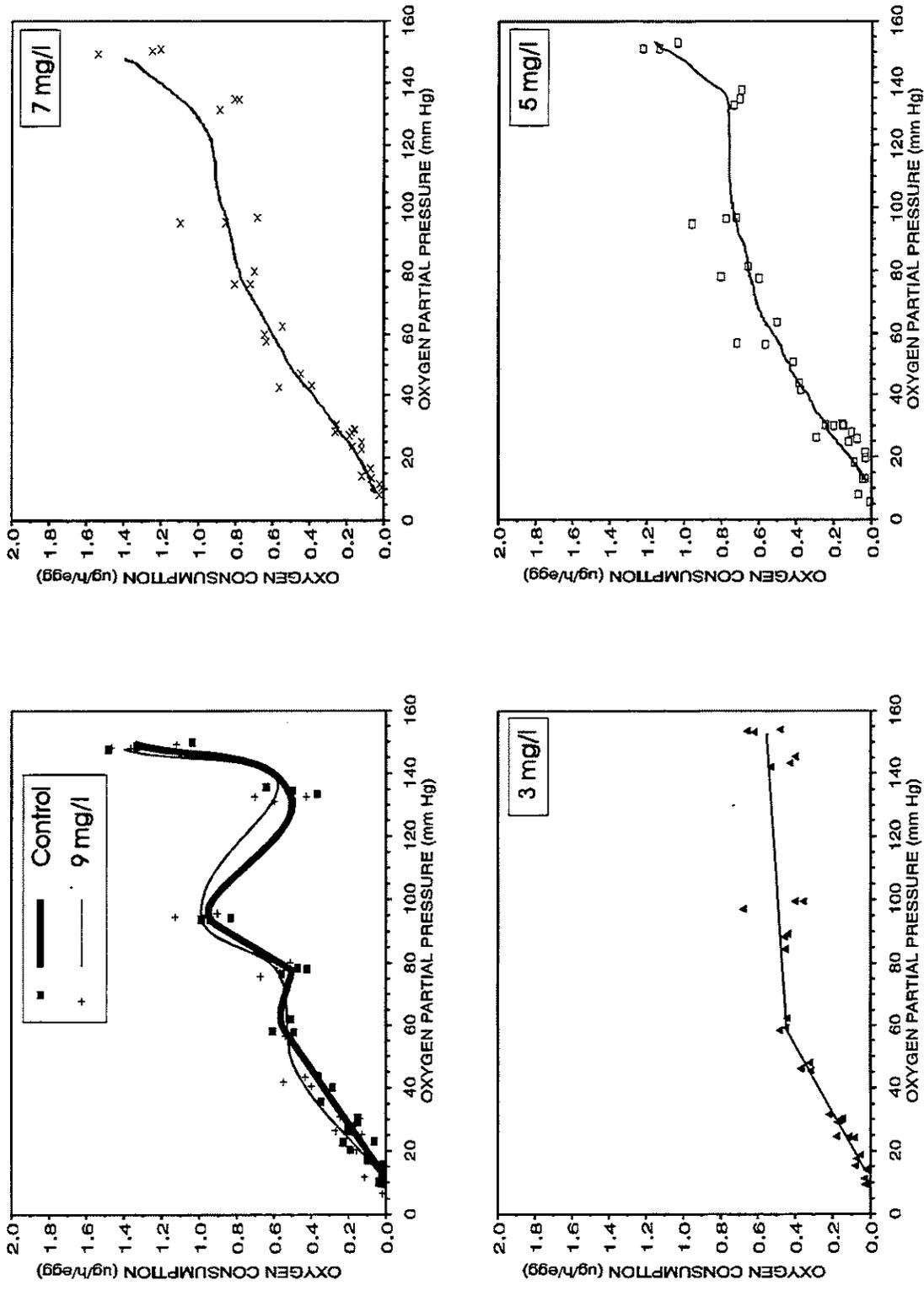


Figure 23. Oxygen Consumption of Bull Trout Eggs (January 25). The lines are fitted by eye.

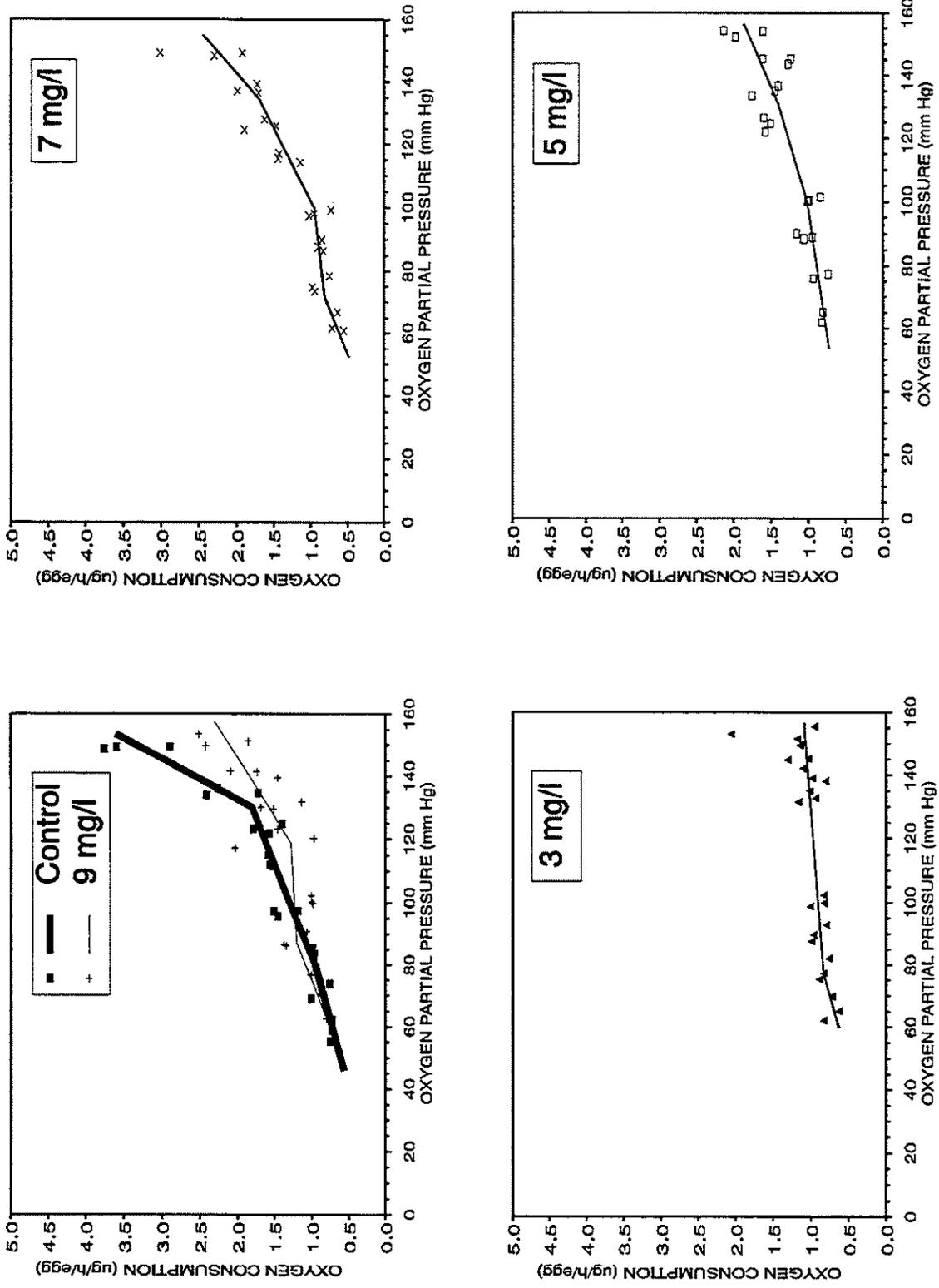
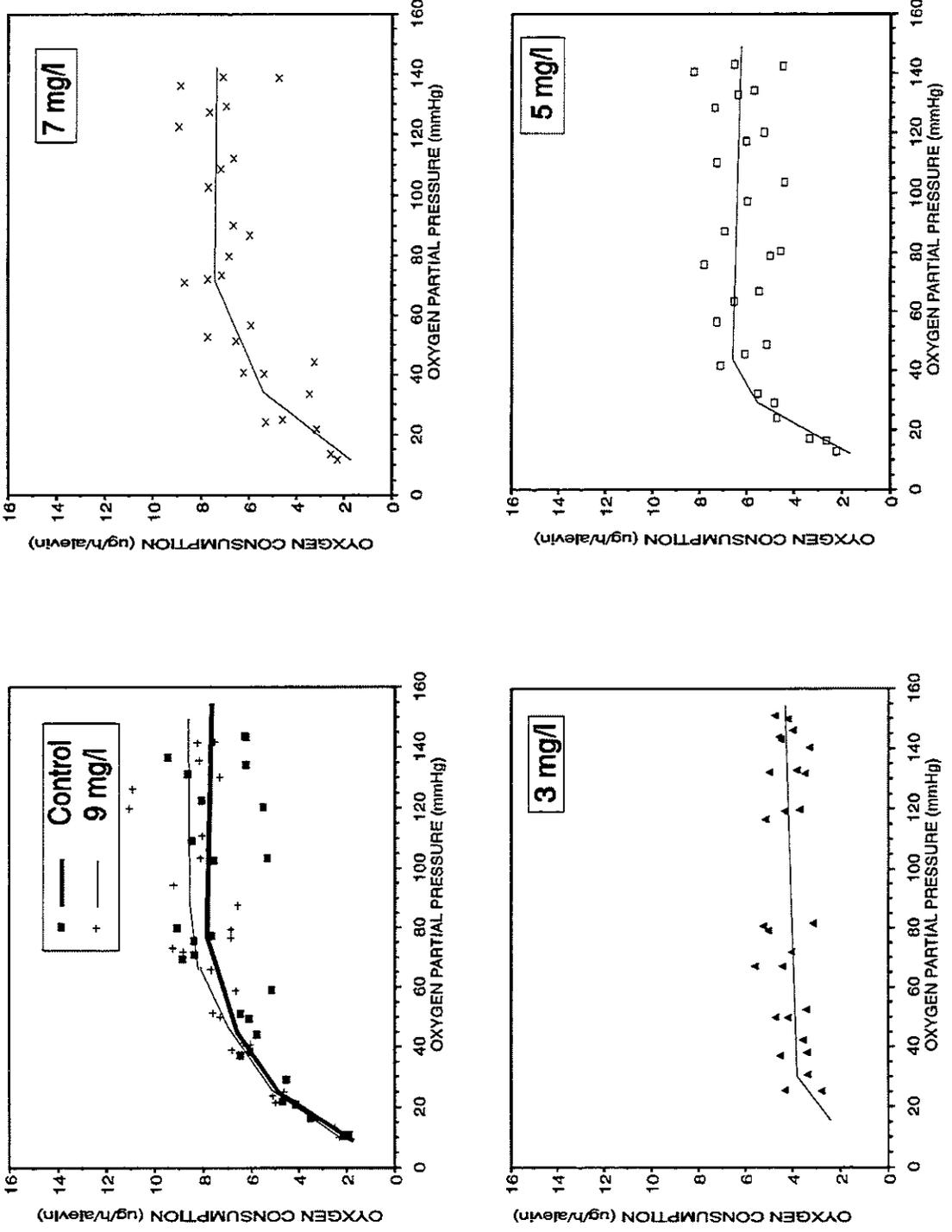


Figure 24. Oxygen Consumption of Bull Trout Eggs (March 2). The lines are fitted by eye.



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

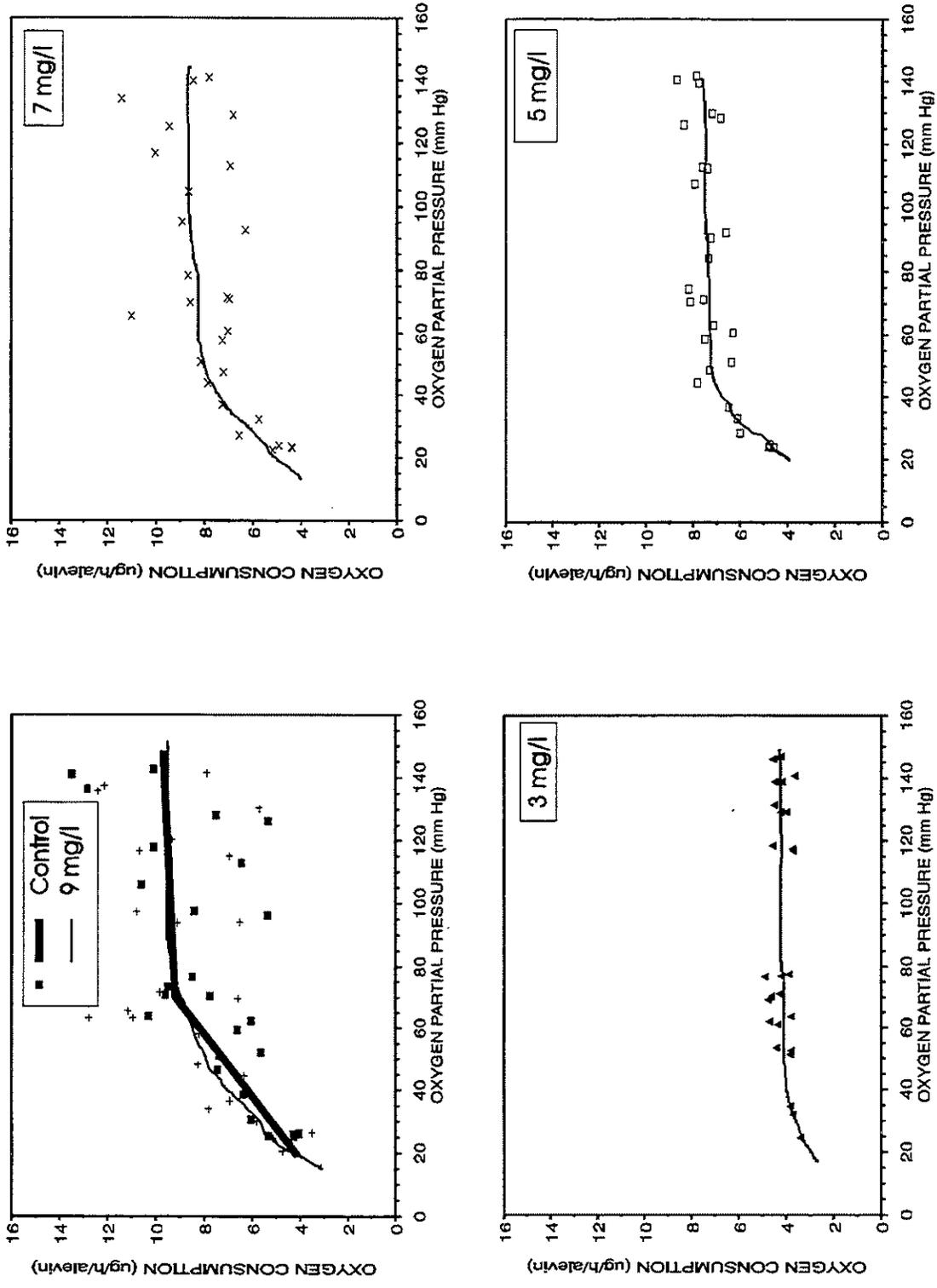


Figure 26. Oxygen Consumption of Bull Trout Alevins (April 28). The lines are fitted by eye.

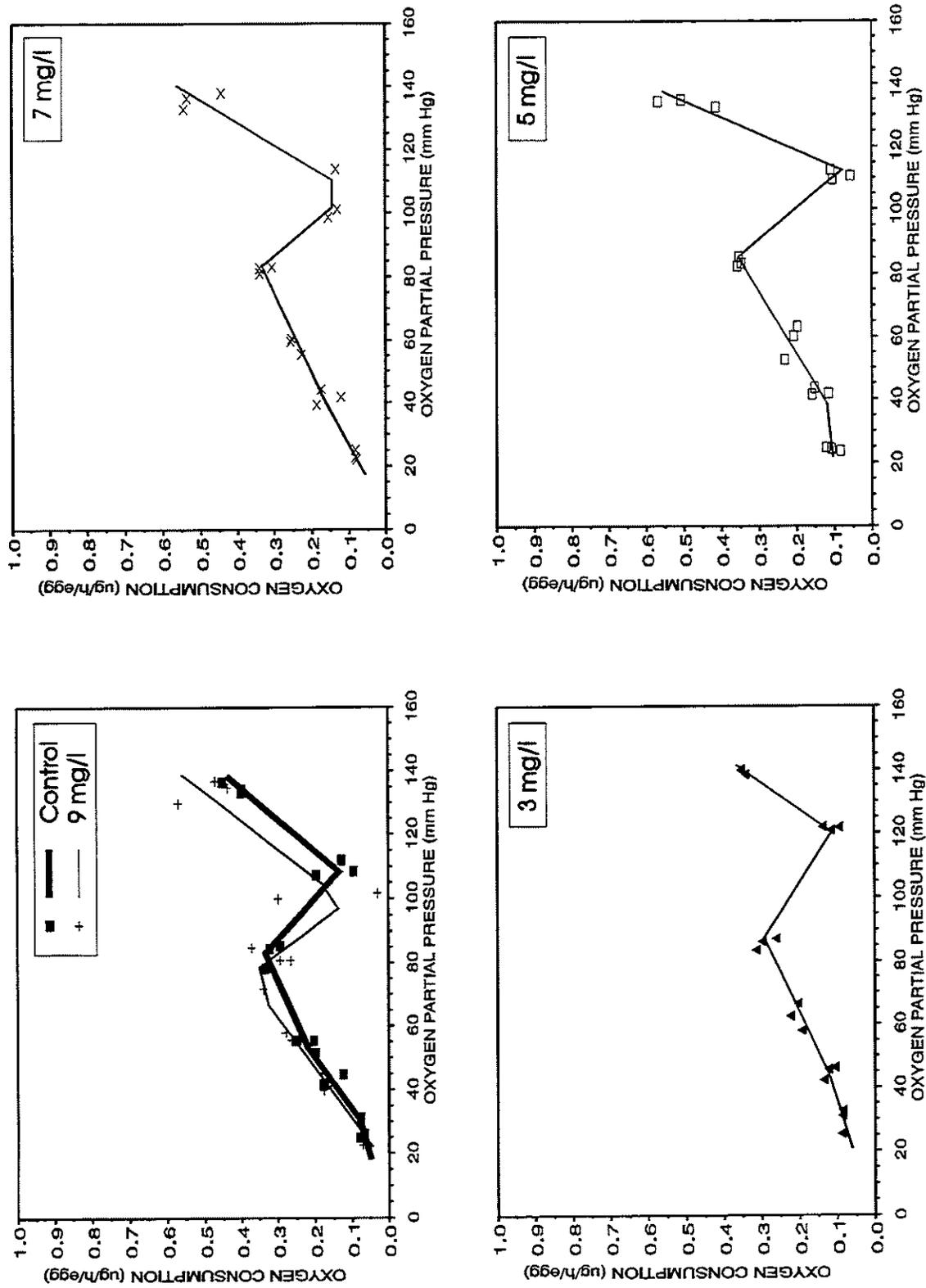


Figure 27. Oxygen Consumption of Mountain Whitefish Eggs (January 20). The lines are fitted by eye.

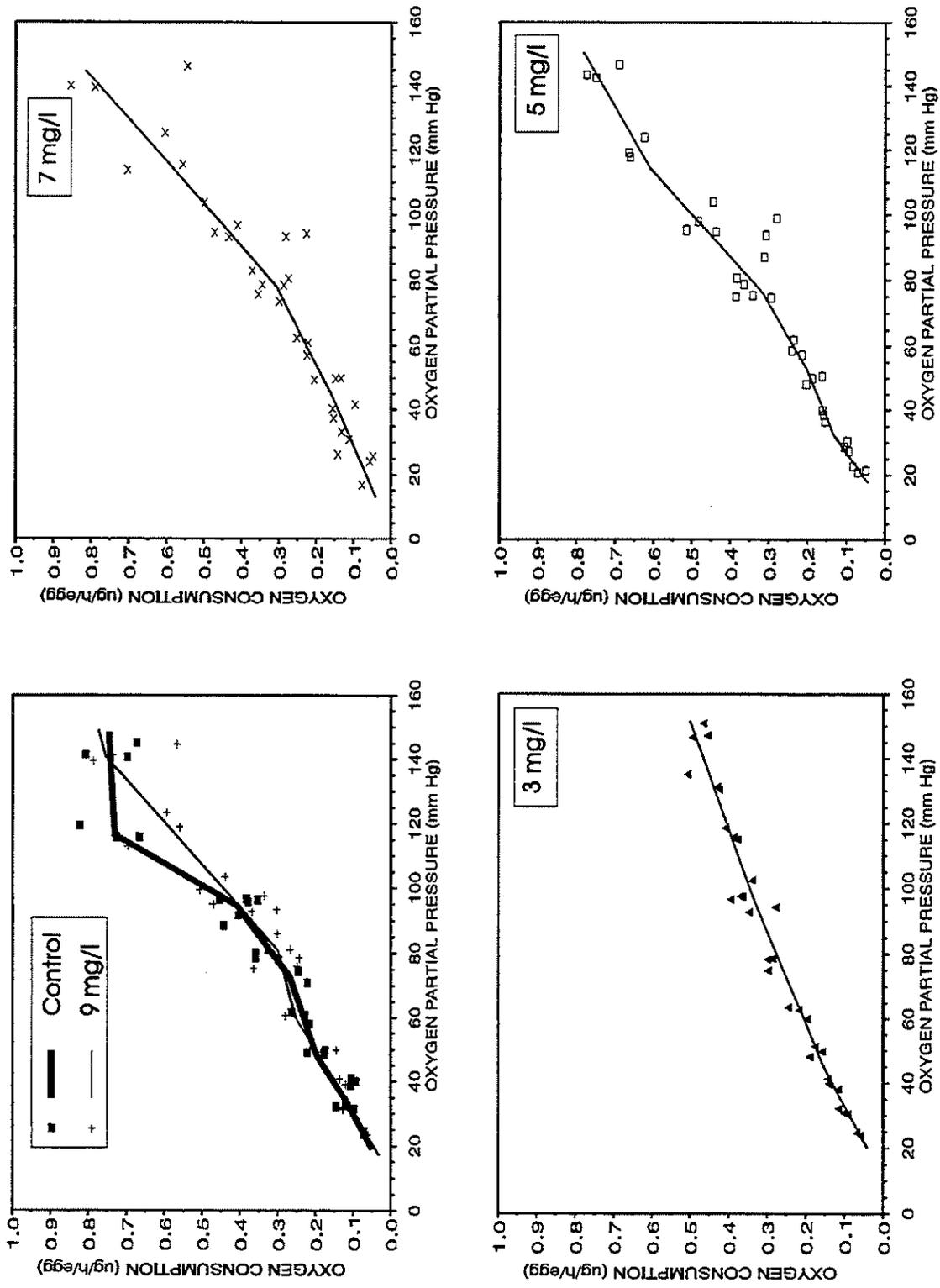


Figure 28. Oxygen Consumption of Mountain Whitefish Eggs (February 9). The lines are fitted by eye.

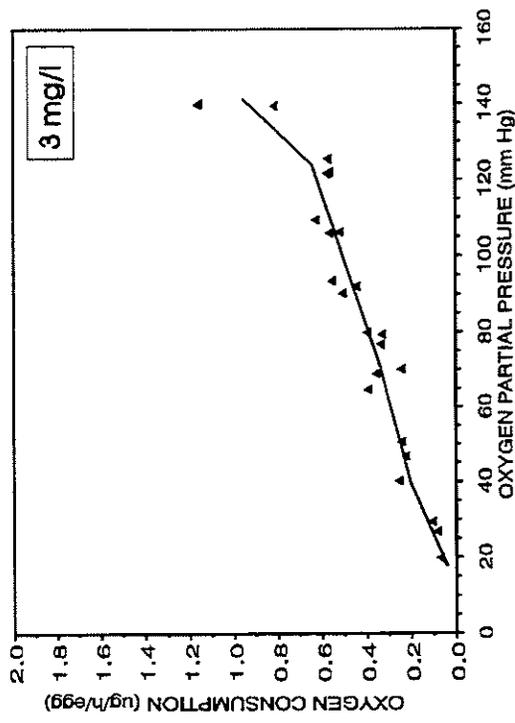
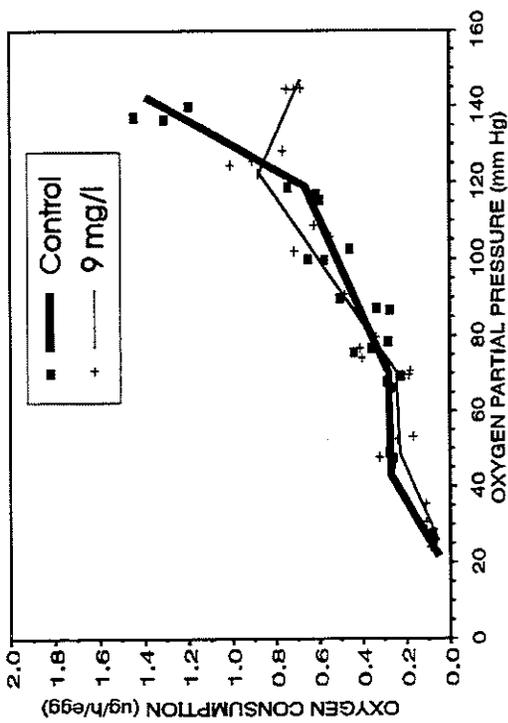
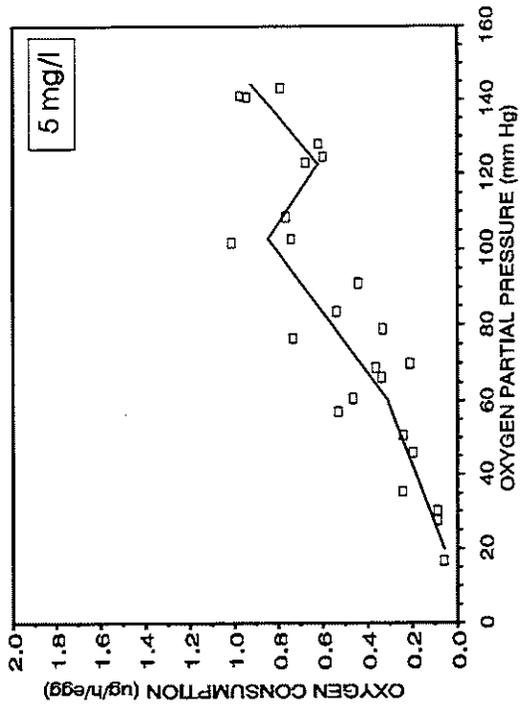
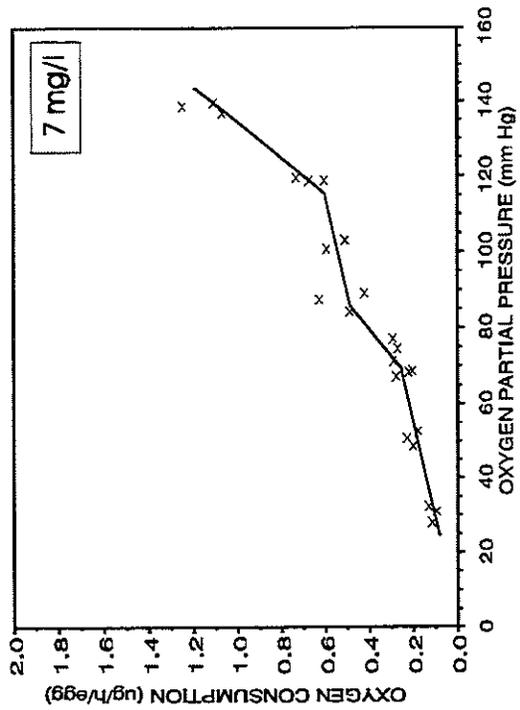
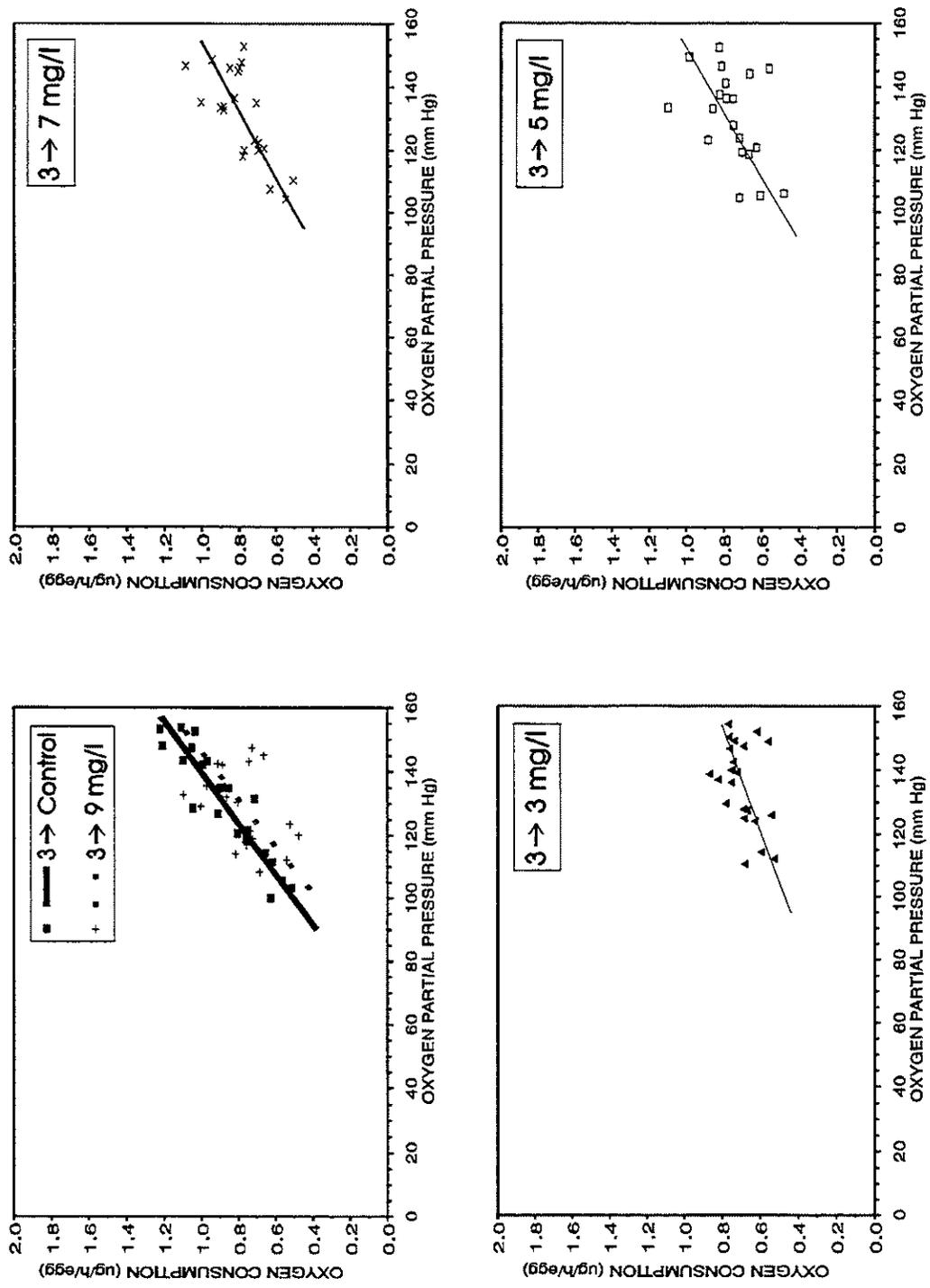


Figure 29. Oxygen Consumption of Mountain Whitefish Eggs (February 23). The lines are fitted by eye.



**Figure 30.** Oxygen Consumption of Mountain Whitefish Eggs 14 Days After Transfer From [DO] of 3 mg/l to Less Hypoxic Water on March 28. 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  $\geq 100$  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]  $\geq 9$  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  $\mu\text{g/h/egg}$  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:

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

where:  $T_h$  = time to 50% hatch in days;

$Q_{O_2}$  = oxygen consumption ( $\mu\text{g/h/egg}$ ) on February 23;

The correlation coefficient for this relationship was 0.9899 which is highly significant ( $P < 0.01$ ,  $df = 3$ ).

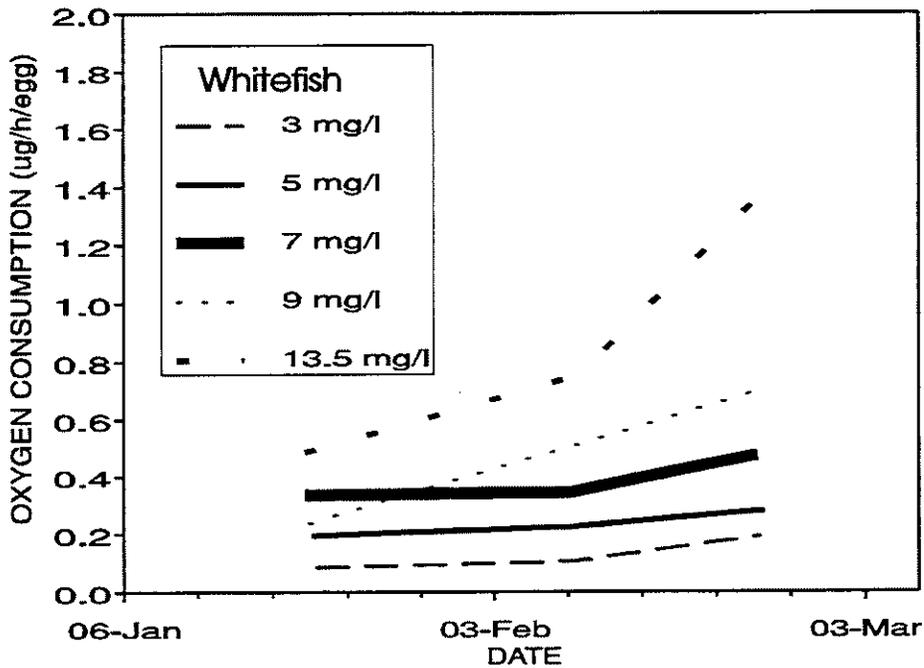
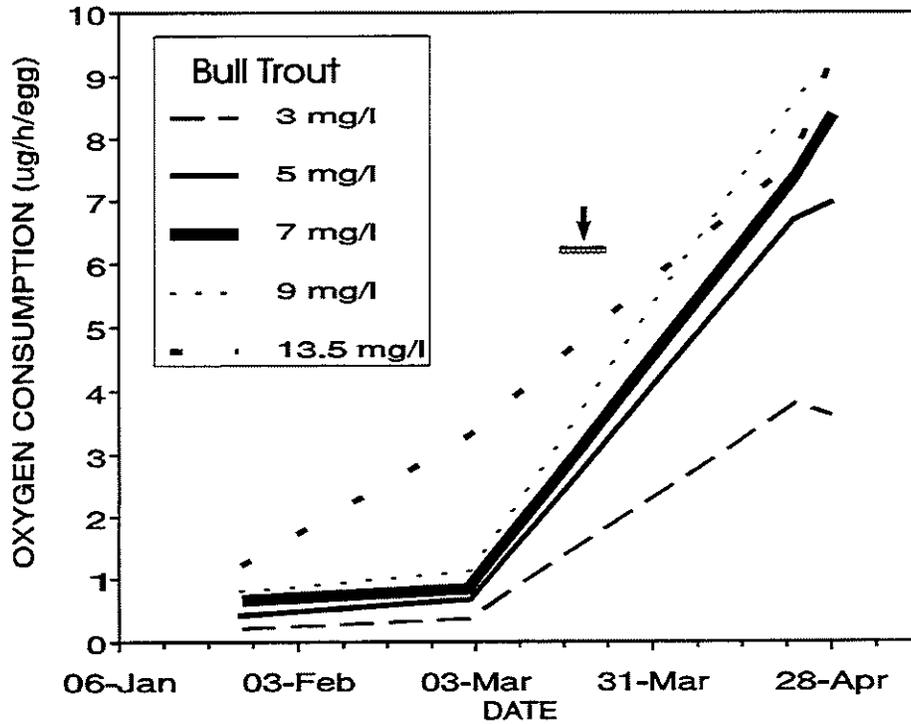
### 3.3.4 Residual Oxygen Levels

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

in the tonometer over several hours to be certain that the embryos were no longer extracting additional oxygen. Death of alevins could be easily observed by the cessation of muscular activity. Tests performed with dead eggs or with test water without eggs confirmed that reduction in oxygen from bacterial activity or other sources was negligible. Measurement of oxygen concentrations at levels approaching complete anoxia, however, are extremely sensitive to electrical noise in the oxygen meter and these results should be viewed with caution. Dissolved oxygen concentration during incubation had no significant effect ( $F < 3.7$ ,  $P > 0.05$ ) upon the oxygen residuals observed in either bull trout or mountain whitefish (Table 1). The changes in residual oxygen with time of development, however, were statistically significant ( $F > 7.5$ ,  $P < 0.01$ ). Bull trout eggs and larvae died at oxygen tensions ranging from 2.3 to 8.7 mm Hg which is equivalent to dissolved oxygen concentrations of 0.20 to 0.75 mg/l at the test temperature of 2°C. The low value recorded on January 15 in eggs from the 3 mg/l [DO] treatment is suspect. Excluding that result the residual oxygen of whitefish eggs ranged from 4.4 to 7.5 mm Hg (0.38 to 0.64 mg/l) on January 15, and from 11.0 to 11.8 mm Hg (0.94 to 1.01 mg/l) on February 22.

**Table 1. Residual Oxygen Levels (mm Hg) in Bull Trout and Mountain Whitefish Eggs Incubated at Different Concentrations of Dissolved Oxygen.** The results are given as the mean  $\pm$  1 standard deviation of the oxygen tension at death for 3 replicates. The value in brackets is the number of eggs or alevins in the tonometer.

Date	Species-Stage	Oxygen Treatment (mg/l)				
		13.5	9	7	5	3
Jan. 25	Bull Trout-egg (3)	6.7 $\pm$ 1.9	6.3 $\pm$ 1.9	7.5 $\pm$ 2.2	8.7 $\pm$ 2.1	7.6 $\pm$ 2.9
Mar. 2	Bull Trout-egg (2)	8.0 $\pm$ 0.6	5.4 $\pm$ 1.9	5.7 $\pm$ 2.0	4.4 $\pm$ 0.3	8.4 $\pm$ 1.7
Apr. 28	Bull Trout-alevin (1)	5.5 $\pm$ 1.3	3.4 $\pm$ 0.3	4.8 $\pm$ 0.7	2.3 $\pm$ 0.7	5.9 $\pm$ 2.7
Jan. 15	Whitefish-egg (10)	7.5 $\pm$ 3.1	5.3 $\pm$ 3.3	4.4 $\pm$ 1.8	5.7 $\pm$ 0.3	1.9 $\pm$ 1.6
Feb. 23	Whitefish-egg (7)	11.8 $\pm$ 0.3	11.0 $\pm$ 3.3	11.8 $\pm$ 2.8	11.4 $\pm$ 2.8	11.4 $\pm$ 0.4



**Figure 31. Oxygen Consumption ( $Q_{O_2}$ ) of Bull Trout and Mountain Whitefish Eggs at the Actual Dissolved Oxygen Concentrations of Incubation.** The estimates of  $Q_{O_2}$  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.

### **3.4 EFFECT OF HYPOXIA UPON CARDIAC RATES**

The effect of incubation at increasing levels of hypoxia upon cardiac rates was measured at eleven periods during the embryonic development of whitefish eggs (Table 2). A small reduction in heart rate (bradycardia) was observed in embryos incubated at [DO] of 3 mg/l. Cardiac rates in these embryos were reduced by 8 to 22% when compared to control values. Cardiac rates increased with the age of the embryos rising from approximately 30 beats/min in early January to 40 beats/min in April in eggs at [DO]  $\geq$  5 mg/l. Eggs transferred from [DO] of 3 mg/l to  $\geq$  5 mg/l on March 28 exhibited an increase in cardiac rate by April 6 and achieved near normal cardiac rates by April 20.

### **3.5 EFFECT OF HYPOXIA ON FEEDING SUCCESS OF WHITEFISH LARVAE**

Feeding trials of whitefish larvae which previously had exhibited active feeding behaviour (experienced larvae) and larvae which previously had not been exposed to food (naive larvae) were conducted on March 29 and April 11, respectively. With one exception, exposure to low concentrations of dissolved oxygen during embryonic development did not result in an impairment in the ability of the larvae to capture live prey (Table 3). Experienced larvae raised at 5 mg/l of dissolved oxygen captured significantly fewer nauplii ( $t = 4.62$ ,  $P < 0.02$ , 18 df) than similar sized larvae raised at 13.5 mg/l when exposed to a prey concentration of 182 nauplii/l. At 123 nauplii/l, however, larvae from the lower oxygen treatment were more successful in capturing prey than those reared at [DO]  $\geq$  7 mg/l.

### **3.6 CRITICAL THERMAL MAXIMA**

Because of substantial differences in the timing of hatch and subsequent acclimation to feeding at 10°C it was not possible to compare whitefish from all dissolved oxygen treatments at one time and at similar weights. All whitefish were thermally acclimated and feeding for at least 2 weeks prior to tests of critical thermal maxima (CTM). No differences in CTM were observed in whitefish from any of the treatments or acclimation periods (Table 4). The overall CTM for these fish was  $28.41 \pm 0.31^\circ\text{C}$ . Bull trout from all oxygen treatments were tested once at the same time and also failed to exhibit treatment-related differences in CTM (Table 4). The overall mean CTM for bull trout was  $28.36 \pm 0.29^\circ\text{C}$ .

### **3.7 EMBRYOLOGICAL DEVELOPMENT AND YOLK UTILIZATION**

#### **3.7.1 Mountain Whitefish**

The effects of hypoxia upon embryological development of mountain whitefish were assessed by determining changes in egg diameter, yolk cross-sectional area, eye length, and interorbital distance at intervals during embryological development. Other physical features including somite development, trunk length and width, and oil droplet size and distribution were also examined but

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 exhibited 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 Bull Trout**

Embryonic development of bull trout was not analyzed in the same detail as whitefish because it was not possible 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 somewhat prematurely in response to the temperature rise in mid-March.

**Table 2. Effect of Hypoxia on Cardiac Rate in Mountain Whitefish Embryos. Results are shown as mean beats/min  $\pm$  1 standard deviation for N=6. The appropriate incubation tank is given in brackets.**

Date	OXYGEN TREATMENT (mg/l)																
	13.5 (T1)	9 (T2)	5 (T3)	7 (T4)	3 (T5)	3 (T6)	3 (T7)	9 (T8)	9 (T9)	7 (T10)	7 (T11)	5 (T12)	5 (T13)	13.5 (T14)	13.5 (T15)		
24 Dec*	44.7 $\pm$ 1.9	42.3 $\pm$ 4.7	38.3 $\pm$ 3.2	36.0 $\pm$ 2.0	35.4 $\pm$ 1.7	ND ND											
04 Jan	29.7 1.9	31.7 1.9	27.3 2.8	28.4 1.3	25.4 2.6	ND ND											
15 Jan	26.9 0.5	30.5 2.4	28.3 0.4	29.0 1.0	28.1 0.3	ND ND											
21 Jan	28.8 1.0	30.4 1.1	29.8 1.0	29.6 1.0	26.5 1.4	ND ND											
27 Jan	30.8 1.4	31.2 1.2	29.6 0.5	29.5 1.6	26.7 1.6	ND ND	LD ND	ND ND	ND ND	ND ND							
04 Feb	34.0 1.3	33.8 1.2	32.9 1.7	34.9 1.5	30.4 1.1	ND ND											
16 Feb	36.0 1.3	37.3 0.8	34.1 2.3	35.2 1.8	28.2 1.4	ND ND											
24 Feb	37.1 2.0	36.0 1.6	36.7 1.3	37.1 1.9	30.8 1.2	ND ND											
08 Mar	43.2 5.3	45.1 1.4	41.6 2.0	38.5 3.0	39.0 2.3	ND ND											
22 Mar	ND ND	ND ND	ND ND	ND ND	33.8 2.1	28.3 1.7	31.8 1.4	ND ND	ND ND								
06 Apr	32.5 1.2	32.9 1.0	31.1 1.5	35.3 2.4	31.6 1.1	29.3 1.4	31.9 2.1	38.7 1.8	37.8 1.5	36.4 1.8	34.3 1.3	34.2 1.3	36.3 2.5	44.9 1.9	42.8 1.7	ND ND	
20 Apr	38.0 2.1	38.6 1.2	34.3 0.6	39.1 1.7	31.8 0.9	33.0 1.2	33.1 0.9	40.2 2.5	38.0 1.4	36.8 2.1	36.9 1.4	38.0 2.1	39.3 0.9	ND ND	ND ND	ND ND	
Transfers								T6-T9		T6-T11		T7-T13		T7-T15			
6 Apr	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	35.2 1.1	33.5 0.9	33.5 0.9	34.1 1.7	34.1 1.7	35.8 1.1	35.8 1.1	35.8 1.1	35.8 1.1	
20 Apr	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	38.0 2.8	37.6 1.6	37.6 1.6	34.8 1.8	34.8 1.8	39.9 1.1	39.9 1.1	39.9 1.1	39.9 1.1	

\* Cardiac rates elevated because of increase in water temperature during measurement.

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

Date	Oxygen Treatment (mg/l O <sub>2</sub> )	Food Density (N/l)		Larvae Tested (N)	No. Larvae With No Nauplii	Food Consumption		Larval Length (mm)
		Nauplii	Eggs			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...

Date	Oxygen Treatment (mg/l O <sub>2</sub> )	Food Density (N/l)		Larvae Tested (N)	No. Larvae With No Nauplii	Food Consumption		Larval Length (mm)
		Nauplii	Eggs			Nauplii/Larvae	Eggs/Larvae	
April 11	9	121	22	10	0	40.7±19.5	1.7±3.0	14.8±0.4
	7	"	"	10	0	42.9±11.6	2.0±1.4	14.7±0.5
	5	"	"	10	1	30.4±18.8	1.3±1.8	14.9±0.4
	3	"	"	10	0	19.1±13.4	1.0±0.5	14.8±0.6
April 11	9	61	11	10	2	19.0±1.1	1.7±1.1	15.4±0.4
	7	"	"	10	2	22.8±17.4	2.0±1.2	14.8±0.7
	5	"	"	10	0	18.7±6.7	2.4±1.3	15.1±0.5
	3	"	"	10	1	17.8±15.6	2.2±1.6	14.3±0.5

\* Stomach contents of larvae prior to feeding trials on March 29.

Concluded

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

**Table 5. Effect of Dissolved Oxygen Upon Embryological Development in Mountain Whitefish.**

DATE	EGG DIAMETER (mm)			YOLK AREA (mm <sup>2</sup> )			EYE LENGTH (mm)			INTERORBITAL DISTANCE (mm)		
	OXYGEN TREATMENT (mg/l)	MEAN	F/P†	N	MEAN	F/P	N	MEAN	F/P	N	MEAN	F/P
22 Dec 93	3	4.07±0.24 <sup>ab*</sup>	1.46/0.222	15	8.54±1.33 <sup>a</sup>	1.13/0.348	12	0.88±0.07 <sup>a</sup>	0.93/0.451	9	0.47±0.12 <sup>a</sup>	0.33/0.855
	5	4.14±0.26 <sup>ab</sup>		15	8.02±1.26 <sup>a</sup>		15	0.88±0.07 <sup>a</sup>		12	0.44±0.07 <sup>a</sup>	
	7	4.10±0.14 <sup>ab</sup>		20	7.98±0.98 <sup>a</sup>		17	0.90±0.07 <sup>a†</sup>		14	0.46±0.07 <sup>a</sup>	
	9	4.17±0.15 <sup>a</sup>		15	8.71±1.19 <sup>a</sup>		15	0.90±0.10 <sup>a</sup>		11	0.46±0.11 <sup>a</sup>	
	13.5	3.99±0.29 <sup>b</sup>		15	8.25±1.36 <sup>a</sup>		12	0.93±0.06 <sup>a</sup>		9	0.48±0.06 <sup>a</sup>	
12 Jan 94	3	4.20±0.19 <sup>a</sup>	4.92/<0.001	20	9.31±1.35 <sup>a</sup>	2.63/0.037	14	0.93±0.05 <sup>c</sup>	11.15/<0.001	8	0.59±0.06 <sup>a</sup>	1.05/0.394
	5	4.05±0.32 <sup>bo</sup>		38	8.73±1.42 <sup>ab</sup>		30	0.97±0.09 <sup>c</sup>		6	0.62±0.02 <sup>a</sup>	
	7	3.99±0.18 <sup>c</sup>		39	9.28±1.49 <sup>a</sup>		26	1.03±0.07 <sup>ab</sup>		13	0.66±0.06 <sup>a</sup>	
	9	4.19±0.20 <sup>a</sup>		29	9.26±1.55 <sup>a</sup>		23	1.08±0.08 <sup>a</sup>		11	0.63±0.14 <sup>a</sup>	
	13.5	4.12±0.19 <sup>ab</sup>		30	8.26±1.66 <sup>b</sup>		19	1.02±0.09 <sup>b</sup>		11	0.60±0.09 <sup>a</sup>	
03 Feb 94	3	4.10±0.34 <sup>a</sup>	4.62/0.002	30	6.49±2.04 <sup>a</sup>	16.61/<0.001	16	0.91±0.07 <sup>b</sup>	3.57/0.011	8	0.54±0.11 <sup>a</sup>	0.14/0.967
	5	4.07±0.26 <sup>a</sup>		30	4.90±1.60 <sup>b</sup>		21	1.00±0.17 <sup>ab</sup>		12	0.55±0.16 <sup>a</sup>	
	7	4.03±0.14 <sup>a</sup>		10	4.34±0.89 <sup>bo</sup>		3	1.08±0.10 <sup>b</sup>		3	0.53±0.10 <sup>a</sup>	
	9	3.86±0.15 <sup>b</sup>		30	3.85±0.85 <sup>c</sup>		15	1.03±0.07 <sup>b</sup>		11	0.53±0.07 <sup>a</sup>	
	13.5	4.04±0.21 <sup>a</sup>		30	3.86±0.97 <sup>c</sup>		19	1.05±0.14 <sup>b</sup>		9	0.51±0.11 <sup>a</sup>	
23 March 94	3	3.91±0.26 <sup>a</sup>	0.90/0.464	30	5.19±1.76 <sup>a</sup>	32.82/<0.001	18	0.94±0.16 <sup>b</sup>	6.25/<0.001	15	0.52±0.13 <sup>a</sup>	2.16/0.084
	5	3.92±0.19 <sup>a</sup>		30	3.21±0.79 <sup>b</sup>		18	1.06±0.09 <sup>a</sup>		13	0.64±0.19 <sup>a</sup>	
	7	3.86±0.15 <sup>a</sup>		28	2.69±0.71 <sup>bo</sup>		22	1.09±0.07 <sup>a</sup>		19	0.58±0.11 <sup>ab</sup>	
	9	3.82±0.22 <sup>a</sup>		26	1.06±0.15 <sup>c</sup>		18	1.06±0.15 <sup>a</sup>		14	0.57±0.07 <sup>ab</sup>	
	13.5	3.91±0.26 <sup>a</sup>		30	2.28±1.07 <sup>c</sup>		13	1.14±0.09 <sup>a</sup>		10	0.62±0.05 <sup>ab</sup>	

\* For each variable and date the means for each oxygen treatment with the same superscript letter are not significantly different (P < 0.05).  
† F and P values calculated by ANOVA with oxygen treatment as the classification variable.

**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  $\pm$  1 standard deviation.**

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

## 4.0 DISCUSSION

### 4.1 EFFECTS OF HYPOXIA UPON EGG MORTALITY

Reduction of dissolved oxygen for a period of 159 days to levels as low as 3 mg/l had no effect upon the survival of either bull trout or mountain whitefish eggs at temperatures of 2 to 3°C. Approximately 15 percent of the bull trout eggs died during the early stages of development but most of this mortality occurred prior to exposure to hypoxia and was probably related to the disintegration of infertile eggs or the death of damaged eggs. A similar level of mortality occurred in the eggs maintained at the Hill Creek Hatchery (G. Thorp; personal communication). Less than 6% of the bull trout eggs died during incubation under hypoxic conditions and the levels of mortality were similar among all oxygen treatments. Mortality during hatching was also low (< 5%) in bull trout eggs. Treatment-related mortality was also absent in mountain whitefish eggs and less than 5% of these eggs died during hatching. The whitefish eggs incubated at 3 mg/l of dissolved oxygen, however, did not hatch until mid-May, 14 days after the oxygen level had been raised to saturation and 5 days after the water temperature had been increased from 2°C. Thus, although these eggs survived it is possible that they would have died if maintained under hypoxic conditions. This possibility is irrelevant to a natural situation in the Study Area, however, since dissolved oxygen levels in hypoxic regions of the rivers commonly begin to rise between mid-March and mid-April (Noton and Allan 1994). Comparison of the present results to those from other studies are complicated by the lack of information of the effects of hypoxia on egg survival at comparable water temperatures. Survival of mountain whitefish from Utah incubated at 4°C was reduced from 85% at saturated levels of dissolved oxygen to about 70 and 17% at 4.6 and 3.3 mg/l, respectively, (Siefert et al., 1974) and much of the mortality occurred during the period of hatch. Lake herring, *Coregonus artedii*, however, exhibited similar levels of survival at all stages of development through hatching when incubated at [DO] levels from 1 to 12 mg/l at 2°C. Reduced survival of other char species has been reported at dissolved oxygen levels of 2.8 to 4.3 mg/l but these studies were conducted at water temperatures exceeding 6°C (Siefert and Spoor, 1974; Carlson and Siefert, 1974). Considering the enormous influence of water temperature upon the oxygen requirements of salmonid embryos (Rombough, 1988), the lack of effect of chronic hypoxia upon embryonic survival observed in the present study is probably related to reduced metabolic requirements for oxygen at the low temperatures employed.

### 4.2 EFFECTS OF HYPOXIA UPON EMBRYOLOGICAL DEVELOPMENT

The majority of the effects of hypoxia upon embryological development of both bull trout and mountain whitefish appear to be related to influences upon their rate of development. Hypoxia retarded the hatching time of bull trout only slightly in that eggs reared at [DO] of 5, 7, and 13.5 mg/l exhibited 50% hatch between 166 and 169 days after fertilization. This level of hatch occurred 7 days later in eggs reared at 3 mg/l of dissolved oxygen. Clearly, however, the developmental stage of the bull trout alevins was retarded at [DO]  $\leq$  5 mg/l as shown by the relatively larger fraction of the total

weight composed of yolk when compared to alevins reared at  $[\text{DO}] \geq 7$  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  $[\text{DO}]$  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  $[\text{DO}]$  treatment had 56% more yolk than alevins from oxygen levels  $\geq 7$  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  $[\text{DO}]$  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  $\leq 7$  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

of the mountain whitefish larvae were related to the severity of hypoxia during incubation. This suggests that the efficiency of the conversion of yolk to tissue was not impaired in whitefish experiencing hypoxia during embryological development. Since the occurrence of physical deformities, ability to feed, and thermal tolerance of whitefish larvae was not adversely affected by hypoxia during embryonic development, the larvae from all treatments would appear to have an equal chance of survival if all other factors were equal.

Residual oxygen levels for developing eggs of both species were extremely low. The residuals ranged from 0.2 to 1.0 mg/l of dissolved oxygen which is equivalent to oxygen saturations of 1.5 to 7.5 percent. Residual oxygen was higher in later developmental stages in whitefish but was similar in the eggs and alevins of bull trout. In some of the residual oxygen tests the embryos were allowed to reduce the oxygen tension to levels near the residual level before the water was replaced by saturated water and the test repeated. This would suggest that, for short periods of exposure time, these embryos were able to survive extremely low oxygen tensions. Residual oxygen values are not known for many fish or life stages especially at low temperatures. For trout at 10°C, however, residual oxygen may range from 0.9 mg/l for young Arctic char, *Salvelinus alpinus*, (Giles, 1991) to 2.7 mg/l for young rainbow trout, *Oncorhynchus mykiss*, (Giles and Klaprat, 1979).

Hypoxia during embryological development had no apparent effect on the ability of whitefish larvae to capture live prey in either feeding-experienced larvae or naive larvae. This would suggest that if appropriate feed were available at the time of hatch whitefish larvae from all [DO] treatments would survive the critical phase of first feeding. Since the bull trout could not be induced to feed, possibly because they were still surviving on yolk reserves, it was not possible to assess the effects of lowered dissolved oxygen levels on their ability to utilize exogenous food sources. It is known, however, that the timing of hatch in relation to other climatological and biological factors can significantly influence the overall survival of juvenile fish through their first year. In this connection, delays caused by hypoxia in hatching and emergence may reduce survival by causing the juvenile fish to be out of phase with the seasonal abundance of suitable prey (Bollens et al., 1992; Ellison and Franzin, 1992). Analysis of feeding success and prey composition of bull trout and mountain whitefish from impacted and pristine regions of the Study Area may be required to fully assess this possibility.

Hypoxic conditions during embryological development had no effect on the tolerance to elevated water temperature as tested by the critical thermal maxima. This would suggest that mortality related to increasing temperature following ice-out would not be influenced by the dissolved oxygen history of the fish during embryonic development.

#### **4.3 RELEVANCE OF EXPERIMENTAL CONDITIONS TO NRB STUDY AREA**

For this study water temperature was regulated at 2.1 and 2.3 ± 0.2°C during the period of November 17, 1993 and May, 1994. Mainstream water temperatures of rivers in the Northern River Basins Study Area during the period of ice cover range from 0 to 1°C (Environment Canada, 1984). Although the difference between the test temperature and natural winter water temperature is relatively small it could produce a significant change in developmental rate in both bull trout and mountain

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  $\times$   $^{\circ}$ 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  $7^{\circ}$ C for less than 4 hours in incubators 1 to 7. Virtually all of the bull trout at  $\text{DO} \geq 5$  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

only three exhibited a definite dose-dependent response to hypoxia over a range of dissolved oxygen levels appropriate to the Study Area. These were time of development from fertilization to hatch, oxygen consumption, and rate of yolk utilization as indicated by yolk area. Clearly, these features all relate to the rate of development during the embryonic phase and may all reflect a common mode of action. The other features examined either failed to exhibit a definite response to hypoxia or exhibited a very small response only at severe levels of hypoxia.

#### **4.5 POTENTIAL INTERACTIVE EFFECTS OF HYPOXIA AND TRICHLOROPHENOL**

The Terms of Reference for this study included a requirement to determine the effect of hypoxia upon the uptake and accumulation of trichlorophenol by developing eggs and newly hatched juveniles of both bull trout and mountain whitefish. Trichlorophenols are present in bleached kraft mill effluent (Servizi et al., 1993). At the TCP levels proposed, (1 and 3  $\mu\text{g/l}$ ), no direct toxic effects of the chemical were anticipated since toxic effects on fish are only observed at concentrations several-fold higher (Sheedy et al., 1991). However, since TCP exhibits a very high octanol:water coefficient (Mackay, 1982) and is lipophilic, the potential for absorption into the yolk of the eggs and early post-hatched life stages of these fish may be substantial. Furthermore, chlorinated phenols may be remobilized as lipid stores as the lipids are metabolized. For example, Burdick et al. (1964) demonstrated a correlation between the concentration of DDT in the lipid of developing lake trout eggs and the level of mortality of fry immediately after the completion of yolk absorption. Bioconcentration factors for some chlorophenols in juvenile salmonids were relatively high (100 to 800) when alevins were exposed to low levels of these materials in normoxic water although eyed eggs did not accumulate substantial levels of contaminant (Servizi et al., 1988). In post-juvenile fish exposure to hypoxic water increases the uptake of organic contaminants probably by elevating the respiratory volume (McKim and Goeden, 1982). Considering the effects of hypoxia upon the rate of embryological and larval development of bull trout and mountain whitefish, the potential for interactive effects with organic toxicants must be considered. Although delays in delivery of the radio-labelled TCP prevented the completion of this part of the study, information of this kind is critical to the application of the DO results to contaminated areas of the river in the Study Area.

#### **4.6 RELATION OF THE RESULTS OF THIS STUDY TO NRB STUDY AREA**

Winter dissolved oxygen levels in rivers in the Study Area vary widely both in locality and over time of ice cover (Noton and Shaw, 1994). The actual dissolved oxygen concentration at any particular site varies in response to numerous factors including time of formation and thickness of ice-cover, distance downstream from headwaters, input of groundwater, presence of rapids or open, ice-free areas, input of effluents with a significant biological or chemical oxygen demand, level of photosynthesis, and inputs of meltwater (ibid). In addition to the foregoing, the inter-gravel concentration of dissolved oxygen may be reduced over that of the mainstream by siltation from natural and anthropogenic sources. Many of these factors are influenced by climatological and anthropogenic events. In the past several years substantial deficiencies in dissolved oxygen have been recorded at several sites in the Athabasca River drainage and most of these occurrences

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.

## 6.0 RECOMMENDATIONS

The effects of hypoxia upon retardation of embryological development were 'dose-dependent' and of sufficient magnitude to form the basis for an *in-situ* bioassay which could be applied to appropriate sites in the Study Area. This is especially true for mountain whitefish which could be obtained easily from spawning populations in the Athabasca River system and distributed to sites within the Study Area in small incubation baskets. Egg baskets should be placed at sites where long-term monitoring of water quality and flow is already in operation. Recovery of egg samples for analysis of yolk size during late stages of development would permit an *in-situ* assessment of the impact of reduced oxygen levels upon the development of these eggs. To verify such a bioassay procedure additional information on the retardation of development by reduced dissolved oxygen would be required. Specifically, information on the appropriate effects of hypoxia which was first experienced at different times and for different durations during embryonic development would be required to produce a duration:response relationship for each developmental stage.

Given the magnitude of the effects on embryological development of both bull trout and mountain whitefish by levels of hypoxia already existent in the Study Area, the potential for additional deleterious impacts of organic contaminants present in mill effluents should be examined. Both direct toxic effects on survival and indirect toxic effects upon development and bioaccumulation are important in this regard.

- 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.

- Environment Canada. 1984. Detailed Surface Water Quality Data. Alberta, 1980-1981. Inland Waters Directorate, Western and Northern Region, Water Quality Branch, Calgary, Alberta. 164 pp.
- Environmental Protection Agency. 1986. Quality Criteria for Water 1986. United States Environmental Protection Agency, Office of Water Regulation Standards. 327 pp.
- Fairless, D.M., S.J. Herman, and P.J. Rhem. 1994. Characteristics of Bull Trout (Salvelinus confluentus) Spawning Sites in Five Tributaries of the Upper Clearwater River, Alberta. Alberta Environmental Protection, Fish and Wildlife Services. 49 pp.
- Giles, M.A., 1991. Strain Differences in Hemoglobin Polymorphism, Oxygen Consumption, and Blood Oxygen Equilibria in Three Hatchery Stocks of Arctic Charr, Salvelinus alpinus. Fish Physiology and Biochemistry. 9: 291-301.
- Giles, M.A., and D Klaprat. 1979. The Residual Oxygen Bioassay: A Rapid Method for Estimation of the Acute Lethal Toxicity of Contaminants. in Toxicity Tests For Aquatic Organisms. Department of Fisheries and Oceans. Miscellaneous Special Publication Series 44. 194pp.
- Mackay, D. 1982. Correlation of Bioconcentration Factors. Environmental Science and Technology. 16: 274-278.
- McKim, J.M., and H.M. Goeden. 1982. A Direct Measure of the Uptake Efficiency of a Xenobiotic Chemical Across the Gills of Brook Trout (Salvelinus fontinalis) Under Normoxic and Hypoxic Conditions. Comparative Biochemistry and Physiology. 72C: 65-74.
- Noton, L.R., and D. Allan. 1994. Oxygen Conditions in the Athabaska River System, With Emphasis on Winters 1990-93. Surface Water Assessment Branch, Technical Services and Monitoring Division, Alberta Environmental Protection. 51 pp.
- Rombough, P.J. 1988. Respiratory Gas Exchange, Aerobic Metabolism, and Effects of Hypoxia During Early Life. Pages 59-161. in W.S. Hoar and D.J. Randall, eds. Fish Physiology, Vol. XIA. Academic Press, San Diego, California. 546 pp.
- Servizi, J.A., R.W. Gordon, and J.H. Carey. 1982. Bioconcentration of Chlorophenols by Early Life Stages of Fraser River Pink and Chinook Salmon (Oncorhynchus gorbuscha, O. tshawytscha). Water Pollution Research Journal of Canada. 23: 88-99.
- Servizi, J.A., R.W. Gordon, D.W. Martens, W.L. Lockhart, D.A. Metner, I.H. Rogers, J.R. McBride, and R.J. Norstrom. 1993. Effects of Biotreated Bleached Kraft Mill Effluent on Fingerling Chinook Salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences. 50: 846-857.

- 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<sub>3</sub>; hardness, 85-145 mg/l as CaCO<sub>3</sub>; 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

potential interactive effects of selected contaminants occurring in pulp mill effluents upon embryonic development of bull trout and mountain whitefish at appropriate water temperatures.

a. During the period of November 1 to May 15 (196 days) groups of trout and whitefish eggs will be reared in water containing >12.5, 9.0, 7.0, 5.0, and 3.0 ( $\pm$  5% of nominal) mg/l of dissolved oxygen. At 28-day intervals throughout this period subsamples of eggs, alevins, or larvae will be extracted from each treatment and examined for sublethal effects on development including; developmental rate, efficiency of yolk conversion, incidence of physical abnormalities, cardiac and respiration rates, hatching success, and weight and length at hatch. Performance of hatched fish from each treatment will be assessed by determining success of first feeding and critical thermal maxima.

b. Acute lethal levels for dissolved oxygen will be determined for both species of fish during early embryonic development (pre-eyed stage), late embryonic development (late eyed stage), and post-hatch (before yolk absorption).

c. After developing to the eyed stage, eggs of bull trout and mountain whitefish will be exposed to 2,4,6-trichlorophenol (TCP) at 1 and 3  $\mu$ g/l in water containing >12.5, 9.0, 7.0, 5.0, and 3.0 mg/l dissolved oxygen at 2°C until hatch. The interactive effects of TCP and reduced oxygen on embryonic development outlined in 2.a will be determined. Subsets of unhatched eggs and newly hatched alevins or larvae will be retained from each treatment for analysis of tissue levels of TCP.

### **III. REPORTING REQUIREMENTS**

1. The exposure and experimental period of this study (November 1/93 to May 15/94) will extend beyond the March 31, 1994 end of the 1993/94 fiscal year. A progress report of results to date will be submitted to the Northern River Basins Study office by March 31/94. Completion of the experimental and analytical work with funding (\$6100) from the 1994/95 fiscal year is anticipated by Mid-May. A final report will be prepared on all results and submitted to the Study office in July, 1994.
2. The final report will include:
  - a. a description of the methods and water treatment systems employed in the study.
  - b. an analysis of the sublethal effects of reduced levels of dissolved oxygen and interactive effects of 1 and 3  $\mu$ g/l trichlorophenol upon embryonic development of bull trout and mountain whitefish.
  - c. a brief interpretation of the meaning of the results with respect to the sensitivity of the early life stages of bull trout and mountain whitefish to oxygen and TCP levels anticipated

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.**

DATE	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. (%)
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

DATE	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. (%)
10-Mar-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Mar-94	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-Mar-94	17.0	19.3	0.0	0.0	15.0	0.0	5.0	59.7	0.0
15-Mar-94	17.0	19.3	0.0	0.0	15.0	0.0	5.0	65.3	0.0
17-Mar-94	17.0	19.3	0.0	0.0	15.0	0.0	5.0	65.3	0.0
18-Mar-94	17.0	19.3	0.0	0.0	15.0	0.0	9.2	70.8	0.0
21-Mar-94	17.0	19.9	0.0	0.0	15.0	0.0	9.2	70.8	0.0
22-Mar-94	17.0	20.5	0.0	0.0	15.0	0.0	9.2	70.8	0.0
24-Mar-94	18.1	41.0	0.0	0.0	22.1	0.0	9.2	70.8	0.0
28-Mar-94	18.1	91.5	0.0	0.0	22.1	0.0	9.2	70.8	0.0
29-Mar-94	18.1	91.5	0.0	0.0	22.1	0.0	9.2	70.8	0.0
31-Mar-94	18.1	94.1	0.0	0.0	42.1	0.0	9.2	89.6	0.0
04-Apr-94	18.1	94.8	0.8	0.0	95.7	0.0	9.2	89.6	0.0
07-Apr-94	20.8	94.8	0.8	0.0	95.7	0.0	9.2	89.6	0.0
11-Apr-94	20.8	94.8	0.8	0.0	95.7	0.0	9.2	89.6	0.0
13-Apr-94	20.8	94.8	0.8	0.0	95.7	0.0	9.2	89.6	0.0
18-Apr-94	20.8	94.8	0.8	0.0	95.7	0.0	9.2	89.6	0.0
21-Apr-94	20.8	94.8	0.8	0.0	95.7	0.0	9.2	89.6	0.0
25-Apr-94	20.8	94.8	0.8	0.0	95.7	0.0	9.2	89.6	0.0
29-Apr-94	20.8	94.8	1.5	0.0	95.7	0.0	9.2	89.6	0.0
02-May-94	20.8	94.8	1.5	0.0	95.7	0.0	9.2	89.6	0.0
05-May-94	20.8	94.8	1.5	0.0	95.7	0.0	9.2	89.6	0.0
09-May-94	20.8	94.8	3.5	0.0	95.7	0.0	9.2	89.6	0.0
12-May-94	20.8	94.8	4.1	0.0	95.7	0.0	9.2	89.6	0.0
16-May-94	20.8	94.8	4.1	0.0	95.7	0.0	9.2	89.6	0.0
19-May-94	20.8	94.8	4.1	0.0	95.7	0.0	9.2	89.6	0.0
23-May-94	20.8	94.8	4.1	0.0	95.7	0.0	9.2	89.6	0.0
26-May-94	20.8	94.8	4.1	0.0	95.7	0.0	9.2	89.6	0.0

Concluded

**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.

DATE	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. (%)
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

DATE	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. (%)
28-Feb-94	20.6	0.8	0.0	0.0	0.0	0.0	5.0	0.0	0.0
01-Mar-94	20.6	1.4	0.0	0.0	0.0	0.0	5.0	0.0	0.0
02-Mar-94	20.6	1.4	0.0	0.0	0.0	0.0	5.0	0.0	0.0
03-Mar-94	20.6	7.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
04-Mar-94	20.6	7.7	0.0	0.0	0.0	0.0	5.0	0.0	0.0
05-Mar-94	20.6	9.2	0.0	0.0	0.0	0.0	5.0	0.0	0.0
07-Mar-94	20.6	13.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
08-Mar-94	20.6	20.9	0.0	0.0	0.0	0.0	5.0	0.0	0.0
10-Mar-94	20.6	28.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
11-Mar-94	20.6	31.6	0.0	5.0	0.0	0.0	5.0	0.0	0.0
14-Mar-94	21.5	93.4	0.0	5.0	5.0	0.0	5.0	0.0	0.0
15-Mar-94	22.0	95.2	0.0	5.0	5.0	0.0	5.0	0.0	0.0
17-Mar-94	22.0	95.2	0.0	5.0	5.0	0.0	5.0	0.0	0.0
18-Mar-94	22.0	95.2	0.0	5.0	5.0	0.0	5.0	0.0	0.0
21-Mar-94	22.0	95.2	0.0	5.0	10.0	0.0	5.0	0.0	0.0
22-Mar-94	22.0	95.2	0.0	5.0	10.0	0.0	5.0	5.0	0.0
24-Mar-94	22.0	95.2	0.0	5.0	100.0	0.0	5.0	95.0	0.0
28-Mar-94	22.0	95.2	0.0	5.0	100.0	0.0	5.0	95.0	0.0
31-Mar-94	22.0	95.2	0.0	5.0	100.0	0.0	5.0	95.0	0.0
04-Apr-94	22.0	95.2	0.0	5.0	100.0	0.0	5.0	95.0	0.0
07-Apr-94	22.0	95.2	0.0	5.0	100.0	0.0	5.0	95.0	0.0
11-Apr-94	22.0	95.2	0.0	5.0	100.0	0.0	5.0	95.0	0.0
13-Apr-94	22.0	95.2	0.0	5.0	100.0	0.0	5.0	95.0	0.0
18-Apr-94	22.0	95.2	0.0	5.0	100.0	0.0	5.0	95.0	0.0
21-Apr-94	22.0	95.2	0.8	5.0	100.0	0.0	5.0	95.0	0.0
25-Apr-94	22.0	95.2	0.8	5.0	100.0	0.0	5.0	95.0	0.0
29-Apr-94	22.0	95.2	0.8	5.0	100.0	0.0	10.0	95.0	0.0
02-May-94	22.0	95.2	0.8	5.0	100.0	10.0	10.0	95.0	0.0
05-May-94	22.0	95.2	0.8	5.0	100.0	10.0	10.0	95.0	0.0
09-May-94	22.0	95.2	0.8	5.0	100.0	10.0	10.0	95.0	0.0
12-May-94	22.0	95.2	1.4	5.0	100.0	10.0	10.0	95.0	0.0
16-May-94	22.0	95.2	1.4	5.0	100.0	10.0	10.0	95.0	5.6
19-May-94	22.0	95.2	2.0	5.0	100.0	10.0	10.0	95.0	5.6
23-May-94	22.0	95.2	2.0	5.0	100.0	10.0	10.0	95.0	5.6
26-May-94	22.0	95.2	2.0	5.0	100.0	10.0	10.0	95.0	5.6

Concluded

**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.**

DATE	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. (%)
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

DATE	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. (%)
03-Mar-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-Mar-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05-Mar-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07-Mar-94	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08-Mar-94	14.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10-Mar-94	14.5	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-Mar-94	14.9	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-Mar-94	15.4	88.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0
15-Mar-94	16.3	98.0	0.6	0.0	5.0	0.0	0.0	0.0	0.0
17-Mar-94	16.3	98.0	0.6	0.0	5.0	0.0	0.0	0.0	0.0
18-Mar-94	16.3	98.0	0.6	0.0	5.0	0.0	0.0	0.0	0.0
21-Mar-94	16.3	98.0	0.6	0.0	30.0	0.0	0.0	5.0	0.0
22-Mar-94	16.3	98.0	0.6	0.0	56.1	0.0	0.0	80.0	0.0
24-Mar-94	16.3	98.0	0.6	0.0	94.4	0.0	0.0	95.0	0.0
28-Mar-94	16.3	98.0	0.6	0.0	94.4	0.0	0.0	95.0	0.0
31-Mar-94	16.3	98.0	0.6	0.0	94.4	0.0	0.0	100.0	5.0
04-Apr-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	5.0
07-Apr-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	5.0
11-Apr-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
13-Apr-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
15-Apr-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
18-Apr-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
21-Apr-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
25-Apr-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
29-Apr-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
02-May-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
05-May-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
09-May-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
12-May-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
16-May-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
19-May-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
23-May-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0
26-May-94	16.8	98.0	0.6	5.6	94.4	0.0	0.0	100.0	10.0

Concluded

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

DATE	Tank 2: (201 eggs)			Tank 8: (8 eggs)	
	Egg Mort. (%)	Total Hatch (%)	Alevin Mort. (%)	Egg Mort. (%)	Total Hatch (%)
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

DATE	Tank 2: (201 eggs)			Tank 8: (8 eggs)	
	Egg Mort. (%)	Total Hatch (%)	Alevin Mort. (%)	Egg Mort. (%)	Total Hatch (%)
21-Feb-94	13.4	0.0	0.0	0.0	0.0
23-Feb-94	13.4	0.0	0.0	0.0	0.0
24-Feb-94	13.4	0.0	0.0	0.0	0.0
28-Feb-94	16.0	0.0	0.0	0.0	0.0
01-Mar-94	16.0	0.0	0.0	0.0	0.0
02-Mar-94	16.0	0.0	0.0	0.0	0.0
03-Mar-94	16.6	0.0	0.0	0.0	0.0
04-Mar-94	16.6	0.6	0.0	0.0	0.0
05-Mar-94	16.6	0.6	0.0	0.0	0.0
07-Mar-94	16.6	0.6	0.0	0.0	0.0
08-Mar-94	16.6	0.6	0.0	0.0	0.0
10-Mar-94	16.6	0.6	0.0	0.0	0.0
11-Mar-94	16.6	0.6	0.0	0.0	0.0
14-Mar-94	16.6	83.4	0.8	0.0	0.0
15-Mar-94	16.6	95.9	1.5	0.0	0.0
17-Mar-94	16.6	95.9	1.5	0.0	0.0
18-Mar-94	16.6	95.9	1.5	0.0	12.5
21-Mar-94	16.6	95.9	1.5	0.0	100.0
22-Mar-94	16.6	95.9	1.5	0.0	100.0
24-Mar-94	16.6	95.9	1.5	0.0	100.0
28-Mar-94	16.6	95.9	1.5	0.0	100.0
31-Mar-94	16.6	100.0	1.5	0.0	100.0
04-Apr-94	16.6	100.0	1.5	0.0	100.0
06-Apr-94	16.6	100.0	1.5	0.0	100.0
07-Apr-94	16.6	100.0	3.8	0.0	100.0
11-Apr-94	16.6	100.0	3.8	0.0	100.0
13-Apr-94	16.6	100.0	3.8	0.0	100.0
15-Apr-94	16.6	100.0	3.8	0.0	100.0
18-Apr-94	16.6	100.0	3.8	0.0	100.0
21-Apr-94	16.6	100.0	3.8	0.0	100.0
25-Apr-94	16.6	100.0	3.8	0.0	100.0
29-Apr-94	16.6	100.0	3.8	0.0	100.0
02-May-94	16.6	100.0	3.8	0.0	100.0
05-May-94	16.6	100.0	5.1	0.0	100.0
09-May-94	16.6	100.0	5.1	0.0	100.0
12-May-94	16.6	100.0	5.1	0.0	100.0
16-May-94	16.6	100.0	5.1	0.0	100.0
19-May-94	16.6	100.0	5.1	0.0	100.0
23-May-94	16.6	100.0	5.1	0.0	100.0
26-May-94	16.6	100.0	5.1	0.0	100.0

Concluded

**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.

DATE	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. (%)
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

DATE	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. (%)
07-Mar-94	14.8	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
08-Mar-94	14.8	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
10-Mar-94	14.8	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
11-Mar-94	14.8	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0
14-Mar-94	14.8	96.0	1.3	6.3	0.0	0.0	0.0	5.0	0.0
15-Mar-94	14.8	100.0	1.3	6.3	0.0	0.0	0.0	10.0	0.0
17-Mar-94	14.8	100.0	1.3	6.3	0.0	0.0	0.0	10.0	5.0
18-Mar-94	14.8	100.0	1.3	6.3	0.0	0.0	0.0	10.0	5.0
21-Mar-94	14.8	100.0	1.3	6.3	0.0	0.0	0.0	25.0	5.0
22-Mar-94	14.8	100.0	1.3	6.3	0.0	0.0	0.0	30.0	5.0
24-Mar-94	14.8	100.0	1.3	6.3	86.6	0.0	0.0	100.0	5.0
28-Mar-94	14.8	100.0	1.3	6.3	93.8	0.0	0.0	100.0	5.0
31-Mar-94	14.8	100.0	1.3	6.3	93.8	0.0	0.0	100.0	5.0
04-Apr-94	14.8	100.0	1.3	6.3	93.8	0.0	0.0	100.0	5.0
07-Apr-94	14.8	100.0	1.3	6.3	100.0	0.0	0.0	100.0	5.0
11-Apr-94	14.8	100.0	1.3	6.3	100.0	0.0	0.0	100.0	5.0
13-Apr-94	14.8	100.0	1.3	6.3	100.0	0.0	0.0	100.0	5.0
15-Apr-94	14.8	100.0	1.3	6.3	100.0	0.0	0.0	100.0	5.0
18-Apr-94	14.8	100.0	1.3	6.3	100.0	0.0	0.0	100.0	5.0
21-Apr-94	14.8	100.0	1.3	6.3	100.0	0.0	0.0	100.0	5.0
25-Apr-94	14.8	100.0	1.3	6.3	100.0	0.0	0.0	100.0	5.0
29-Apr-94	14.8	100.0	1.3	6.3	100.0	0.0	0.0	100.0	5.0
02-May-94	14.8	100.0	1.3	6.3	100.0	0.0	0.0	100.0	5.0
05-May-94	14.8	100.0	1.9	6.3	100.0	0.0	0.0	100.0	5.0
09-May-94	14.8	100.0	1.9	6.3	100.0	0.0	0.0	100.0	5.0
12-May-94	14.8	100.0	1.9	6.3	100.0	0.0	0.0	100.0	5.0
16-May-94	14.8	100.0	1.9	6.3	100.0	0.0	0.0	100.0	5.0
19-May-94	14.8	100.0	1.9	6.3	100.0	0.0	0.0	100.0	5.0
23-May-94	14.8	100.0	1.9	6.3	100.0	0.0	0.0	100.0	5.0
26-May-94	14.8	100.0	1.9	6.3	100.0	0.0	0.0	100.0	5.0

Concluded

**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.

DATE	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. (%)
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

DATE	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. (%)
10-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	23.7	0.0	0.0
11-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	24.3	0.0	0.0
14-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	24.3	0.0	0.0
15-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	24.3	0.0	0.0
17-Mar-94	7.7	0.0	0.0	21.0	0.0	0.0	24.3	0.0	0.0
18-Mar-94	7.7	0.0	0.0	21.2	0.3	0.0	24.3	0.0	0.0
21-Mar-94	7.7	0.0	0.0	21.2	0.3	0.0	24.3	0.3	0.0
22-Mar-94	7.7	0.0	0.0	21.2	0.3	0.0	24.3	0.3	0.0
24-Mar-94	7.7	0.0	0.0	21.2	0.3	0.0	24.6	1.0	0.0
28-Mar-94	7.7	0.0	0.0	21.2	0.3	0.0	24.6	1.0	0.0
29-Mar-94	7.7	0.0	0.0	21.2	0.3	0.0	24.6	1.0	0.0
31-Mar-94	7.7	0.0	0.0	21.2	0.3	0.0	24.6	1.0	0.0
04-Apr-94	7.7	0.0	0.0	21.2	0.3	0.0	24.6	1.2	0.0
07-Apr-94	7.7	0.0	0.0	21.2	0.3	0.0	24.6	1.2	0.0
11-Apr-94	7.7	0.0	0.0	21.2	0.3	0.0	24.8	1.5	0.0
13-Apr-94	7.7	0.0	0.0	21.2	0.3	0.0	25.0	2.1	0.0
18-Apr-94	7.7	0.0	0.0	21.2	1.2	0.0	25.2	2.6	0.0
21-Apr-94	7.7	0.0	0.0	21.2	15.5	0.0	25.2	2.6	0.0
25-Apr-94	7.7	0.0	0.0	21.2	15.7	0.0	25.5	2.6	0.0
29-Apr-94	7.7	0.0	0.0	21.2	15.7	0.0	25.5	2.9	0.0
02-May-94	7.7	0.0	0.0	21.2	16.0	0.0	25.5	3.5	0.0
05-May-94	7.7	0.0	0.0	21.2	17.4	0.0	25.5	3.5	0.0
09-May-94	7.7	0.0	0.0	21.2	17.8	0.0	25.5	3.5	0.0
12-May-94	7.7	0.0	0.0	21.2	17.8	0.0	25.5	5.7	0.0
16-May-94	7.7	0.0	0.0	21.2	17.8	0.0	25.5	6.8	0.3
19-May-94	7.7	0.0	0.0	21.2	17.8	0.0	26.6	98.9	19.6
23-May-94	7.7	85.8	0.0	21.2	96.6	0.3	26.6	98.9	19.6
26-May-94	7.7	85.8	0.0	21.2	96.6	0.3	26.6	98.9	19.6

Concluded

**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.

DATE	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. (%)
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

DATE	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. (%)
02-Mar-94	7.2	0.3	0.0	15.0	0.1	0.0	23.6	0.2	0.0
03-Mar-94	7.2	1.3	0.0	15.0	0.1	0.0	23.6	0.2	0.0
04-Mar-94	7.2	1.8	0.0	15.0	0.1	0.0	23.6	0.2	0.0
05-Mar-94	7.2	2.3	0.0	15.0	0.1	0.0	23.6	0.2	0.0
07-Mar-94	7.2	2.3	0.0	15.0	0.2	0.0	23.6	0.2	0.0
08-Mar-94	7.2	2.3	0.0	15.0	0.2	0.0	23.6	0.3	0.0
10-Mar-94	7.2	2.3	0.0	15.0	0.2	0.0	23.9	0.5	0.0
11-Mar-94	7.2	3.1	0.0	15.0	0.4	0.0	23.9	0.8	0.0
14-Mar-94	7.2	20.1	0.0	15.0	0.5	0.0	23.9	0.8	0.0
15-Mar-94	7.2	23.8	0.0	15.0	0.6	0.0	23.9	0.9	0.0
17-Mar-94	7.2	23.8	0.0	15.0	0.6	0.0	23.9	0.9	0.0
18-Mar-94	7.2	24.1	0.0	15.0	0.8	0.0	23.9	0.9	0.0
21-Mar-94	7.2	24.1	0.0	15.0	0.8	0.0	23.9	1.3	0.0
22-Mar-94	7.2	24.4	0.0	15.0	1.0	0.0	23.9	1.4	0.0
24-Mar-94	7.2	24.6	0.0	15.0	4.2	0.0	23.9	1.6	0.0
28-Mar-94	7.2	25.2	0.0	15.0	4.6	0.0	23.9	2.9	0.0
31-Mar-94	7.2	25.2	0.0	15.0	4.7	0.0	23.9	3.3	0.0
04-Apr-94	8.4	25.2	0.0	15.0	5.0	0.0	23.9	5.1	0.0
07-Apr-94	8.4	25.2	0.0	15.0	5.6	0.2	23.9	5.6	0.0
11-Apr-94	8.4	25.2	0.0	15.0	5.7	0.2	23.9	6.3	0.0
13-Apr-94	8.4	25.2	0.0	15.0	5.7	0.2	23.9	7.2	0.0
18-Apr-94	9.2	35.1	0.0	15.0	5.8	0.2	23.9	11.7	0.0
21-Apr-94	9.2	40.3	0.0	15.0	16.6	0.4	23.9	23.5	0.0
25-Apr-94	9.2	40.3	0.0	15.0	29.8	0.4	24.2	28.8	0.0
29-Apr-94	9.2	45.7	0.9	15.0	40.4	0.4	24.5	40.8	0.0
02-May-94	9.8	47.9	0.9	15.0	49.2	0.4	24.5	48.3	0.0
05-May-94	10.6	52.7	0.9	15.0	90.3	0.5	26.1	57.5	0.0
09-May-94	10.6	52.7	0.9	15.0	90.4	0.5	26.1	58.0	0.2
12-May-94	10.6	53.3	0.9	15.0	90.6	0.5	26.1	58.0	0.2
16-May-94	10.6	59.5	0.9	15.0	93.0	0.5	26.6	84.9	1.0
19-May-94	10.6	68.4	0.9	15.0	95.5	0.5	26.8	92.3	1.1
23-May-94	10.6	97.5	0.9	15.0	99.5	0.5	27.2	95.8	1.3
26-May-94	10.6	97.5	0.9	15.0	99.5	0.5	27.2	95.8	1.3

Concluded

**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.

DATE	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. (%)
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

DATE	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. (%)
02-Mar-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.3	0.0
03-Mar-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.3	0.0
04-Mar-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.6	0.0
05-Mar-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.6	0.0
07-Mar-94	9.2	0.0	0.0	14.5	0.0	0.0	26.8	0.6	0.0
08-Mar-94	9.2	0.0	0.0	14.5	0.0	0.0	26.9	0.6	0.0
10-Mar-94	9.2	0.0	0.0	14.5	0.0	0.0	26.9	0.7	0.0
11-Mar-94	9.2	0.0	0.0	14.5	0.2	0.0	26.9	0.7	0.0
14-Mar-94	9.2	85.7	0.0	14.5	0.2	0.0	26.9	0.7	0.0
15-Mar-94	9.2	88.9	0.3	14.5	0.2	0.0	26.9	1.1	0.0
17-Mar-94	9.2	88.9	0.3	14.5	0.2	0.0	26.9	1.1	0.0
18-Mar-94	9.2	89.2	0.3	14.5	0.3	0.0	26.9	1.1	0.0
21-Mar-94	9.2	89.2	0.3	14.5	0.3	0.0	26.9	1.8	0.0
22-Mar-94	9.2	89.2	0.3	14.5	0.3	0.0	26.9	3.4	0.0
24-Mar-94	9.2	89.2	0.3	14.5	0.3	0.0	26.9	4.3	0.0
28-Mar-94	9.2	89.2	0.3	14.5	0.5	0.0	26.9	4.3	0.0
31-Mar-94	9.2	89.2	0.3	14.5	0.5	0.0	26.9	6.7	0.0
04-Apr-94	9.2	89.2	0.3	14.5	12.6	0.0	26.9	13.7	0.0
07-Apr-94	9.2	89.4	0.3	14.5	19.7	0.2	26.9	46.9	0.0
11-Apr-94	9.2	89.4	0.3	14.5	32.6	0.4	26.9	47.8	0.1
13-Apr-94	9.2	90.5	0.3	14.5	48.1	0.4	26.9	48.0	0.1
15-Apr-94	9.2	90.5	0.3	14.5	57.4	0.4	26.9	64.6	0.1
18-Apr-94	9.2	95.4	0.3	14.5	70.1	0.4	26.9	66.4	0.1
21-Apr-94	9.2	96.2	0.3	14.5	88.5	0.6	27.0	84.8	0.1
25-Apr-94	9.2	96.2	0.3	14.7	88.8	0.6	27.0	86.9	0.1
29-Apr-94	9.2	96.2	0.3	14.7	89.3	0.6	27.0	88.3	0.1
02-May-94	9.2	96.2	0.3	14.7	89.6	0.6	27.0	88.6	0.2
05-May-94	9.2	96.2	0.3	14.7	91.0	0.6	27.0	89.9	0.2
09-May-94	9.2	96.2	0.3	14.7	91.9	0.6	27.0	91.1	0.4
12-May-94	9.2	96.2	0.3	14.7	91.9	0.6	27.0	92.3	0.4
16-May-94	9.2	96.9	0.3	14.7	95.1	0.6	27.0	93.0	0.4
19-May-94	9.2	97.1	0.3	14.7	95.1	0.6	27.0	97.2	0.4
23-May-94	9.2	97.1	0.3	14.7	95.1	0.6	27.0	97.2	0.4
26-May-94	9.2	97.1	0.3	14.7	95.1	0.6	27.0	97.2	0.4

**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.**

DATE	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. (%)
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

DATE	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.
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
21-Feb-94	7.1	0.0	0.0	23.4	58.0	46.7	27.6	0.3	0.0
23-Feb-94	7.1	0.0	0.0	23.4	58.5	46.8	27.6	0.3	0.0
24-Feb-94	7.1	0.0	0.0	23.5	59.1	46.8	28.0	0.3	0.0
28-Feb-94	7.1	0.0	0.0	23.6	59.1	46.8	28.0	0.3	0.0
01-Mar-94	7.1	0.0	0.0	23.6	59.5	46.8	28.0	0.3	0.0
02-Mar-94	7.1	0.0	0.0	23.6	59.5	46.8	28.0	0.4	0.0
03-Mar-94	7.1	0.0	0.0	23.6	59.7	46.8	28.0	0.4	0.0
04-Mar-94	7.1	0.0	0.0	23.6	59.7	46.8	28.0	0.4	0.0
05-Mar-94	7.1	0.0	0.0	23.6	59.7	46.8	28.0	0.4	0.0
07-Mar-94	7.1	0.0	0.0	23.6	59.7	46.8	28.0	0.7	0.0
08-Mar-94	7.1	0.0	0.0	23.6	59.8	46.8	28.1	0.7	0.0
10-Mar-94	7.1	0.0	0.0	23.6	59.8	46.8	28.1	0.9	0.0
11-Mar-94	7.1	0.0	0.0	23.6	59.8	46.8	28.4	0.9	0.0
14-Mar-94	7.1	40.6	0.0	23.6	59.9	46.8	28.4	1.1	0.0
15-Mar-94	7.1	52.4	0.0	23.6	60.3	46.8	28.5	1.6	0.0
17-Mar-94	7.1	52.4	0.0	23.6	60.5	46.8	28.5	2.2	0.0
18-Mar-94	7.1	53.3	0.0	23.6	60.5	46.8	28.5	3.2	0.0
21-Mar-94	7.1	53.3	0.0	23.6	63.3	46.8	28.5	3.5	0.0
22-Mar-94	7.1	53.3	0.0	23.6	65.1	46.8	28.5	6.3	0.0
24-Mar-94	7.1	54.1	0.0	23.6	74.8	46.8	28.5	26.1	0.0
28-Mar-94	7.1	54.1	0.0	23.6	77.9	46.9	28.5	38.5	0.1
31-Mar-94	7.1	54.1	0.0	23.6	82.4	46.9	28.5	41.5	0.1
04-Apr-94	7.1	66.9	0.0	23.6	87.7	46.9	28.5	59.4	0.8
06-Apr-94	7.1	66.9	0.0	23.6	89.8	46.9	28.5	63.6	0.8
07-Apr-94	7.1	68.0	0.0	23.6	91.0	47.0	28.5	64.6	1.1
11-Apr-94	7.1	73.2	0.0	23.6	91.6	47.0	28.5	64.9	1.1
13-Apr-94	7.1	87.3	0.0	23.6	94.8	47.0	28.5	79.8	1.1
15-Apr-94	7.1	87.3	0.0	23.6	95.6	47.0	28.5	81.7	1.2
18-Apr-94	7.1	91.6	0.0	23.6	96.2	47.1	28.5	83.1	1.2
21-Apr-94	7.1	97.5	0.0	23.6	96.2	47.1	28.5	89.1	1.2
25-Apr-94	7.1	97.8	0.0	23.6	96.2	47.1	28.5	89.3	1.2
29-Apr-94	7.1	98.1	0.0	23.6	96.4	47.1	28.5	92.0	1.3
02-May-94	7.1	98.1	0.0	23.6	96.4	47.1	28.5	92.1	1.3
05-May-94	7.1	98.1	0.0	23.6	96.4	47.1	28.5	92.9	1.3
09-May-94	7.1	98.1	0.0	23.6	96.4	47.1	28.5	93.0	1.3
12-May-94	7.1	98.1	0.0	23.6	96.4	47.1	28.5	93.0	1.3
16-May-94	7.1	98.1	0.0	23.6	96.4	47.1	28.5	93.0	1.3
19-May-94	7.1	98.1	0.0	23.6	96.4	47.1	28.5	93.0	1.3
23-May-94	7.1	98.1	0.0	23.6	96.4	47.1	28.5	93.0	1.3
26-May-94	7.1	98.1	0.0	23.6	96.4	47.1	28.5	93.0	1.3

Concluded

**Table 16. Mortality and Hatching of Mountain Whitefish 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.

DATE	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. (%)
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

DATE	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. (%)
07-Mar-94	7.7	0.0	0.0	23.1	0.9	0.0	24.4	2.3	0.6
08-Mar-94	7.7	0.0	0.0	23.1	0.9	0.0	24.4	2.5	0.6
10-Mar-94	7.7	0.3	0.0	23.1	1.1	0.2	24.4	2.7	0.8
11-Mar-94	7.7	0.3	0.0	23.1	1.4	0.2	24.4	2.7	0.8
14-Mar-94	7.7	55.7	0.0	23.1	4.9	0.2	24.4	2.9	0.8
15-Mar-94	7.7	61.2	0.3	23.1	8.7	0.2	24.4	7.7	0.8
17-Mar-94	7.7	62.0	0.3	23.1	30.3	0.4	24.4	52.5	0.8
18-Mar-94	7.7	63.2	0.5	23.1	40.6	0.4	24.4	55.4	0.8
21-Mar-94	7.7	65.0	0.5	23.1	43.2	0.4	24.4	58.2	0.8
22-Mar-94	7.7	65.0	0.5	23.1	43.4	0.4	24.4	59.3	0.8
24-Mar-94	7.7	66.1	0.8	23.1	51.6	0.4	24.4	81.2	0.8
28-Mar-94	7.7	66.1	0.8	23.1	77.3	0.4	24.4	83.3	0.8
31-Mar-94	7.7	67.3	0.8	23.1	84.4	0.4	24.4	84.1	0.8
04-Apr-94	7.7	83.4	0.8	23.1	91.7	0.4	24.4	94.5	0.8
07-Apr-94	7.7	83.4	0.8	23.1	93.1	0.4	24.4	96.4	0.8
11-Apr-94	7.7	83.4	0.8	23.1	93.1	0.4	24.4	96.6	0.8
13-Apr-94	7.7	90.0	0.8	23.1	95.0	0.4	24.4	96.6	0.8
15-Apr-94	7.7	90.0	0.8	23.1	95.4	0.4	24.4	96.6	0.8
18-Apr-94	7.7	97.6	1.1	23.1	96.0	0.4	24.4	96.6	0.8
21-Apr-94	7.7	97.9	1.1	23.1	96.0	0.4	24.4	96.6	0.8
25-Apr-94	7.7	97.9	1.1	23.1	96.0	0.4	24.4	96.6	0.8
29-Apr-94	7.7	98.2	1.1	23.1	96.0	0.4	24.4	96.6	0.8
02-May-94	7.7	99.1	1.1	23.1	96.0	0.4	24.4	96.6	0.8
05-May-94	7.7	99.1	1.1	23.1	96.0	0.4	24.4	96.6	0.8
09-May-94	7.7	99.1	1.1	23.1	96.0	0.4	24.4	96.6	0.8
12-May-94	7.7	99.1	1.1	23.1	96.0	0.4	24.4	96.6	0.8
16-May-94	7.7	99.1	1.1	23.1	96.0	0.4	24.4	96.6	0.8
19-May-94	7.7	99.1	1.1	23.1	96.0	0.4	24.4	96.6	0.8
23-May-94	7.7	99.1	1.1	23.1	96.0	0.4	24.4	96.6	0.8
26-May-94	7.7	99.1	1.1	23.1	96.0	0.4	24.4	96.6	0.8

Concluded

**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.**

DATE	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								
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

	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								
DATE	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
14-Mar-94	25.2	0.8	20.8	0.0	27.8	0.0	19.2	1.9	24.1	0.8	29.9	0.2
15-Mar-94	25.2	0.8	20.8	0.0	27.8	0.0	19.2	1.9	24.1	0.8	29.9	0.2
17-Mar-94	25.2	0.8	20.8	0.0	28.1	0.4	19.2	2.3	24.1	0.8	29.9	0.2
18-Mar-94	25.4	0.8	20.8	0.0	28.1	0.4	19.2	2.8	24.1	1.0	30.3	0.4
21-Mar-94	25.7	0.8	20.8	0.0	28.1	0.4	19.2	2.8	24.1	1.0	30.3	0.4
22-Mar-94	25.7	1.2	20.8	0.0	28.1	0.4	19.2	2.8	24.1	1.0	30.3	0.4
24-Mar-94	26.0	1.7	20.8	0.0	28.1	0.4	19.2	46.4	24.1	1.0	30.3	0.6
28-Mar-94	26.3	1.7	20.8	33.2	28.1	0.4	19.2	92.5	24.1	1.2	30.3	0.6
29-Mar-94	26.3	1.7	20.8	45.6	28.1	0.4	19.2	93.4	ND	ND	ND	ND
31-Mar-94	26.3	1.7	20.8	52.3	28.1	0.4	19.5	94.4	24.1	1.2	30.3	0.9
04-Apr-94	26.5	1.7	20.8	74.7	28.1	0.8	19.5	94.9	24.1	1.2	30.3	0.9
07-Apr-94	26.5	2.7	21.1	76.5	28.1	0.8	19.5	94.9	24.3	1.5	30.3	1.7
11-Apr-94	26.5	2.7	21.1	77.6	28.1	0.8	19.5	94.9	24.3	1.5	30.3	1.7
13-Apr-94	26.5	2.7	22.1	79.2	28.1	0.8	19.5	94.9	24.3	1.8	30.3	1.7
18-Apr-94	26.5	3.0	23.2	81.6	28.1	0.8	20.6	94.9	24.3	2.1	30.3	2.8
21-Apr-94	26.5	4.0	23.9	82.7	28.1	1.3	21.0	95.4	24.3	2.5	30.3	3.1
25-Apr-94	26.5	4.2	23.9	83.7	28.1	1.3	21.0	95.4	24.3	3.1	30.3	3.1
29-Apr-94	26.8	4.5	23.9	93.4	28.1	2.4	21.0	95.4	24.3	4.0	30.3	5.1
02-May-94	26.8	4.7	23.9	93.4	28.1	2.4	21.0	95.4	24.3	4.9	30.3	5.6
05-May-94	26.8	6.6	24.7	93.4	28.1	3.1	21.0	95.4	24.3	11.0	30.3	6.1
09-May-94	26.8	6.6	25.1	93.4	28.1	3.4	21.0	95.4	24.3	11.8	30.3	11.9
12-May-94	26.8	7.1	25.1	93.4	28.1	17.8	21.0	95.4	24.3	32.5	30.3	41.4
16-May-94	26.8	7.1	25.1	93.4	28.1	25.2	21.0	95.4	24.3	68.0	30.3	56.6
19-May-94	27.0	19.8	25.1	93.4	28.1	68.3	21.0	95.4	24.3	78.9	30.3	73.3
23-May-94	27.0	92.7	25.1	93.4	28.1	99.8	21.0	95.4	24.3	99.8	30.3	99.5
26-May-94	27.0	92.7	25.1	93.4	28.1	99.8	21.0	95.4	24.3	99.8	30.3	99.5
31-May-94	27.0	96.1	25.1	98.5	28.1	100	21.0	97.7	0.0	100.0	ND	ND

Concluded

**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  $\mu\text{g O}_2$  consumed per hour per individual organism at each oxygen partial pressure ( $\text{Po}_2$ ).

Date	N/test	Oxygen Treatment	Replicate	$\text{Po}_2$	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	( $\mu\text{g/h/egg}$ )
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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(μg/h/egg)
25-Jan-94	3 eggs	7	replic1	75.9	0.806
25-Jan-94	3 eggs	7	replic1	59.9	0.645
25-Jan-94	3 eggs	7	replic1	42.6	0.566
25-Jan-94	3 eggs	7	replic1	28.3	0.261
25-Jan-94	3 eggs	7	replic1	27.0	0.186
25-Jan-94	3 eggs	7	replic1	22.7	0.120
25-Jan-94	3 eggs	7	replic1	13.5	0.066
25-Jan-94	3 eggs	7	replic1	10.4	0.011
25-Jan-94	3 eggs	7	replic2	149.3	1.539
25-Jan-94	3 eggs	7	replic2	131.2	0.887
25-Jan-94	3 eggs	7	replic2	95.1	1.097
25-Jan-94	3 eggs	7	replic2	75.9	0.722
25-Jan-94	3 eggs	7	replic2	57.7	0.636
25-Jan-94	3 eggs	7	replic2	43.3	0.389
25-Jan-94	3 eggs	7	replic2	29.2	0.155
25-Jan-94	3 eggs	7	replic2	28.1	0.173
25-Jan-94	3 eggs	7	replic2	24.9	0.120
25-Jan-94	3 eggs	7	replic2	14.2	0.120
25-Jan-94	3 eggs	7	replic2	8.0	0.027
25-Jan-94	3 eggs	7	replic3	150.9	1.203
25-Jan-94	3 eggs	7	replic3	134.6	0.807
25-Jan-94	3 eggs	7	replic3	96.8	0.685
25-Jan-94	3 eggs	7	replic3	79.9	0.699
25-Jan-94	3 eggs	7	replic3	62.6	0.548
25-Jan-94	3 eggs	7	replic3	47.1	0.450
25-Jan-94	3 eggs	7	replic3	30.7	0.254
25-Jan-94	3 eggs	7	replic3	29.0	0.159
25-Jan-94	3 eggs	7	replic3	23.7	0.167
25-Jan-94	3 eggs	7	replic3	16.5	0.072
25-Jan-94	3 eggs	7	replic3	11.5	0.025
25-Jan-94	3 eggs	5	replic1	151.1	1.138
25-Jan-94	3 eggs	5	replic1	134.8	0.705
25-Jan-94	3 eggs	5	replic1	96.3	0.777
25-Jan-94	3 eggs	5	replic1	78.0	0.804
25-Jan-94	3 eggs	5	replic1	56.4	0.566
25-Jan-94	3 eggs	5	replic1	43.9	0.384
25-Jan-94	3 eggs	5	replic1	30.3	0.246
25-Jan-94	3 eggs	5	replic1	30.0	0.150
25-Jan-94	3 eggs	5	replic1	24.8	0.123
25-Jan-94	3 eggs	5	replic1	19.7	0.035
25-Jan-94	3 eggs	5	replic1	13.0	0.051

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(μg/h/egg)
25-Jan-94	3 eggs	3	replic2	24.4	0.116
25-Jan-94	3 eggs	3	replic2	17.6	0.079
25-Jan-94	3 eggs	3	replic2	11.2	0.034
25-Jan-94	3 eggs	3	replic3	154.0	0.482
25-Jan-94	3 eggs	3	replic3	145.4	0.402
25-Jan-94	3 eggs	3	replic3	99.4	0.402
25-Jan-94	3 eggs	3	replic3	89.2	0.438
25-Jan-94	3 eggs	3	replic3	62.3	0.445
25-Jan-94	3 eggs	3	replic3	47.9	0.323
25-Jan-94	3 eggs	3	replic3	29.6	0.167
25-Jan-94	3 eggs	3	replic3	29.3	0.176
25-Jan-94	3 eggs	3	replic3	24.2	0.089
25-Jan-94	3 eggs	3	replic3	15.4	0.084
25-Jan-94	3 eggs	3	replic3	9.3	0.031
25-Jan-94	3 eggs	13.5	replic1	147.7	1.484
25-Jan-94	3 eggs	13.5	replic1	133.5	0.369
25-Jan-94	3 eggs	13.5	replic1	93.9	0.990
25-Jan-94	3 eggs	13.5	replic1	78.4	0.474
25-Jan-94	3 eggs	13.5	replic1	57.9	0.609
25-Jan-94	3 eggs	13.5	replic1	35.7	0.349
25-Jan-94	3 eggs	13.5	replic1	26.6	0.208
25-Jan-94	3 eggs	13.5	replic1	26.4	0.197
25-Jan-94	3 eggs	13.5	replic1	23.1	0.064
25-Jan-94	3 eggs	13.5	replic1	13.5	0.027
25-Jan-94	3 eggs	13.5	replic1	9.6	0.029
25-Jan-94	3 eggs	13.5	replic2	148.5	1.334
25-Jan-94	3 eggs	13.5	replic2	134.4	0.500
25-Jan-94	3 eggs	13.5	replic2	93.6	0.943
25-Jan-94	3 eggs	13.5	replic2	78.2	0.424
25-Jan-94	3 eggs	13.5	replic2	61.9	0.510
25-Jan-94	3 eggs	13.5	replic2	43.7	0.362
25-Jan-94	3 eggs	13.5	replic2	30.6	0.152
25-Jan-94	3 eggs	13.5	replic2	29.1	0.153
25-Jan-94	3 eggs	13.5	replic2	22.8	0.229
25-Jan-94	3 eggs	13.5	replic2	17.2	0.099
25-Jan-94	3 eggs	13.5	replic2	11.7	0.026
25-Jan-94	3 eggs	13.5	replic3	149.9	1.040
25-Jan-94	3 eggs	13.5	replic3	135.7	0.642
25-Jan-94	3 eggs	13.5	replic3	94.3	0.834
25-Jan-94	3 eggs	13.5	replic3	76.6	0.561
25-Jan-94	3 eggs	13.5	replic3	57.7	0.496

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(µg/h/egg)
02-Mar-94	2 eggs	7	replic2	117.0	1.427
02-Mar-94	2 eggs	7	replic2	97.3	1.028
02-Mar-94	2 eggs	7	replic2	86.4	0.837
02-Mar-94	2 eggs	7	replic2	73.5	0.947
02-Mar-94	2 eggs	7	replic2	60.7	0.563
02-Mar-94	2 eggs	7	replic3	148.2	2.307
02-Mar-94	2 eggs	7	replic3	137.0	1.996
02-Mar-94	2 eggs	7	replic3	124.6	1.903
02-Mar-94	2 eggs	7	replic3	114.2	1.141
02-Mar-94	2 eggs	7	replic3	98.2	0.957
02-Mar-94	2 eggs	7	replic3	87.7	0.904
02-Mar-94	2 eggs	7	replic3	74.8	0.982
02-Mar-94	2 eggs	7	replic3	61.5	0.724
02-Mar-94	2 eggs	9	replic1	153.5	2.517
02-Mar-94	2 eggs	9	replic1	141.6	2.099
02-Mar-94	2 eggs	9	replic1	131.7	1.141
02-Mar-94	2 eggs	9	replic1	123.3	1.458
02-Mar-94	2 eggs	9	replic1	102.3	1.009
02-Mar-94	2 eggs	9	replic1	90.7	1.072
02-Mar-94	2 eggs	9	replic1	76.7	1.013
02-Mar-94	2 eggs	9	replic1	62.5	0.808
02-Mar-94	2 eggs	9	replic2	149.8	2.427
02-Mar-94	2 eggs	9	replic2	139.4	1.460
02-Mar-94	2 eggs	9	replic2	129.5	1.523
02-Mar-94	2 eggs	9	replic2	117.4	2.034
02-Mar-94	2 eggs	9	replic2	100.4	1.001
02-Mar-94	2 eggs	9	replic2	86.6	1.373
02-Mar-94	2 eggs	9	replic3	151.2	1.865
02-Mar-94	2 eggs	9	replic3	141.4	1.743
02-Mar-94	2 eggs	9	replic3	130.0	1.688
02-Mar-94	2 eggs	9	replic3	120.4	0.980
02-Mar-94	2 eggs	9	replic3	99.8	0.991
02-Mar-94	2 eggs	9	replic3	86.2	1.351
02-Mar-94	2 eggs	5	replic1	152.2	1.981
02-Mar-94	2 eggs	5	replic1	143.6	1.275
02-Mar-94	2 eggs	5	replic1	133.5	1.763
02-Mar-94	2 eggs	5	replic1	122.1	1.582
02-Mar-94	2 eggs	5	replic1	100.1	1.017
02-Mar-94	2 eggs	5	replic1	88.9	0.951
02-Mar-94	2 eggs	5	replic1	75.9	0.939
02-Mar-94	2 eggs	5	replic1	61.8	0.821

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(μg/h/egg)
22-Apr-94	1 alevin	9	replic1	87.6	6.586
22-Apr-94	1 alevin	9	replic1	73.1	9.550
22-Apr-94	1 alevin	9	replic1	51.3	7.639
22-Apr-94	1 alevin	9	replic1	39.0	6.832
22-Apr-94	1 alevin	9	replic1	21.5	4.990
22-Apr-94	1 alevin	9	replic1	10.1	2.3
22-Apr-94	1 alevin	9	replic2	141.4	8.269
22-Apr-94	1 alevin	9	replic2	126.1	10.941
22-Apr-94	1 alevin	9	replic2	103.4	8.141
22-Apr-94	1 alevin	9	replic2	79.2	6.873
22-Apr-94	1 alevin	9	replic2	76.5	6.868
22-Apr-94	1 alevin	9	replic2	58.8	6.667
22-Apr-94	1 alevin	9	replic2	41.4	6.357
22-Apr-94	1 alevin	9	replic2	25.0	4.648
22-Apr-94	1 alevin	9	replic2	13.4	2.5
22-Apr-94	1 alevin	9	replic3	135.4	8.204
22-Apr-94	1 alevin	9	replic3	119.7	11.084
22-Apr-94	1 alevin	9	replic3	94.3	9.239
22-Apr-94	1 alevin	9	replic3	71.8	8.848
22-Apr-94	1 alevin	9	replic3	65.7	7.721
22-Apr-94	1 alevin	9	replic3	50.0	7.336
22-Apr-94	1 alevin	9	replic3	40.8	6.071
22-Apr-94	1 alevin	9	replic3	23.7	5.101
22-Apr-94	1 alevin	9	replic3	11.4	2.3
22-Apr-94	1 alevin	7	replic1	138.6	4.754
22-Apr-94	1 alevin	7	replic1	129.2	6.980
22-Apr-94	1 alevin	7	replic1	112.2	6.667
22-Apr-94	1 alevin	7	replic1	90.1	6.679
22-Apr-94	1 alevin	7	replic1	70.8	8.713
22-Apr-94	1 alevin	7	replic1	51.2	6.570
22-Apr-94	1 alevin	7	replic1	40.3	5.369
22-Apr-94	1 alevin	7	replic1	24.1	5.312
22-Apr-94	1 alevin	7	replic1	11.7	2.3
22-Apr-94	1 alevin	7	replic2	136.0	8.861
22-Apr-94	1 alevin	7	replic2	122.3	8.927
22-Apr-94	1 alevin	7	replic2	102.6	7.736
22-Apr-94	1 alevin	7	replic2	79.6	6.865
22-Apr-94	1 alevin	7	replic2	71.8	7.766
22-Apr-94	1 alevin	7	replic2	52.5	7.757
22-Apr-94	1 alevin	7	replic2	44.2	3.261
22-Apr-94	1 alevin	7	replic2	33.5	3.461

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(μg/h/egg)
22-Apr-94	1 alevin	3	replic1	81.5	3.159
22-Apr-94	1 alevin	3	replic1	71.8	4.061
22-Apr-94	1 alevin	3	replic1	52.4	3.441
22-Apr-94	1 alevin	3	replic1	42.1	3.570
22-Apr-94	1 alevin	3	replic1	30.6	3.4
22-Apr-94	1 alevin	3	replic2	150.9	4.777
22-Apr-94	1 alevin	3	replic2	143.8	4.590
22-Apr-94	1 alevin	3	replic2	132.1	5.000
22-Apr-94	1 alevin	3	replic2	116.4	5.165
22-Apr-94	1 alevin	3	replic2	80.6	5.269
22-Apr-94	1 alevin	3	replic2	66.9	5.618
22-Apr-94	1 alevin	3	replic2	49.9	4.742
22-Apr-94	1 alevin	3	replic2	38.1	3.401
22-Apr-94	1 alevin	3	replic2	25.5	4.3
22-Apr-94	1 alevin	3	replic3	149.8	4.205
22-Apr-94	1 alevin	3	replic3	142.9	4.509
22-Apr-94	1 alevin	3	replic3	132.7	3.849
22-Apr-94	1 alevin	3	replic3	119.1	4.349
22-Apr-94	1 alevin	3	replic3	79.0	5.059
22-Apr-94	1 alevin	3	replic3	66.9	4.444
22-Apr-94	1 alevin	3	replic3	49.7	4.205
22-Apr-94	1 alevin	3	replic3	36.9	4.542
22-Apr-94	1 alevin	3	replic3	25.2	2.8
22-Apr-94	1 alevin	13.5	replic1	143.7	6.302
22-Apr-94	1 alevin	13.5	replic1	134.2	6.253
22-Apr-94	1 alevin	13.5	replic1	120.3	5.532
22-Apr-94	1 alevin	13.5	replic1	103.4	5.343
22-Apr-94	1 alevin	13.5	replic1	75.6	8.406
22-Apr-94	1 alevin	13.5	replic1	59.0	5.164
22-Apr-94	1 alevin	13.5	replic1	44.1	5.791
22-Apr-94	1 alevin	13.5	replic1	29.1	4.549
22-Apr-94	1 alevin	13.5	replic1	16.3	3.5
22-Apr-94	1 alevin	13.5	replic2	143.1	6.252
22-Apr-94	1 alevin	13.5	replic2	131.0	8.667
22-Apr-94	1 alevin	13.5	replic2	109.2	8.512
22-Apr-94	1 alevin	13.5	replic2	79.7	9.107
22-Apr-94	1 alevin	13.5	replic2	70.8	8.393
22-Apr-94	1 alevin	13.5	replic2	51.0	6.479
22-Apr-94	1 alevin	13.5	replic2	37.1	6.497
22-Apr-94	1 alevin	13.5	replic2	20.9	4.148
22-Apr-94	1 alevin	13.5	replic2	10.9	1.9

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(μg/h/egg)
28-Apr-94	1 alevin	7	replic1	60.5	7.054
28-Apr-94	1 alevin	7	replic1	47.5	7.229
28-Apr-94	1 alevin	7	replic1	32.2	5.752
28-Apr-94	1 alevin	7	replic1	23.4	4.414
28-Apr-94	1 alevin	7	replic2	139.8	8.485
28-Apr-94	1 alevin	7	replic2	125.2	9.468
28-Apr-94	1 alevin	7	replic2	104.5	8.664
28-Apr-94	1 alevin	7	replic2	78.2	8.692
28-Apr-94	1 alevin	7	replic2	69.8	8.592
28-Apr-94	1 alevin	7	replic2	57.7	7.269
28-Apr-94	1 alevin	7	replic2	43.9	7.871
28-Apr-94	1 alevin	7	replic2	27.0	6.578
28-Apr-94	1 alevin	7	replic2	23.8	4.932
28-Apr-94	1 alevin	7	replic3	134.0	11.424
28-Apr-94	1 alevin	7	replic3	116.7	10.054
28-Apr-94	1 alevin	7	replic3	95.1	8.936
28-Apr-94	1 alevin	7	replic3	70.8	6.999
28-Apr-94	1 alevin	7	replic3	65.5	11.023
28-Apr-94	1 alevin	7	replic3	50.9	8.173
28-Apr-94	1 alevin	7	replic3	36.9	7.272
28-Apr-94	1 alevin	7	replic3	22.9	4.385
28-Apr-94	1 alevin	7	replic3	22.4	5.185
28-Apr-94	1 alevin	5	replic1	140.6	8.706
28-Apr-94	1 alevin	5	replic1	128.3	6.846
28-Apr-94	1 alevin	5	replic1	112.3	7.402
28-Apr-94	1 alevin	5	replic1	92.1	6.613
28-Apr-94	1 alevin	5	replic1	74.5	8.208
28-Apr-94	1 alevin	5	replic1	63.1	7.147
28-Apr-94	1 alevin	5	replic1	51.3	6.370
28-Apr-94	1 alevin	5	replic1	36.7	6.489
28-Apr-94	1 alevin	5	replic1	23.8	4.591
28-Apr-94	1 alevin	5	replic2	139.3	7.774
28-Apr-94	1 alevin	5	replic2	126.1	8.417
28-Apr-94	1 alevin	5	replic2	107.3	7.956
28-Apr-94	1 alevin	5	replic2	84.0	7.363
28-Apr-94	1 alevin	5	replic2	70.6	8.128
28-Apr-94	1 alevin	5	replic2	58.5	7.532
28-Apr-94	1 alevin	5	replic2	44.5	7.840
28-Apr-94	1 alevin	5	replic2	28.2	6.015
28-Apr-94	1 alevin	5	replic2	24.0	4.799
28-Apr-94	1 alevin	5	replic3	141.7	7.880

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(μg/h/egg)
28-Apr-94	1 alevin	13.5	replic1	52.1	5.665
28-Apr-94	1 alevin	13.5	replic1	39.0	6.293
28-Apr-94	1 alevin	13.5	replic1	25.8	4.325
28-Apr-94	1 alevin	13.5	replic2	142.6	10.119
28-Apr-94	1 alevin	13.5	replic2	128.2	7.541
28-Apr-94	1 alevin	13.5	replic2	106.1	10.623
28-Apr-94	1 alevin	13.5	replic2	76.8	8.507
28-Apr-94	1 alevin	13.5	replic2	70.3	7.795
28-Apr-94	1 alevin	13.5	replic2	59.4	6.645
28-Apr-94	1 alevin	13.5	replic2	46.4	7.483
28-Apr-94	1 alevin	13.5	replic2	30.6	6.067
28-Apr-94	1 alevin	13.5	replic2	26.2	4.091
28-Apr-94	1 alevin	13.5	replic3	136.3	12.869
28-Apr-94	1 alevin	13.5	replic3	118.0	10.117
28-Apr-94	1 alevin	13.5	replic3	97.5	8.437
28-Apr-94	1 alevin	13.5	replic3	70.8	9.624
28-Apr-94	1 alevin	13.5	replic3	63.9	10.320
28-Apr-94	1 alevin	13.5	replic3	50.9	7.400
28-Apr-94	1 alevin	13.5	replic3	38.6	6.390
28-Apr-94	1 alevin	13.5	replic3	25.3	5.347
28-Apr-94	1 alevin	13.5	replic3	25.2	4.299

Concluded

**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  $\mu\text{g O}_2$  consumed per hour per egg at each oxygen partial pressure ( $\text{Po}_2$ ).

Date	N/test	Oxygen Treatment	Replicate	$\text{Po}_2$ (mm Hg)	Q ( $\mu\text{g/h/egg}$ )
		(mg/l O <sub>2</sub> )			
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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O2)		(mm Hg)	(ug/h/egg)
20-Jan-94	20	5mg	replic2	41.4	0.1602
20-Jan-94	20	5mg	replic2	23.6	0.0845
20-Jan-94	20	5mg	replic3	134.8	0.5088
20-Jan-94	20	5mg	replic3	110.6	0.0577
20-Jan-94	20	5mg	replic3	82.3	0.3581
20-Jan-94	20	5mg	replic3	52.6	0.2325
20-Jan-94	20	5mg	replic3	41.8	0.1158
20-Jan-94	20	5mg	replic3	24.7	0.1220
20-Jan-94	20	7mg	replic1	136.2	0.5357
20-Jan-94	20	7mg	replic1	98.5	0.1552
20-Jan-94	20	7mg	replic1	81.0	0.3397
20-Jan-94	20	7mg	replic1	55.4	0.2285
20-Jan-94	20	7mg	replic1	39.2	0.1881
20-Jan-94	20	7mg	replic1	22.1	0.0814
20-Jan-94	20	7mg	replic2	132.7	0.5448
20-Jan-94	20	7mg	replic2	101.0	0.1310
20-Jan-94	20	7mg	replic2	82.6	0.3398
20-Jan-94	20	7mg	replic2	59.5	0.2570
20-Jan-94	20	7mg	replic2	41.7	0.1223
20-Jan-94	20	7mg	replic2	25.1	0.0840
20-Jan-94	20	7mg	replic3	137.9	0.4451
20-Jan-94	20	7mg	replic3	113.7	0.1361
20-Jan-94	20	7mg	replic3	83.0	0.3063
20-Jan-94	20	7mg	replic3	60.3	0.2543
20-Jan-94	20	7mg	replic3	44.2	0.1752
20-Jan-94	20	7mg	replic3	22.8	0.0839
20-Jan-94	20	9mg	replic1	134.7	0.4387
20-Jan-94	20	9mg	replic1	100.0	0.2977
20-Jan-94	20	9mg	replic1	80.8	0.2654
20-Jan-94	20	9mg	replic1	55.4	0.2636
20-Jan-94	20	9mg	replic1	39.7	0.1773
20-Jan-94	20	9mg	replic1	22.7	0.0718
20-Jan-94	20	9mg	replic2	129.9	0.5700
20-Jan-94	20	9mg	replic2	101.7	0.0292
20-Jan-94	20	9mg	replic2	80.9	0.2946
20-Jan-94	20	9mg	replic2	58.0	0.2794
20-Jan-94	20	9mg	replic2	42.2	0.1580
20-Jan-94	20	9mg	replic2	25.5	0.0702
20-Jan-94	20	9mg	replic3	136.8	0.4722
20-Jan-94	20	9mg	replic3	109.5	0.1449
20-Jan-94	20	9mg	replic3	84.8	0.3716
20-Jan-94	20	9mg	replic3	71.6	0.3385
20-Jan-94	20	9mg	replic3	45.2	0.1820
20-Jan-94	20	9mg	replic3	28.5	0.0736
09-Feb-94	10	13.45	replic1	140.6	0.6992
09-Feb-94	10	13.45	replic1	115.9	0.7273
09-Feb-94	10	13.45	replic1	96.4	0.3547
09-Feb-94	10	13.45	replic1	88.5	0.4453
09-Feb-94	10	13.45	replic1	81.1	0.3266
09-Feb-94	10	13.45	replic1	71.0	0.2236
09-Feb-94	10	13.45	replic1	58.0	0.2159

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(ug/h//egg)
09-Feb-94	10	3	replic3	97.6	0.3704
09-Feb-94	10	3	replic3	92.7	0.3485
09-Feb-94	10	3	replic3	75.0	0.2984
09-Feb-94	10	3	replic3	60.1	0.1964
09-Feb-94	10	3	replic3	48.1	0.1903
09-Feb-94	10	3	replic3	38.2	0.1160
09-Feb-94	10	3	replic3	30.5	0.0918
09-Feb-94	10	3	replic3	23.9	0.0587
09-Feb-94	10	5	replic1	146.6	0.6908
09-Feb-94	10	5	replic1	124.0	0.6256
09-Feb-94	10	5	replic1	104.1	0.4464
09-Feb-94	10	5	replic1	94.8	0.4379
09-Feb-94	10	5	replic1	86.9	0.3123
09-Feb-94	10	5	replic1	74.7	0.2947
09-Feb-94	10	5	replic1	58.7	0.2411
09-Feb-94	10	5	replic1	50.6	0.1631
09-Feb-94	10	5	replic1	39.9	0.1621
09-Feb-94	10	5	replic1	30.4	0.0975
09-Feb-94	10	5	replic1	22.6	0.0832
09-Feb-94	10	5	replic2	143.4	0.7746
09-Feb-94	10	5	replic2	119.1	0.6658
09-Feb-94	10	5	replic2	97.8	0.4829
09-Feb-94	10	5	replic2	93.7	0.3076
09-Feb-94	10	5	replic2	78.7	0.3646
09-Feb-94	10	5	replic2	75.0	0.3859
09-Feb-94	10	5	replic2	57.4	0.2139
09-Feb-94	10	5	replic2	48.2	0.2040
09-Feb-94	10	5	replic2	36.5	0.1546
09-Feb-94	10	5	replic2	27.4	0.0951
09-Feb-94	10	5	replic2	21.4	0.0501
09-Feb-94	10	5	replic3	142.5	0.7507
09-Feb-94	10	5	replic3	117.9	0.6622
09-Feb-94	10	5	replic3	99.0	0.2798
09-Feb-94	10	5	replic3	95.3	0.5150
09-Feb-94	10	5	replic3	80.6	0.3837
09-Feb-94	10	5	replic3	75.3	0.3431
09-Feb-94	10	5	replic3	61.9	0.2360
09-Feb-94	10	5	replic3	50.0	0.1881
09-Feb-94	10	5	replic3	38.4	0.1585
09-Feb-94	10	5	replic3	28.6	0.1065
09-Feb-94	10	5	replic3	20.9	0.0708
09-Feb-94	10	7mg	replic1	139.4	0.7891
09-Feb-94	10	7mg	replic1	115.3	0.5572
09-Feb-94	10	7mg	replic1	96.6	0.4094
09-Feb-94	10	7mg	replic1	94.1	0.2260
09-Feb-94	10	7mg	replic1	80.3	0.2746
09-Feb-94	10	7mg	replic1	78.4	0.3444
09-Feb-94	10	7mg	replic1	60.9	0.2217
09-Feb-94	10	7mg	replic1	49.7	0.1492
09-Feb-94	10	7mg	replic1	41.6	0.0966
09-Feb-94	10	7mg	replic1	33.1	0.1319

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(ug/h//egg)
09-Feb-94	10	9mg	replic3	65.1	0.2457
09-Feb-94	10	9mg	replic3	50.0	0.2164
09-Feb-94	10	9mg	replic3	39.1	0.1217
09-Feb-94	10	9mg	replic3	30.6	0.1067
09-Feb-94	10	9mg	replic3	23.3	0.0637
23-Feb-94	7	13.45mg	replic1	139.8	1.198
23-Feb-94	7	13.45mg	replic1	118.6	0.744
23-Feb-94	7	13.45mg	replic1	99.9	0.654
23-Feb-94	7	13.45mg	replic1	86.7	0.275
23-Feb-94	7	13.45mg	replic1	75.6	0.441
23-Feb-94	7	13.45mg	replic1	66.2	0.273
23-Feb-94	7	13.45mg	replic1	45.6	0.269
23-Feb-94	7	13.45mg	replic1	25.8	0.077
23-Feb-94	7	13.45mg	replic2	137.0	1.447
23-Feb-94	7	13.45mg	replic2	115.3	0.598
23-Feb-94	7	13.45mg	replic2	99.8	0.578
23-Feb-94	7	13.45mg	replic2	87.2	0.337
23-Feb-94	7	13.45mg	replic2	76.8	0.359
23-Feb-94	7	13.45mg	replic2	67.9	0.292
23-Feb-94	7	13.45mg	replic2	47.3	0.260
23-Feb-94	7	13.45mg	replic2	27.7	0.082
23-Feb-94	7	13.45mg	replic3	136.4	1.311
23-Feb-94	7	13.45mg	replic3	116.8	0.614
23-Feb-94	7	13.45mg	replic3	102.7	0.458
23-Feb-94	7	13.45mg	replic3	89.7	0.506
23-Feb-94	7	13.45mg	replic3	78.4	0.283
23-Feb-94	7	13.45mg	replic3	69.3	0.225
23-Feb-94	7	13.45mg	replic3	48.9	0.279
23-Feb-94	7	13.45mg	replic3	26.9	0.097
23-Feb-94	7	3mg	replic1	140.0	1.160
23-Feb-94	7	3mg	replic1	122.0	0.567
23-Feb-94	7	3mg	replic1	106.0	0.566
23-Feb-94	7	3mg	replic1	90.3	0.508
23-Feb-94	7	3mg	replic1	76.8	0.338
23-Feb-94	7	3mg	replic1	64.7	0.395
23-Feb-94	7	3mg	replic1	40.2	0.258
23-Feb-94	7	3mg	replic1	19.8	0.070
23-Feb-94	7	3mg	replic2	139.5	0.817
23-Feb-94	7	3mg	replic2	125.5	0.574
23-Feb-94	7	3mg	replic2	109.5	0.628
23-Feb-94	7	3mg	replic2	93.5	0.557
23-Feb-94	7	3mg	replic2	79.9	0.396
23-Feb-94	7	3mg	replic2	70.1	0.246
23-Feb-94	7	3mg	replic2	50.5	0.245
23-Feb-94	7	3mg	replic2	29.5	0.109
23-Feb-94	7	3mg	replic3	139.7	1.162
23-Feb-94	7	3mg	replic3	121.7	0.578
23-Feb-94	7	3mg	replic3	106.2	0.521
23-Feb-94	7	3mg	replic3	92.0	0.445
23-Feb-94	7	3mg	replic3	79.3	0.330
23-Feb-94	7	3mg	replic3	69.0	0.357

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(ug/h/egg)
23-Feb-94	7	9mg	replic1	124.7	1.010
23-Feb-94	7	9mg	replic1	102.0	0.714
23-Feb-94	7	9mg	replic1	86.3	0.407
23-Feb-94	7	9mg	replic1	74.2	0.403
23-Feb-94	7	9mg	replic1	69.7	0.189
23-Feb-94	7	9mg	replic1	47.7	0.323
23-Feb-94	7	9mg	replic1	24.1	0.090
23-Feb-94	7	9mg	replic2	144.4	0.717
23-Feb-94	7	9mg	replic2	125.6	0.909
23-Feb-94	7	9mg	replic2	105.8	0.548
23-Feb-94	7	9mg	replic2	90.8	0.482
23-Feb-94	7	9mg	replic2	76.7	0.411
23-Feb-94	7	9mg	replic2	70.6	0.182
23-Feb-94	7	9mg	replic2	52.5	0.243
23-Feb-94	7	9mg	replic2	30.7	0.111
23-Feb-94	7	9mg	replic3	144.7	0.685
23-Feb-94	7	9mg	replic3	128.3	0.767
23-Feb-94	7	9mg	replic3	108.8	0.623
23-Feb-94	7	9mg	replic3	92.7	0.459
23-Feb-94	7	9mg	replic3	79.7	0.338
23-Feb-94	7	9mg	replic3	69.7	0.279
23-Feb-94	7	9mg	replic3	53.2	0.169
23-Feb-94	7	9mg	replic3	35.3	0.113
24-Mar-94	8	T5-3mg	replic1	144.8	1.2364
24-Mar-94	8	T5-3mg	replic1	133.6	0.6023
24-Mar-94	8	T5-3mg	replic1	123.8	0.9082
24-Mar-94	8	T5-3mg	replic1	113.4	0.4857
24-Mar-94	8	T5-3mg	replic1	101.4	0.6719
24-Mar-94	8	T5-3mg	replic1	87.3	0.3956
24-Mar-94	8	T5-3mg	replic1	72.1	0.5169
24-Mar-94	8	T5-3mg	replic2	146.5	1.3590
24-Mar-94	8	T5-3mg	replic2	134.0	0.6564
24-Mar-94	8	T5-3mg	replic2	125.4	0.6659
24-Mar-94	8	T5-3mg	replic2	115.6	0.5805
24-Mar-94	8	T5-3mg	replic2	103.3	0.6074
24-Mar-94	8	T5-3mg	replic2	89.4	0.4401
24-Mar-94	8	T5-3mg	replic2	74.2	0.4909
24-Mar-94	8	T5-3mg	replic3	145.9	1.3782
24-Mar-94	8	T5-3mg	replic3	133.2	0.6670
24-Mar-94	8	T5-3mg	replic3	124.3	0.6947
24-Mar-94	8	T5-3mg	replic3	114.1	0.6008
24-Mar-94	8	T5-3mg	replic3	101.4	0.6109
24-Mar-94	8	T5-3mg	replic3	87.4	0.4346
24-Mar-94	8	T5-3mg	replic3	72.0	0.4913
24-Mar-94	8	T5-3mg	replic4	149.8	1.3088
24-Mar-94	8	T5-3mg	replic4	140.0	0.4293
24-Mar-94	8	T5-3mg	replic4	131.5	0.9185
24-Mar-94	8	T5-3mg	replic4	118.4	0.7685
24-Mar-94	8	T5-3mg	replic4	104.4	0.5915
24-Mar-94	8	T5-3mg	replic4	90.2	0.4696
24-Mar-94	8	T5-3mg	replic4	74.8	0.4825

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(ug/h//egg)
24-Mar-94	8	T7-3mg	replic4	134.6	0.8090
24-Mar-94	8	T7-3mg	replic4	125.4	0.3903
24-Mar-94	8	T7-3mg	replic4	114.1	0.6271
24-Mar-94	8	T7-3mg	replic4	98.8	0.4393
24-Mar-94	8	T7-3mg	replic4	85.7	0.2711
11-Apr-94	4	3 to 13.5	replic1	152.7	1.038
11-Apr-94	4	3 to 13.5	replic1	143.4	0.973
11-Apr-94	4	3 to 13.5	replic1	131.6	0.717
11-Apr-94	4	3 to 13.5	replic1	119.0	0.764
11-Apr-94	4	3 to 13.5	replic1	105.6	0.569
11-Apr-94	4	3 to 13.5	replic2	153.3	1.225
11-Apr-94	4	3 to 13.5	replic2	142.3	0.996
11-Apr-94	4	3 to 13.5	replic2	126.9	0.917
11-Apr-94	4	3 to 13.5	replic2	111.6	0.620
11-Apr-94	4	3 to 13.5	replic2	100.1	0.628
11-Apr-94	4	3 to 13.5	replic3	153.9	1.111
11-Apr-94	4	3 to 13.5	replic3	143.5	1.105
11-Apr-94	4	3 to 13.5	replic3	128.6	1.050
11-Apr-94	4	3 to 13.5	replic3	114.6	0.657
11-Apr-94	4	3 to 13.5	replic3	103.1	0.515
11-Apr-94	4	3 to 3mg	replic1	153.0	0.405
11-Apr-94	4	3 to 3mg	replic1	146.7	0.763
11-Apr-94	4	3 to 3mg	replic1	136.1	0.751
11-Apr-94	4	3 to 3mg	replic1	124.1	0.628
11-Apr-94	4	3 to 3mg	replic1	112.2	0.528
11-Apr-94	4	3 to 3mg	replic2	154.2	0.768
11-Apr-94	4	3 to 3mg	replic2	147.4	0.687
11-Apr-94	4	3 to 3mg	replic2	137.1	0.821
11-Apr-94	4	3 to 3mg	replic2	125.8	0.541
11-Apr-94	4	3 to 3mg	replic2	114.3	0.595
11-Apr-94	4	3 to 3mg	replic3	152.7	0.091
11-Apr-94	4	3 to 3mg	replic3	148.8	0.558
11-Apr-94	4	3 to 3mg	replic3	138.7	0.871
11-Apr-94	4	3 to 3mg	replic3	124.9	0.684
11-Apr-94	4	3 to 3mg	replic3	110.5	0.681
11-Apr-94	4	3 to 5mg	replic1	152.7	0.776
11-Apr-94	4	3 to 5mg	replic1	144.9	0.805
11-Apr-94	4	3 to 5mg	replic1	132.8	0.884
11-Apr-94	4	3 to 5mg	replic1	118.1	0.780
11-Apr-94	4	3 to 5mg	replic1	104.3	0.548
11-Apr-94	4	3 to 5mg	replic2	153.2	0.545
11-Apr-94	4	3 to 5mg	replic2	146.0	0.852
11-Apr-94	4	3 to 5mg	replic2	133.8	0.885
11-Apr-94	4	3 to 5mg	replic2	120.5	0.666
11-Apr-94	4	3 to 5mg	replic2	107.5	0.632
11-Apr-94	4	3 to 5mg	replic3	152.5	0.376
11-Apr-94	4	3 to 5mg	replic3	146.1	0.798
11-Apr-94	4	3 to 5mg	replic3	135.0	0.707
11-Apr-94	4	3 to 5mg	replic3	122.4	0.694
11-Apr-94	4	3 to 5mg	replic3	110.3	0.506
11-Apr-94	4	3 to 7mg	replic1	149.2	0.264

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(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

Date	N/test	Oxygen Treatment	Replicate	Po <sub>2</sub>	Q
		(mg/l O <sub>2</sub> )		(mm Hg)	(ug/h/egg)
13-Apr-94	6	3 to 5(t13)	replic2	141.0	0.792
13-Apr-94	6	3 to 5(t13)	replic2	127.7	0.750
13-Apr-94	6	3 to 5(t13)	replic3	149.3	0.986
13-Apr-94	6	3 to 5(t13)	replic3	137.3	0.824
13-Apr-94	6	3 to 5(t13)	replic3	123.2	0.886
13-Apr-94	6	3 to 7(t11)	replic1	147.7	0.788
13-Apr-94	6	3 to 7(t11)	replic1	135.1	1.004
13-Apr-94	6	3 to 7(t11)	replic1	119.9	0.771
13-Apr-94	6	3 to 7(t11)	replic2	146.6	1.091
13-Apr-94	6	3 to 7(t11)	replic2	133.4	0.902
13-Apr-94	6	3 to 7(t11)	replic2	120.0	0.696
13-Apr-94	6	3 to 7(t11)	replic3	148.6	0.948
13-Apr-94	6	3 to 7(t11)	replic3	136.5	0.825
13-Apr-94	6	3 to 7(t11)	replic3	123.3	0.715
13-Apr-94	6	3 to 9(t9)	replic1	143.2	0.744
13-Apr-94	6	3 to 9(t9)	replic1	132.2	0.868
13-Apr-94	6	3 to 9(t9)	replic1	119.1	0.725
13-Apr-94	6	3 to 9(t9)	replic2	147.5	0.728
13-Apr-94	6	3 to 9(t9)	replic2	135.7	0.976
13-Apr-94	6	3 to 9(t9)	replic2	121.6	0.739
13-Apr-94	6	3 to 9(t9)	replic3	142.1	0.891
13-Apr-94	6	3 to 9(t9)	replic3	130.6	0.806
13-Apr-94	6	3 to 9(t9)	replic3	117.3	0.760

Concluded

**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  $2 \pm 0.2^\circ\text{C}$ . 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 <sub>2</sub> )																		
Date	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	
	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	
04-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	ND
04-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	ND
04-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	ND
04-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	ND
04-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	ND
04-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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	ND

OXYGEN TREATMENT (mg/l O <sub>2</sub> )																			
Date	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
	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
27-JAN-94	28.4	30.9	29.0	29.7	26.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
27-JAN-94	29.8	29.8	30.0	29.3	26.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
04-FEB-94	33.9	33.5	35.2	36.4	30.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
04-FEB-94	33.0	31.7	30.9	33.4	29.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
04-FEB-94	32.1	33.8	35.1	37.0	30.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
04-FEB-94	35.1	34.9	31.7	33.2	32.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
04-FEB-94	35.9	33.8	31.8	33.9	30.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
04-FEB-94	33.9	35.3	32.6	35.7	29.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
16-FEB-94	38.2	38.2	37.3	37.5	29.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
16-FEB-94	36.9	37.2	37.1	34.4	30.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
16-FEB-94	36.1	38.5	32.2	34.0	28.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
16-FEB-94	34.6	36.7	32.0	32.9	27.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
16-FEB-94	34.5	36.2	33.8	37.6	26.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
16-FEB-94	35.9	37.0	32.2	34.5	27.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
24-FEB-94	33.3	36.1	37.8	37.6	30.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
24-FEB-94	36.5	38.7	35.7	40.9	32.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
24-FEB-94	38.2	36.6	38.2	35.6	31.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
24-FEB-94	39.7	36.0	38.0	37.4	31.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
24-FEB-94	37.0	34.6	35.4	36.1	29.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
24-FEB-94	38.2	33.8	35.4	35.0	29.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
08-MAR-94	49.8	46.0	41.4	38.5	35.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
08-MAR-94	49.5	47.0	40.0	44.3	43.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
08-MAR-94	45.0	44.6	45.2	35.5	38.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
08-MAR-94	36.5	42.9	43.0	35.5	39.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
08-MAR-94	37.8	43.9	39.3	39.4	39.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
08-MAR-94	40.4	46.2	40.6	37.5	38.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22-MAR-94	ND	ND	ND	ND	33.2	28.6	31.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

OXYGEN TREATMENT (mg/l O <sub>2</sub> )																			
Date	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
	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	36.0	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.

Date	Artemia Concentration			Gut Contents		Larvae Length (mm)
	Nauplii (N/l)	Eggs (N/l)	Larval Treatment	Nauplii N	Eggs N	
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

Date	Artemia Concentration			Gut Contents		Larvae Length (mm)
	Nauplii (N/l)	Eggs (N/l)	Larval Treatment	Nauplii N	Eggs N	
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	17	0	15.5
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	17	0	16
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	26	1	15.5
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	33	0	15.5
11-May-94	61 (10)	11 (4)	9 mg/l:(t8-9)	37	3	15
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	0	0	14.6
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	0	0	15.2
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	3	0	13.3
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	4	0	15.1
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	5	1	14.7
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	18	1	14.4
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	23	1	15
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	34	4	15.4
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	47	2	15.9
11-May-94	61 (10)	11 (4)	7 mg/l:(t10-11)	48	3	14.2
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	8	0	14.8
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	11	0	14.9
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	11	0	14.2
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	16	0	15.6
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	19	4	15.8
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	20	1	15.4
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	24	0	15.3
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	24	1	14.7
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	24	3	15.4
11-May-94	61 (10)	11 (4)	5 mg/l:(t(12-13)	30	3	15.4
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	0	0	15.3
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	3	1	14.8
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	3	0	14
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	3	0	14
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	5	0	13.9
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	14	1	13.5
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	18	1	14.7
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	29	0	14.7
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	42	4	14.4
11-May-94	61 (10)	11 (4)	3 mg/l:(t 6-7)	43	4	14.4
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	49	0	18
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	55	4	17.5
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	57	1	17.5
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	82	7	17
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	54	3	16.5
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	75	14	17
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	46	6	16
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	69	1	16.5
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	29	4	15.5
29-Mar-94	182 (34)	62 (16)	13.5 mg/l:(t1)	83	6	17
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	63	6	17
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	47	5	17.5
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	51	10	17
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	48	9	17
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	45	2	17.5
29-Mar-94	182 (34)	62 (16)	9 mg/l:(t2)	59	9	16.5

Date	Artemia Concentration			Gut Contents		Larvae Length (mm)
	Nauplii (N/l)	Eggs (N/l)	Larval Treatment	Nauplii N	Eggs N	
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

Date	Artemia Concentration			Gut Contents		Larvae Length (mm)
	Nauplii (N/l)	Eggs (N/l)	Larval Treatment	Nauplii N	Eggs N	
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	28	2	16
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	28	4	16.8
29-Mar-94	123 (15)	42 (7)	7 mg/l:(t4)	51	4	16.8
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	27	4	16.5
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	52	3	16
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	1	5	17.6
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	38	11	16.6
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	28	3	16.4
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	40	3	17
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	56	10	17
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	54	2	15.9
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	58	8	16.9
29-Mar-94	123 (15)	42 (7)	5 mg/l:(t3)	40	10	16.7
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	15	3	15.7
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	11	7	17.1
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	8	1	16.6
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	25	4	16.8
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	35	1	16.8
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	50	5	16.8
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	14	5	16.9
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	7	4	17.8
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	14	6	18.2
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	22	2	16.5
29-Mar-94	62 (8)	21 (4)	13.5 mg/l:(t1)	24	4	15.8
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	18	0	16.8
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	17	2	15.6
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	6	0	16.2
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	14	0	17.4
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	13	1	16.9
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	40	4	n/a
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	8	2	16.5
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	14	5	17
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	9	1	15.3
29-Mar-94	62 (8)	21 (4)	7 mg/l:(t4)	8	3	16.6
29-Mar-94	62 (8)	21 (4)	5 mg/l:(t3)	0	6	16.3
29-Mar-94	62 (8)	21 (4)	5 mg/l:(t3)	2	0	17.1
29-Mar-94	62 (8)	21 (4)	5 mg/l:(t3)	17	5	17.2
29-Mar-94	62 (8)	21 (4)	5 mg/l:(t3)	19	2	16.6
29-Mar-94	62 (8)	21 (4)	5 mg/l:(t3)	22	1	17.1
29-Mar-94	62 (8)	21 (4)	5 mg/l:(t3)	23	6	16.7
29-Mar-94	62 (8)	21 (4)	5 mg/l:(t3)	25	8	16.7
29-Mar-94	0	0	13.5	0	1	16
29-Mar-94	0	0	13.5	0	0	17
29-Mar-94	0	0	13.5	0	2	16.0
29-Mar-94	0	0	13.5	0	0	16.5
29-Mar-94	0	0	13.5	0	6	16.5
29-Mar-94	0	0	13.5	0	0	16.5
29-Mar-94	0	0	13.5	0	6	16
29-Mar-94	0	0	13.5	0	0	17
29-Mar-94	0	0	13.5	0	0	17
29-Mar-94	0	0	13.5	0	0	16.5

Date	Artemia Concentration		Larval Treatment	Gut Contents		Larvae Length (mm)
	Nauplii (N/l)	Eggs (N/l)		Nauplii N	Eggs N	
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 (#) used to rear each fish is indicated next to the acclimation date.

Species	Oxygen Treatment	Acclimation Date	Temperature	Wet Weight
	(mg/l)		(°C)	(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

Species	Oxygen Treatment	Acclimation Date	Temperature	Wet Weight
	(mg/l)		(°C)	(g)
Whitefish	9	March 17:(t3)	28.92	0.275
Whitefish	9	March 17:(t3)	28.92	0.214
Whitefish	9	March 17:(t3)	28.92	0.509
Whitefish	9	March 17:(t3)	28.92	0.559
Whitefish	9	March 17:(t3)	29.04	0.770
Whitefish	9	March 17:(t3)	29.04	nm
Whitefish	9	March 17:(t3)	29.09	nm
Whitefish	7	Mar. 17 & Apr.17:(t3)	27.78	0.072
Whitefish	7	Mar. 17 & Apr.17:(t3)	27.97	0.090
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.01	0.112
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.05	0.089
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.08	0.068
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.11	0.103
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.19	0.131
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.34	0.055
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.37	0.093
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.39	0.460
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.46	0.592
Whitefish	7	Mar. 17 & Apr.17:(t3)	28.63	0.567
Whitefish	7	May 5:(t4)	23.21	0.047
Whitefish	7	May 5:(t4)	26.69	0.034
Whitefish	7	May 5:(t4)	27.66	0.025
Whitefish	7	May 5:(t4)	28.23	0.030
Whitefish	7	May 5:(t4)	28.32	0.019
Whitefish	7	May 5:(t4)	28.49	0.032
Whitefish	7	May 5:(t4)	28.56	0.036
Whitefish	7	May 5:(t4)	28.57	0.023
Whitefish	7	May 5:(t4)	28.59	0.142
Whitefish	7	May 5:(t4)	28.59	0.025
Whitefish	7	May 5:(t4)	28.59	0.020
Whitefish	7	May 5:(t4)	28.60	0.032
Whitefish	5: (Tank 3)	May 5:(t4)	28.61	0.033
Whitefish	5: (Tank 3)	May 5:(t4)	28.65	0.030
Whitefish	5: (Tank 3)	May 5:(t4)	28.65	0.032
Whitefish	5: (Tank 3)	May 5:(t4)	28.75	0.034
Whitefish	5: (Tank 3)	May 5:(t4)	28.75	0.041
Whitefish	5: (Tank 3)	May 5:(t4)	28.75	0.031
Whitefish	5: (Tank 3)	May 5:(t4)	28.76	0.032
Whitefish	5: (Tank 3)	May 5:(t4)	28.76	0.036
Whitefish	5: (Tank 3)	May 5:(t4)	28.85	0.034
Whitefish	5: (Tank 3)	May 5:(t4)	28.87	0.035
Whitefish	5: (Tank 3)	May 5:(t4)	28.94	0.030

Species	Oxygen Treatment	Acclimation Date	Temperature	Wet Weight
	(mg/l)		(°C)	(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

Species	Oxygen Treatment	Acclimation Date	Temperature	Wet Weight
	(mg/l)		(°C)	(g)
Whitefish	3: (Tank 6)	May 26:(t5)	28.46	0.018
Whitefish	3: (Tank 6)	May 26:(t5)	28.46	0.016
Whitefish	3: (Tank 6)	May 26:(t5)	28.46	0.020
Whitefish	3: (Tank 6)	May 26:(t5)	28.46	0.013
Whitefish	3: (Tank 6)	May 26:(t5)	28.46	0.022
Whitefish	3: (Tank 6)	May 26:(t5)	28.46	0.022
Whitefish	3: (Tank 6)	May 26:(t5)	28.83	0.017
Whitefish	3: (Tank 5)	May 26:(t5)	27.81	0.024
Whitefish	3: (Tank 5)	May 26:(t5)	28.20	0.023
Whitefish	3: (Tank 5)	May 26:(t5)	28.54	0.019
Whitefish	3: (Tank 5)	May 26:(t5)	28.54	0.019
Whitefish	3: (Tank 5)	May 26:(t5)	28.54	0.023
Whitefish	3: (Tank 5)	May 26:(t5)	28.54	0.020
Whitefish	3: (Tank 5)	May 26:(t5)	28.54	0.024
Whitefish	3: (Tank 5)	May 26:(t5)	28.54	0.025
Whitefish	3: (Tank 5)	May 26:(t5)	28.54	0.020
Whitefish	3: (Tank 5)	May 26:(t5)	28.54	0.025
Whitefish	3: (Tank 5)	May 26:(t5)	28.54	0.023
Whitefish	3: (Tank 5)	May 26:(t5)	28.86	0.025
Bull Trout	13.5	May 26:(t6)	27.91	0.099
Bull Trout	13.5	May 26:(t6)	27.95	0.130
Bull Trout	13.5	May 26:(t6)	28.33	0.124
Bull Trout	13.5	May 26:(t6)	28.35	0.086
Bull Trout	13.5	May 26:(t6)	28.39	0.123
Bull Trout	13.5	May 26:(t6)	28.64	0.088
Bull Trout	13.5	May 26:(t6)	28.67	0.097
Bull Trout	13.5	May 26:(t6)	28.70	0.103
Bull Trout	13.5	May 26:(t6)	28.73	0.108
Bull Trout	5	May 26:(t6)	27.03	0.113
Bull Trout	5	May 26:(t6)	27.81	0.109
Bull Trout	5	May 26:(t6)	27.87	0.103
Bull Trout	5	May 26:(t6)	28.08	0.101
Bull Trout	5	May 26:(t6)	28.88	0.101
Bull Trout	5	May 26:(t6)	28.88	0.114
Bull Trout	5	May 26:(t6)	28.78	0.096
Bull Trout	5	May 26:(t6)	28.03	0.112
Bull Trout	5	May 26:(t6)	28.53	0.084
Bull Trout	5	May 26:(t6)	28.75	0.113
Bull Trout	5	May 26:(t6)	29.12	nm
Bull Trout	3	May 26:(t6)	27.14	0.112
Bull Trout	3	May 26:(t6)	27.34	0.111
Bull Trout	3	May 26:(t6)	27.54	0.110

Species	Oxygen Treatment	Acclimation Date	Temperature	Wet Weight
	(mg/l)		(°C)	(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 <sub>2</sub> )	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

Date	TREATMENT	Length
	(mg/l O <sub>2</sub> )	(mm)
06-May-94	13.5	25.77
06-May-94	13.5	24.38
06-May-94	9	25.04
06-May-94	9	23.95
06-May-94	9	24.86
06-May-94	9	26.05
06-May-94	9	25.48
06-May-94	9	25.84
06-May-94	9	26.41
06-May-94	9	25.37
06-May-94	9	24.83
06-May-94	9	25.74
06-May-94	7	26.95
06-May-94	7	26.11
06-May-94	7	26.75
06-May-94	7	26.66
06-May-94	7	24.44
06-May-94	7	27.52
06-May-94	7	26.62
06-May-94	7	26.28
06-May-94	7	26.60
06-May-94	7	24.81
06-May-94	5	24.04
06-May-94	5	24.95
06-May-94	5	24.11
06-May-94	5	24.91
06-May-94	5	25.82
06-May-94	5	25.37
06-May-94	5	23.59
06-May-94	5	23.98
06-May-94	5	22.28
06-May-94	3	22.83
06-May-94	3	22.09
06-May-94	3	21.81
06-May-94	3	23.22
06-May-94	3	23.65
06-May-94	3	22.33
06-May-94	3	23.39
06-May-94	3	23.17
06-May-94	3	22.81

Concluded

**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	STAGE	WET WT.	DRY WT.	DRY WT. BODY	DRY WT. YOLK	YOLK
	(mg/l)		(mg)	(mg)	(mg)	(mg)	(%)
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

DATE	OXYGEN TREATMENT	STAGE	WET WT.	DRY WT.	DRY WT. BODY	DRY WT. YOLK	YOLK
	(mg/l)		(mg)	(mg)	(mg)	(mg)	(%)
13-Apr	13.5	L	ND	21.0	8.6	12.4	58.9
13-Apr	13.5	L	ND	24.7	9.5	15.2	61.5
13-Apr	13.5	L	ND	24.8	9.8	15.0	60.6
13-Apr	9	L	ND	23.4	9.2	14.2	60.7
13-Apr	9	L	ND	20.2	7.0	13.3	65.5
13-Apr	9	L	ND	22.9	10.4	12.5	54.6
13-Apr	9	L	ND	25.3	9.8	15.5	61.2
13-Apr	9	L	ND	21.0	8.6	12.4	59.0
13-Apr	7	L	ND	28.0	12.9	15.0	53.8
13-Apr	7	L	ND	24.9	9.9	15.0	60.3
13-Apr	7	L	ND	24.3	10.5	13.8	56.8
13-Apr	7	L	ND	27.9	14.0	13.9	49.9
13-Apr	7	L	ND	21.5	9.3	12.2	56.9
13-Apr	5	L	ND	23.9	7.9	16.0	67.1
13-Apr	5	L	ND	22.5	8.1	14.4	63.8
13-Apr	5	L	ND	22.5	8.7	13.8	61.2
13-Apr	5	L	ND	23.8	7.2	16.6	69.8
13-Apr	5	L	ND	28.6	8.3	20.3	71.1
13-Apr	3	L	ND	26.6	5.5	21.0	79.2
13-Apr	3	L	ND	23.6	4.5	19.1	80.8
13-Apr	3	L	ND	25.8	4.5	21.3	82.7
13-Apr	3	L	ND	27.2	5.9	21.3	78.2
13-Apr	3	L	ND	25.7	5.7	20.1	78.0
25-Apr	13.5	L	ND	21.8	13.3	8.5	39.0
25-Apr	13.5	L	ND	15.0	9.7	5.3	35.6
25-Apr	13.5	L	ND	20.9	9.6	11.4	54.2
25-Apr	9	L	ND	21.0	11.3	9.7	46.1
25-Apr	9	L	ND	19.9	11.0	8.9	44.7
25-Apr	9	L	ND	20.5	9.8	10.7	52.2
25-Apr	7	L	ND	18.5	9.5	9.1	49.0
25-Apr	7	L	ND	18.3	10.8	7.5	40.9
25-Apr	7	L	ND	17.5	8.0	9.5	54.5
25-Apr	5	L	ND	22.8	8.6	14.2	62.4
25-Apr	5	L	ND	21.5	12.2	9.3	43.1
25-Apr	5	L	ND	21.7	6.9	14.8	68.3
25-Apr	3	L	ND	23.2	7.6	15.6	67.3
25-Apr	3	L	ND	22.3	7.8	14.5	65.2
25-Apr	3	L	ND	28.9	8.1	20.9	72.2
03-May	13.5	L	ND	22.7	13.4	9.3	41.0
03-May	13.5	L	ND	21.4	12.8	8.7	40.4
03-May	13.5	L	ND	29.2	15.8	13.5	46.1
03-May	9	L	ND	21.4	13.8	7.6	35.4
03-May	9	L	ND	28.9	15.4	13.5	46.6
03-May	9	L	ND	25.3	14.1	11.3	44.5
03-May	7	L	ND	22.5	13.3	9.2	41.0
03-May	7	L	ND	25.4	15.1	10.3	40.7
03-May	7	L	ND	27.2	13.8	13.5	49.4
03-May	5	L	ND	23.3	12.8	10.5	45.2
03-May	5	L	ND	27.0	12.8	14.2	52.6
03-May	5	L	ND	22.1	11.8	10.3	46.6
03-May	3	L	ND	25.8	8.1	17.6	68.5

DATE	OXYGEN TREATMENT	STAGE	WET WT.	DRY WT.	DRY WT. BODY	DRY WT. YOLK	YOLK
	(mg/l)		(mg)	(mg)	(mg)	(mg)	(%)
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

**Table 25. Wet and Dry Weights of Mountain Whitefish Eggs and Larvae Incubated as Eggs at Different Levels of Hypoxia.**

	Oxygen Treatment			Wet Wt. mean	Wet Wt. S.D.	Dry Wt. mean	Dry Wt. S.D.
Date	(mg/l)	N	Stage	(mg)	(mg)	(mg)	(mg)
11-Jan-94	13.5	20	Egg	31.6	6.5	ND	ND
11-Jan-94	9	20	Egg	31.0	4.2	ND	ND
11-Jan-94	5	20	Egg	32.0	4.9	ND	ND
11-Jan-94	7	20	Egg	29.9	2.7	ND	ND
11-Jan-94	3	19	Egg	30.1	4.1	ND	ND
18-Jan-94	7	6	Egg	30.5	0.5	4.5	0.1
18-Jan-94	5	6	Egg	30.7	0.8	4.4	0.1
18-Jan-94	3	6	Egg	31.5	0.6	4.8	0.1
21-Jan-94	13.5	3	Egg	30.9	0.9	4.5	0.1
21-Jan-94	9	3	Egg	29.9	0.7	4.4	0.2
21-Jan-94	7	3	Egg	30.4	0.3	4.4	0.1
21-Jan-94	5	3	Egg	30.4	1.0	4.5	0.1
21-Jan-94	3	3	Egg	30.6	0.6	4.5	0.1
11-Feb-94	13.5	30	Egg	30.2	2.5	ND	ND
11-Feb-94	9	30	Egg	29.9	2.1	ND	ND
11-Feb-94	7	30	Egg	29.2	2.6	ND	ND
11-Feb-94	5	30	Egg	30.6	3.3	ND	ND
11-Feb-94	3	30	Egg	29.4	3.0	ND	ND
17-Mar-94	13.5	12	Larvae	ND	ND	2.4	0.2
17-Mar-94	9	12	Larvae	ND	ND	2.4	0.2
17-Mar-94	7	12	Larvae	ND	ND	2.4	0.2
17-Mar-94	5	13	Larvae	ND	ND	2.5	0.2
24-Mar-94	3	95	Egg	29.6	3.6	ND	ND
28-Mar-94	7	12	Larvae	ND	ND	3.4	0.2
28-Mar-94	5	12	Larvae	ND	ND	3.2	0.1
06-Apr-94	9	20	Larvae	ND	ND	2.9	0.2
06-Apr-94	7	10	Larvae	ND	ND	2.6	0.2
08-Apr-94	13.5	26	Larvae	ND	ND	2.5	0.2
13-Apr-94	3	11	Egg	29.7	2.4	ND	ND
13-Apr-94	5	12	Egg	29.4	3.1	ND	ND
13-Apr-94	7	11	Egg	28	1.2	ND	ND
13-Apr-94	9	10	Egg	30.2	3.2	ND	ND
13-Apr-94	13.5	9	Egg	29.2	3.3	ND	ND
15-Apr-94	5	10	Larvae	ND	ND	2.7	0.2
18-Apr-94	9	9	Larvae	ND	ND	2.5	0.2
18-Apr-94	7	10	Larvae	ND	ND	2.4	0.3
19-Apr-94	5	10	Larvae	ND	ND	2.7	0.2
11-May-94	3 to 13.5	15	Larvae	ND	ND	2.5	0.3
11-May-94	3 to 9	15	Larvae	ND	ND	2.5	0.2
11-May-94	3 to 7	15	Larvae	ND	ND	2.6	0.2
12-May-94	3 to 13.5	16	Larvae	ND	ND	2.6	0.2
24-May-94	5 to 7	15	Larvae	ND	ND	2.6	0.2
25-May-94	3 to 9	15	Larvae	ND	ND	2.2	0.3
25-May-94	3	44	Larvae	ND	ND	2.5	0.3

**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.**

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((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

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((mm)
22-Dec-93	7	11	4.22	8.33	0.87	0.44
22-Dec-93	7	11	3.99	7.00	0.89	NM
22-Dec-93	7	11	4.11	8.05	NM	NM
22-Dec-93	9	9	4.21	8.63	1.07	NM
22-Dec-93	9	9	4.39	9.02	0.80	0.55
22-Dec-93	9	9	4.19	8.75	0.85	0.47
22-Dec-93	9	9	4.20	8.15	0.86	0.55
22-Dec-93	9	9	4.03	10.44	0.73	0.44
22-Dec-93	13.5	14	4.18	8.49	0.99	0.62
22-Dec-93	13.5	14	4.08	8.06	0.98	NM
22-Dec-93	13.5	14	3.94	8.81	NM	NM
22-Dec-93	13.5	14	4.33	10.52	1.00	0.48
22-Dec-93	13.5	14	3.99	6.22	0.84	NM
22-Dec-93	3	6	4.18	8.86	0.95	0.60
22-Dec-93	3	6	4.11	8.00	0.99	NM
22-Dec-93	3	6	3.82	8.57	NM	NM
22-Dec-93	3	6	4.29	10.42	0.99	0.48
22-Dec-93	3	6	3.96	5.92	0.89	NM
22-Dec-93	5	12	4.53	9.67	0.95	0.47
22-Dec-93	5	12	4.46	10.44	0.95	0.35
22-Dec-93	5	12	4.38	9.39	0.90	0.45
22-Dec-93	5	12	4.15	8.21	0.93	0.54
22-Dec-93	5	12	3.78	7.38	0.81	0.53
22-Dec-93	7	10	4.25	7.22	NM	NM
22-Dec-93	7	10	3.94	7.10	0.85	0.38
22-Dec-93	7	10	4.47	10.73	1.00	0.50
22-Dec-93	7	10	4.13	9.03	0.93	0.49
22-Dec-93	7	10	3.92	7.39	0.73	0.45
22-Dec-93	9	8	4.24	8.28	0.88	NM
22-Dec-93	9	8	4.11	7.81	0.96	0.57
22-Dec-93	9	8	4.47	11.47	1.02	NM
22-Dec-93	9	8	3.98	7.10	0.69	0.64
22-Dec-93	9	8	4.14	9.13	0.98	NM
12-Jan-94	13.5	1	4.25	8.94	0.90	NM
12-Jan-94	13.5	1	4.37	NM	1.07	0.46
12-Jan-94	13.5	1	4.28	8.37	1.12	NM
12-Jan-94	13.5	1	4.27	10.18	1.13	NM
12-Jan-94	13.5	1	3.77	7.10	NM	NM
12-Jan-94	13.5	1	4.14	8.17	0.99	0.44
12-Jan-94	13.5	1	3.90	7.33	1.04	0.51
12-Jan-94	13.5	1	4.20	7.92	1.08	NM
12-Jan-94	13.5	1	4.23	9.34	1.01	0.65
12-Jan-94	13.5	1	3.89	8.98	1.05	NM
12-Jan-94	5	3	4.10	11.19	1.14	NM
12-Jan-94	5	3	4.01	8.17	0.95	0.63
12-Jan-94	5	3	4.37	NM	NM	NM
12-Jan-94	5	3	4.13	9.86	0.79	0.62
12-Jan-94	5	3	3.92	9.69	1.07	0.61
12-Jan-94	5	3	4.17	9.79	1.04	NM
12-Jan-94	5	3	4.06	10.44	1.09	NM
12-Jan-94	5	3	3.98	10.18	1.03	NM

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((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

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((mm)
12-Jan-94	13.5	15	3.90	NM	NM	NM
12-Jan-94	3	7	4.15	9.82	0.91	0.55
12-Jan-94	3	7	4.37	9.75	NM	0.57
12-Jan-94	3	7	3.99	9.21	NM	NM
12-Jan-94	3	7	4.20	10.03	NM	NM
12-Jan-94	3	7	4.00	6.65	0.90	0.56
12-Jan-94	3	7	3.91	6.62	0.87	0.55
12-Jan-94	3	7	3.96	9.63	0.82	NM
12-Jan-94	3	7	4.08	NM	NM	NM
12-Jan-94	3	7	4.44	10.77	0.90	0.62
12-Jan-94	3	7	4.03	7.87	0.93	0.51
12-Jan-94	5	13	4.36	11.33	NM	NM
12-Jan-94	5	13	4.31	7.95	0.99	NM
12-Jan-94	5	13	4.67	9.06	1.05	NM
12-Jan-94	5	13	4.34	8.41	0.93	NM
12-Jan-94	5	13	4.30	8.03	1.06	NM
12-Jan-94	5	13	4.07	7.34	1.03	NM
12-Jan-94	5	13	4.13	6.83	1.04	NM
12-Jan-94	5	13	4.29	8.59	1.03	NM
12-Jan-94	5	13	4.16	8.44	NM	NM
12-Jan-94	5	13	4.22	8.73	1.05	NM
12-Jan-94	7	11	4.67	11.57	1.06	NM
12-Jan-94	7	11	4.27	8.89	1.02	0.68
12-Jan-94	7	11	4.15	10.01	1.03	0.65
12-Jan-94	7	11	4.08	8.43	0.93	0.63
12-Jan-94	7	11	3.98	7.47	NM	NM
12-Jan-94	7	11	3.97	8.25	NM	NM
12-Jan-94	7	11	4.08	9.73	1.04	NM
12-Jan-94	7	11	4.38	11.38	1.02	0.67
12-Jan-94	7	11	4.02	7.69	NM	NM
12-Jan-94	9	9	4.20	8.46	0.87	NM
12-Jan-94	9	9	4.16	8.33	1.07	NM
12-Jan-94	9	9	4.33	8.21	1.07	0.66
12-Jan-94	9	9	4.31	8.80	1.10	NM
12-Jan-94	9	9	4.53	7.02	NM	NM
12-Jan-94	9	9	4.10	7.37	1.10	NM
12-Jan-94	9	9	3.93	9.27	1.02	NM
12-Jan-94	9	9	4.16	9.46	0.98	NM
12-Jan-94	9	9	3.98	7.91	NM	NM
12-Jan-94	9	9	4.11	8.63	NM	NM
12-Jan-94	13.5	14	4.37	9.37	NM	NM
12-Jan-94	13.5	14	4.35	NM	NM	NM
12-Jan-94	13.5	14	4.35	7.50	0.99	NM
12-Jan-94	13.5	14	4.41	10.74	1.06	0.71
12-Jan-94	13.5	14	4.11	6.02	1.03	NM
12-Jan-94	13.5	14	4.07	6.21	0.98	0.67
12-Jan-94	13.5	14	4.32	6.25	NM	0.57
12-Jan-94	13.5	14	4.15	8.14	1.15	NM
12-Jan-94	13.5	14	4.10	7.73	1.02	NM
12-Jan-94	13.5	14	4.36	9.27	NM	NM
12-Jan-94	3	6	4.36	10.38	0.92	NM

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((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

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((mm)
03-Feb-94	3	5	4.59	8.71	0.93	0.55
03-Feb-94	3	5	4.72	10.84	0.93	0.59
03-Feb-94	3	5	4.30	8.60	1.10	0.31
03-Feb-94	3	5	4.49	9.45	0.82	0.52
03-Feb-94	3	5	4.27	5.61	0.89	NM
03-Feb-94	5	3	4.32	5.84	1.02	NM
03-Feb-94	5	3	4.12	3.67	0.98	NM
03-Feb-94	5	3	4.14	8.71	1.16	0.26
03-Feb-94	5	3	4.09	3.26	1.04	0.71
03-Feb-94	5	3	4.21	4.03	0.92	0.55
03-Feb-94	5	3	4.48	7.28	1.19	0.55
03-Feb-94	5	3	4.31	4.93	1.03	0.71
03-Feb-94	5	3	4.26	8.54	1.24	NM
03-Feb-94	5	3	4.17	6.17	1.03	0.73
03-Feb-94	5	3	4.74	7.64	1.02	0.58
03-Feb-94	9	2	4.01	3.17	NM	NM
03-Feb-94	9	2	4.28	2.76	1.04	0.44
03-Feb-94	9	2	3.94	3.05	1.09	NM
03-Feb-94	9	2	3.99	3.72	NM	NM
03-Feb-94	9	2	3.79	3.33	1.01	0.50
03-Feb-94	9	2	3.74	4.01	NM	NM
03-Feb-94	9	2	3.87	3.99	0.96	0.52
03-Feb-94	9	2	3.94	2.55	NM	NM
03-Feb-94	9	2	3.87	3.66	1.00	NM
03-Feb-94	9	2	3.87	4.60	1.02	NM
03-Feb-94	13.5	15	4.10	3.84	NM	0.58
03-Feb-94	13.5	15	3.89	4.60	1.11	0.63
03-Feb-94	13.5	15	4.12	3.00	NM	NM
03-Feb-94	13.5	15	4.04	3.59	NM	NM
03-Feb-94	13.5	15	3.82	2.83	1.08	NM
03-Feb-94	13.5	15	3.76	3.86	0.93	0.45
03-Feb-94	13.5	15	3.89	3.91	0.98	NM
03-Feb-94	13.5	15	4.03	1.08	0.62	NM
03-Feb-94	13.5	15	3.81	3.15	1.02	NM
03-Feb-94	13.5	15	3.81	NM	1.13	NM
03-Feb-94	3	7	3.78	5.42	0.90	0.54
03-Feb-94	3	7	3.65	4.18	NM	NM
03-Feb-94	3	7	3.74	4.13	NM	NM
03-Feb-94	3	7	4.07	5.13	NM	NM
03-Feb-94	3	7	3.82	4.90	NM	NM
03-Feb-94	3	7	3.84	5.06	NM	NM
03-Feb-94	3	7	3.91	3.20	NM	NM
03-Feb-94	3	7	3.84	3.89	NM	NM
03-Feb-94	3	7	3.66	4.50	NM	NM
03-Feb-94	3	7	3.75	5.74	NM	NM
03-Feb-94	5	13	3.89	4.07	NM	NM
03-Feb-94	5	13	4.04	3.26	0.92	NM
03-Feb-94	5	13	3.77	3.99	1.05	NM
03-Feb-94	5	13	3.89	4.26	NM	NM
03-Feb-94	5	13	3.77	4.28	NM	NM
03-Feb-94	5	13	4.21	5.40	NM	NM

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((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

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((mm))
03-Feb-94	7	10	4.21	5.46	NM	NM
03-Feb-94	7	10	4.01	3.65	1.19	0.44
03-Feb-94	7	10	3.86	3.59	NM	NM
03-Feb-94	9	8	3.91	NM	NM	NM
03-Feb-94	9	8	3.79	4.54	0.88	0.60
03-Feb-94	9	8	3.82	3.30	1.04	0.57
03-Feb-94	9	8	4.01	4.24	1.04	NM
03-Feb-94	9	8	3.72	4.85	NM	NM
03-Feb-94	9	8	3.71	5.11	1.05	0.60
03-Feb-94	9	8	3.60	3.17	NM	NM
03-Feb-94	9	8	3.82	3.91	NM	NM
03-Feb-94	9	8	3.75	3.76	1.17	0.66
03-Feb-94	9	8	3.77	4.46	NM	NM
23-Mar-94	13.5	1	3.98	NM	NM	NM
23-Mar-94	13.5	1	3.83	2.15	NM	NM
23-Mar-94	13.5	1	3.83	4.74	1.14	0.60
23-Mar-94	13.5	1	3.85	1.88	NM	NM
23-Mar-94	13.5	1	3.90	NM	1.16	NM
23-Mar-94	13.5	1	3.67	2.03	1.12	NM
23-Mar-94	13.5	1	4.03	5.52	NM	NM
23-Mar-94	13.5	1	4.18	1.95	NM	NM
23-Mar-94	13.5	1	3.96	3.87	NM	NM
23-Mar-94	13.5	1	3.81	2.78	NM	NM
23-Mar-94	3	5	3.93	8.68	0.91	0.56
23-Mar-94	3	5	3.88	8.54	0.93	0.57
23-Mar-94	3	5	3.63	5.74	0.96	0.58
23-Mar-94	3	5	4.09	9.53	0.96	0.51
23-Mar-94	3	5	3.74	6.01	0.83	0.46
23-Mar-94	3	5	3.83	4.50	1.00	NM
23-Mar-94	3	5	3.67	5.91	0.92	NM
23-Mar-94	3	5	3.48	3.67	0.88	0.65
23-Mar-94	3	5	3.62	7.38	0.93	0.48
23-Mar-94	3	5	3.52	8.20	0.94	0.54
23-Mar-94	5	3	3.95	3.55	NM	NM
23-Mar-94	5	3	4.07	3.80	NM	1.06
23-Mar-94	5	3	3.80	NM	1.06	NM
23-Mar-94	5	3	3.77	NM	1.10	0.66
23-Mar-94	5	3	3.95	3.55	NM	NM
23-Mar-94	5	3	3.77	2.21	0.92	NM
23-Mar-94	5	3	3.76	2.60	1.13	NM
23-Mar-94	5	3	3.67	3.05	NM	NM
23-Mar-94	5	3	3.95	4.86	1.15	0.69
23-Mar-94	5	3	4.19	3.21	NM	NM
23-Mar-94	5	3	3.57	2.75	NM	NM
23-Mar-94	7	4	4.00	1.94	NM	NM
23-Mar-94	7	4	4.11	NM	1.09	0.72
23-Mar-94	7	4	3.86	NM	1.12	0.60
23-Mar-94	7	4	3.63	2.49	NM	NM
23-Mar-94	7	4	4.15	2.69	1.19	NM
23-Mar-94	7	4	4.05	2.15	1.08	NM
23-Mar-94	7	4	3.75	4.45	1.13	0.60

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((mm)
23-Mar-94	7	4	3.72	3.98	1.08	0.60
23-Mar-94	7	4	3.72	2.98	1.11	0.54
23-Mar-94	9	2	3.90	2.03	NM	NM
23-Mar-94	9	2	3.76	2.48	NM	NM
23-Mar-94	9	2	3.91	NM	1.12	NM
23-Mar-94	9	2	4.01	1.48	1.18	0.65
23-Mar-94	9	2	3.73	2.36	NM	NM
23-Mar-94	9	2	4.08	1.78	NM	NM
23-Mar-94	9	2	3.31	1.59	NM	NM
23-Mar-94	9	2	3.99	1.96	1.30	NM
23-Mar-94	9	2	3.64	1.68	1.18	0.50
23-Mar-94	13.5	15	3.67	1.87	NM	NM
23-Mar-94	13.5	15	3.79	0.99	1.17	0.65
23-Mar-94	13.5	15	3.88	1.70	NM	NM
23-Mar-94	13.5	15	3.99	1.85	NM	NM
23-Mar-94	13.5	15	3.96	1.84	NM	NM
23-Mar-94	13.5	15	3.80	1.65	NM	NM
23-Mar-94	13.5	15	3.81	1.51	NM	NM
23-Mar-94	13.5	15	3.85	1.90	NM	NM
23-Mar-94	13.5	15	3.54	2.67	1.01	0.66
23-Mar-94	13.5	15	3.78	NM	1.00	0.53
23-Mar-94	3	7	4.52	5.05	1.50	NM
23-Mar-94	3	7	4.45	5.16	NM	NM
23-Mar-94	3	7	3.91	5.09	0.84	0.49
23-Mar-94	3	7	4.20	5.62	0.86	0.42
23-Mar-94	3	7	3.77	3.30	0.86	0.29
23-Mar-94	3	7	3.77	3.73	NM	NM
23-Mar-94	3	7	3.93	4.27	NM	NM
23-Mar-94	3	7	4.00	3.17	NM	NM
23-Mar-94	3	7	4.24	5.03	NM	NM
23-Mar-94	3	7	4.16	5.55	0.99	0.57
23-Mar-94	5	13	4.01	2.50	NM	NM
23-Mar-94	5	13	3.88	2.63	NM	NM
23-Mar-94	5	13	4.04	2.55	NM	NM
23-Mar-94	5	13	4.22	3.67	NM	NM
23-Mar-94	5	13	3.91	2.89	NM	NM
23-Mar-94	5	13	3.88	2.69	NM	NM
23-Mar-94	5	13	3.79	3.88	NM	NM
23-Mar-94	5	13	4.23	2.88	1.16	0.60
23-Mar-94	5	13	3.96	2.24	1.13	0.52
23-Mar-94	5	13	3.94	4.83	0.95	0.42
23-Mar-94	7	11	3.99	3.51	1.03	0.69
23-Mar-94	7	11	4.03	2.37	1.12	0.69
23-Mar-94	7	11	3.92	1.54	1.18	0.61
23-Mar-94	7	11	3.93	3.29	1.08	0.51
23-Mar-94	7	11	3.74	2.20	NM	NM
23-Mar-94	7	11	3.86	2.51	1.04	0.33
23-Mar-94	7	11	3.86	2.61	NM	NM
23-Mar-94	7	11	3.96	3.14	1.04	0.44
23-Mar-94	7	11	3.76	2.49	0.90	0.65
23-Mar-94	7	11	3.87	3.92	1.12	0.35

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((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

	Oxygen Treatment		Egg Diameter	Yolk Area	Eye Length	Interorbital Distance
Date	(mg/l)	Tank	(mm)	(mm <sup>2</sup> )	(mm)	((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

- 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.