Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: Year 3 of 3

Submitted to:
Colville Confederated Tribes

Submitted by:
Okanagan Nation Fisheries Commission

May 2003

Okanagan Nation Alliance
3255 C Shannon Lake Road,
Westbank, BC V4T 1V4
Phone: (250) 707-0095 Fax: (250) 707-0166

PREFACE

The Okanagan Nation Alliance in Canada and Colville Confederated Tribes in the U.S. have proposed re-introducing sockeye salmon to their historic range (Figure 1). The purpose of this project has been to assess the risks and benefits of an experimental sockeye re-introduction into Skaha Lake, by completing the following six objectives over three years:

1. Disease risk assessment;
2. Exotic fish risk assessment;
3. Inventory of sockeye salmon habitat and opportunities for habitat enhancement;
4. Development of a life-cycle model of sockeye, including interaction with resident kokanee;
5. Development of an experimental design and;
6. Finalization of a plan for re-introduction of sockeye salmon into Skaha Lake and associated monitoring programs.

The following compilation of reports includes the third year of assessments for Objectives 1 – 3, the model design document for Objective 4, experimental design strategies for Objective 5 and a 2000 - 2003 project summary for Objective 6. For a full list of reports completed over the three years of the project, please refer to Table 1.

The actual re-introduction and monitoring plan is currently being developed based upon options and strategies identified during the Year 3 analyses review workshop in March 2003. The information contained in this plan, as well as the information gathered from the re-introduction itself, will support future decisions on protection and restoration strategies for the Okanagan River sockeye stock.

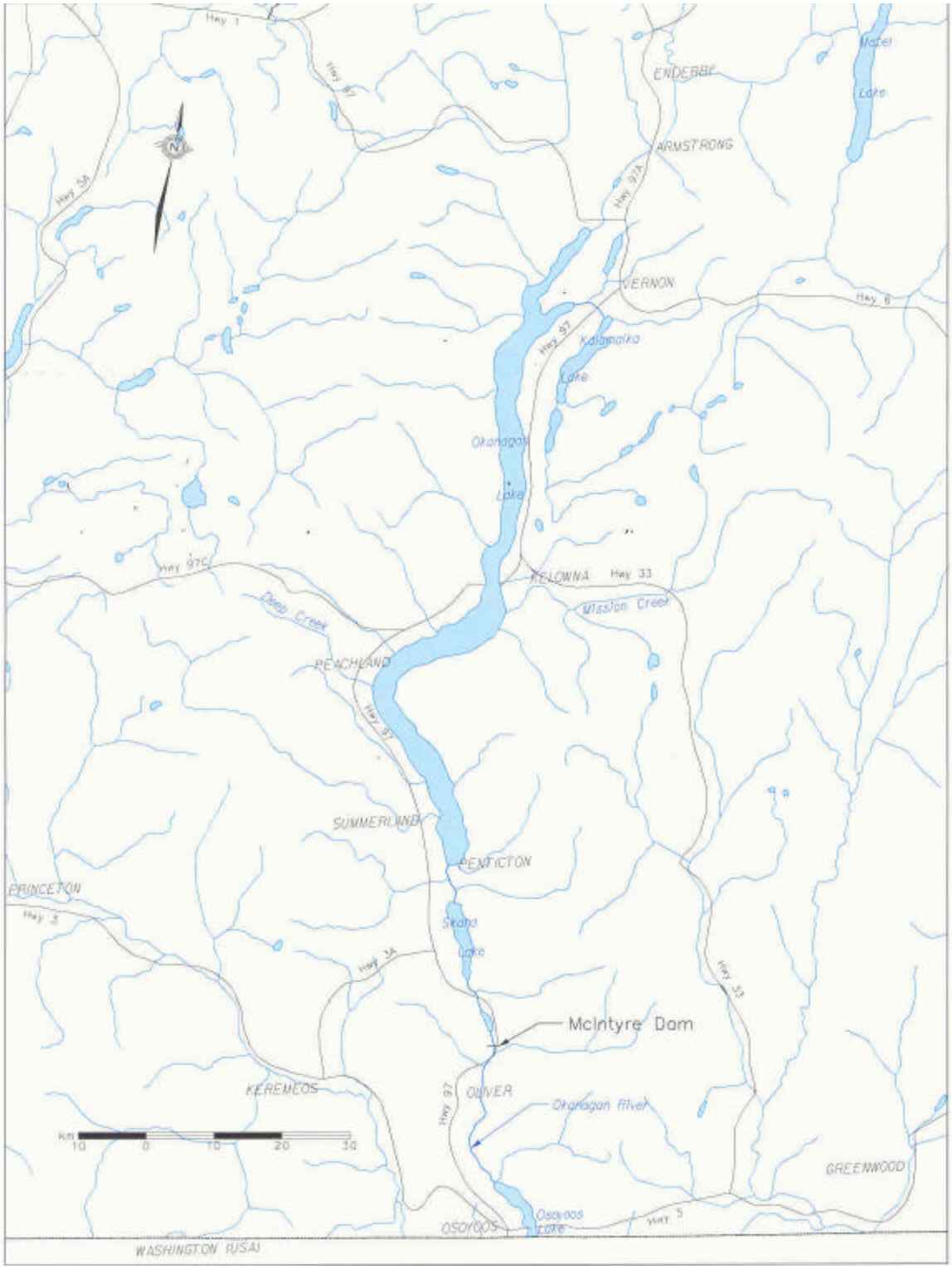


Figure 1. Overview of the Canadian Okanagan Basin

Table 1. A list of Project objectives, tasks and reports.

OBJECTIVE	TASKS	REPORTS / STATUS
1 Disease Risk Assessment	**A** – sample collection, diagnostic test, data entry, data analysis **B** - evaluate risk for developing disease or potential for introduced infectious agents **C** – Assess whether re-introduced sockeye interact with resident fish	*Disease Risk Assessment* Year 1, Year 2 and Year 3
2 Exotic Fish Risk Assessment	**A** –Review fish inventory information	➢ *Review available fish inventory information in the Okanagan River system below Skaha Lake, and in Skaha and the southern portion of Okanagan Lake* and ➢ *Interaction of kokanee and rainbow trout with exotic species*
	B- Inventory exotic fish species and habitat	*Exotic Fish Species Risk Assessment* Year 1, Year 2 and Year 3
	B1 – sample predator community in the Zosel Dam tailrace	*Results of sockeye smolt predator sampling in the forebay and tailrace of Zosel Dam* Year 2 and Year 3
	C- Complete literature review of habitat requirements for exotic species of concern	➢ *Habitat requirements for exotic species identified as being present in the Okanagan system below Skaha Lake but not in Skaha or Okanagan Lake* ➢ *Literature review of habitat requirements for exotic species of concern (bluegill)* ➢ *Historical habitat of salmon of the Okanagan River* ➢ *North American Lakes where kokanee, rainbow trout and sockeye occur with exotic species* ➢ *Leaping abilities of exotic species of concern* ➢ *Movement and colonization of walleye* ➢ *Consumption of incubating salmon eggs by black bullheads (Ameriurus melas)*
	D – Assess availability of suitable habitat requirements for exotic species and likelihood of these species becoming established in Skaha Lake **E**- Compile information from Tasks A to D	*Exotic Fish Species Risk Assessment* Year 1, Year 2 and Year 3

3 Inventory sockeye habitat and identify opportunities for enhancement	**A** - Review literature for evidence of beach or stream spawning plasticity in sockeye salmon	*Evidence of beach-stream spawning plasticity in sockeye salmon populations and to determine attributes of sockeye spawning and incubation habitat*
	B –Identify potential spawning habitat in the study area	*Sockeye Salmon Habitat Assessment* Year 1 and Year 2
	C – Identify opportunities for sockeye habitat enhancement and development	- *Discussion of spawning areas enhancement and opportunities* - *Okanagan River (Reach A and B) spawning area restoration feasibility*
	D – Assess potential rearing conditions in Vaseux, Skaha and Okanagan Lakes	*Assessment of juvenile Oncorhynchus nerka (sockeye and kokanee) rearing conditions of Skaha and Osoyoos Lakes* Year 2 and Year 3
4 Develop life-cycle Model of Okanagan	**A** – Review literature on life-cycle of Okanagan Salmonids **B** - Design document of model **C** – Review model structure & assumptions **D** – Model development **E** – Develop user interface **F** – Document	*Ok Sockeye: A simple life-cycle model of Okanagan Basin sockeye salmon Version 2.2 Design Document and User's Guide*
5 Development of an experimental design	**A –** Multi-agency workshop to review existing information **B** – survey /compile baseline data to test hypotheses **C** – design alternative implementation designs and monitoring programs to collect data **D** – Test alternative designs and monitoring programs in context of entire life-cycle using life-cycle model	*Evaluate Alternative Experimental Strategies for Reintroducing Sockeye Salmon to Skaha Lake*
6 Finalize plan for experimental re-introduction of sockeye salmon into Skaha Lake and associated monitoring programs	**A –** Multi-agency workshop to: review results of Objective 1-5 and develop experimental management plan; develop workplan for obtaining necessary approvals and additional funding	*An evaluation of a proposed experimental reintroduction of sockeye salmon into Skaha Lake: Project summary 2000-2003*
	B – Obtain necessary funding/approval for implementation of plan	In progress
	C – Multi-agency workshop to review progress on obtaining approval/funding; finalize plans for experimental re-introduction	In progress

Acknowledgements

The Okanagan Nation Alliance would like to thank a number of organizations and individuals who have made valuable contributions to various aspects this project and our work over the past three years. We truly could not have done it without you!

Thank you to the Bonneville Power Administration for providing funding for this project. This has been an important contribution towards securing the future of Okanagan sockeye.

To the Colville Confederated Tribes, especially Joe Peone, Chris Fisher, Monte Miller and Cindy McCartney – thank you for working with us to honour the spirit of the salmon and the knowledge of our ancestors.

Thank you to the Canadian Okanagan Basin Technical Working Group representatives for providing valuable input and guidance into the design and review of the project.

For all of the technical support and assistance we have received from the following individuals, we thank you for the knowledge and insights that you have shared with us:

> Fisheries and Oceans Canada Staff: Dr. Kim Hyatt, Paul Rankin, Elmer Fast, Dave Smith, Garth Traxler, John Richard, and Barry Hanslit.
>
> Ministry of Water Land and Air Protection Staff: Steve Matthews, Vic Jensen, Andrew Wilson, Sally Goldes, Sherri Guest, and Tina McCann.
>
> Independent Contractors: Chris Bull, Dr. Trevor Evelyn, Dave Marmorek with Calvin Peters and Ian Parnell (ESSA Technologies), Dr. Larry Hammell, Carol Cooper and Al Hirst (AMC Labs), Dr. Robert Newbury, Howard Smith, Brent Phillips (Summit Environmental Consultants), Mark Siemens and Klaus Wolff (Summerland Hatchery), Lee Granberg, Jason Webster, and Dave Cassidy.

And, saving the best for last, to all of the Okanagan Nation Alliance Fisheries Department Staff who have been involved with this project and who worked tirelessly, and with good humour, in fair and foul weather to collect the data, complete the reports and attend a LOT of project meetings, you have our heartfelt gratitude: (in alphabetical order) Dion Alex, Herb Alex, Fabian Alexis, Neil "Nibs" Baptiste, Stacey Bonneau, Shayla Lawrence, Kalum Lezzard, Byron Louis, Keith "Yogi" Louis, Kari Long, Dawn Machin, Deana Machin, Alfred Snow, Bob Swite, Adrienne Vedan, Howie Wright, and the 2001 "E-Team".

2003 Contributions to
An Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: Year 3 of 3

1. Disease Risk Assessment
2. Exotic Fish Species Risk Assessment
3. Results of Sockeye Fry Predator Sampling in Osoyoos Lake
4. Results of Sockeye Smolt Predator Sampling in the Forebay and Tailrace of Zosel Dam
5. Okanagan River (Reach A and B) Spawning Area Restoration Feasibility
6. Assessment of Juvenile *Oncorhynchus nerka* (Sockeye and Kokanee) Rearing Conditions of Skaha and Osoyoos Lakes 2002
7. Historical Habitat of Salmon of The Okanagan River
8. North American Lakes Where Kokanee, Rainbow Trout and Sockeye Occur with Exotic Species
9. Leaping Abilities of Exotic Species of Concern
10. Movement and Colonization of Walleye
11. Consumption of Incubating Salmon Eggs by Black Bullheads
12. OkSockeye: A Simple Lifecycle Model of Okanagan Basin Sockeye Salmon Version 2.2: Design Document
13. Evaluate Alternative Experimental Strategies for Re-Introducing Sockeye Salmon to Skaha Lake
14. An Evaluation of a Proposed Experimental Re-Introduction of Sockeye Salmon into Skaha Lake: Project Summary 2000-2003

GLENFIR RESOURCES

May 26, 2003.

Deana Machin,
Okanagan Nation Alliance Fisheries Department,
3255 C Shannon Lake Road,
Westbank, B.C.
V4T 1V4

Dear Ms. Machin:

Re: R.P. Bio Review of an Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3

I have completed my review of the reports (as listed below) and will sign them off.

The reports that I have found technically acceptable include:

- Objective 1 – *Disease Risk Assessment*
- Objective 2 – *Exotic Fish Risk Assessment*
  - Task B1 – Fry and smolt predator sampling
    - *Results of sockeye fry predator sampling in Osoyoos Lake*
    - *Results of sockeye smolt predator sampling in the forebay and tailrace of Zosel Dam 2002*
  - Task C – Literature Reviews
    - *Historical habitat of salmon of the Okanagan River*
    - *North American Lakes where kokanee, rainbow trout and sockeye occur with exotic species*
    - *Leaping abilities of exotic species of concern*
    - *Movement and colonization of walleye*
    - *Consumption of incubating salmon eggs by black bullheads (Ameriurus melas)*
- Objective 3 Task C – *Okanagan River (Reach A) Spawning Area Restoration Feasibility*
- Objective 3 Task D – *Assessment of juvenile Onchorhynchus nerka (sockeye and kokanee) rearing conditions of Skaha and Osoyoos Lakes 2002*

Sincerely,

Chris Bull
R.P. Bio

ASSOCIATION OF PROFESSIONAL BIOLOGISTS OF B.C.
Christopher J. Bull
R.P. Bio
#105
APB

Chris Bull, BSc MSc RPBio
RR#1 Site 16 Comp 10, Naramata, B.C., Canada. V0H 1N0
Phone (250) 496-4059 Fax (250) 496-5235 Email: cbull@vip.net

FINAL

OBJECTIVE 1
Disease Risk Assessment

Contribution No. *1* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Authors: Trevor Evelyn
Shayla Lawrence, BSc

Reviewed by: Chris Bull, R.P. Bio

Edited by: Trevor Evelyn

EXECUTIVE SUMMARY

The Okanagan Nation and tribes in the U.S. have proposed re-introducing sockeye salmon into Okanagan Lake. To investigate the risks involved, a multi-agency workshop recommended an experimental re-introduction into Skaha Lake. Risks might include competition between sockeye and kokanee, the introduction of exotic species, and the introduction of new diseases. This report summarizes the findings from the third year of a three-year disease risk assessment.

The first task was to compare the disease and infection status of fish above and below McIntyre Dam (the present limit of sockeye migration). Additional tasks included determining if lake conditions would contribute disease risks and assessing whether re-introduced fish were likely to interact with resident fish or extend the range of pathogens.

The disease agents of particular concern are:

- infectious pancreatic necrosis virus (IPNV),
- infectious haematopoietic necrosis virus type 2 (IHNV type2),
- erythrocytic inclusion body syndrome virus (EIBSV),
- the whirling disease agent (*Myxobolus cerebralis*), and
- the ceratomyxosis agent (*Ceratomyxa shasta*).

The Okanagan Nation Fisheries Commission was responsible for collecting fish from above and below McIntyre Dam, and, in year 2002, the number of fish collected surpassed the target of 720 fish from each area, although below the Dam, there was a shortfall of 11 fish in the non-salmonid fish sample. A wide variety of species was captured including sockeye, kokanee, whitefish and 11 species of non-salmonids.

Provincial and federal fish health laboratories performed the laboratory analyses. All of the virus isolates obtained appeared to be IHNV type I. However, IHNV type I is not a concern because it is already found above McIntyre Dam.

There was no indication of IPNV in any of the samples tested. Sampling for the erythrocytic inclusion body syndrome (EIBS), indicative of the presence of the EIBS virus, was not done this year because sampling for it in years 2000 and 2001 showed it to be widely distributed in fish above and below McIntyre Dam.

All adult sockeye samples tested in 2002 again proved negative for the whirling disease agent (*Myxobolus cerebralis*) and the ceratomyxosis agent (*Ceratomyxa shasta*). Live box exposures in 2002 of sentinel rainbow trout susceptible to these agents were conducted in spring but the results are not yet available. However, results from the fall 2001 exposures are now available. They failed to detect *M. cerebralis* above and below the Dam but detected *C. shasta* at one site below the Dam. Results for *C. shasta* testing in kokanee and whitefish collected in 2000 and 2001 above and below the Dam were delayed by an equipment failure but are now available. They proved negative for *M. cerebralis* but they detected *C. shasta* in kokanee above the Dam in 2000. Results of the 2002 exposures plus those of an additional live box test planned for the spring of 2003 will be presented in an addendum to this report later in 2003. (The planned live box test in 2003 was necessitated when the fall 2002 test proved impractical because of the unavailability of suitable sentinel test fish). Taken together, results for the myxosporidian

parasites to date suggest that *C. shasta* occurs both below and above the Dam but that *M. cerebralis* does not occur in either of these areas.

Samples of sockeye spawners, collected in 2001 and 2002 in the Okanagan River below McIntyre Dam as part of an unrelated study, proved positive for a myxosporidian parasite, *Parvicapsula minibicornis.* This parasite was not included in the list of "disease agents of particular concern" because it has only recently given cause for concern (it recently caused significant pre-spawning mortalities in sockeye in the Fraser River). Whether the parasite also occurs in fish above McIntyre Dam is unkown, but its presence in sockeye below the Dam, taken together with its pathogenicity potential, will have to be considered when making a decision on whether to proceed with the introduction of sockeye into Skaha Lake. Actions to be taken as a result of the *P. minibicornis* finding are discussed.

Limnological data for Okanagan and Skaha Lakes in 2002 revealed no extraordinary risk of predisposing fish to disease. Both lakes become stratified with a warm epilimnion and a cooler hypolimnion in summer followed by an overturn. Thus salmonids should be able to reside in non-stressful oxygen and temperature conditions all year long. However, Skaha Lake, which is much smaller and shallower than Okanagan Lake, may be slightly stressful to salmonids in very warm years.

Kokanee in Okanagan and Skaha Lakes have declined drastically due to reduced nutrient input and the introduction of mysids which compete with kokanee for zooplankton. There is some speculation that sockeye would add to the competition and could adversely affect the health of kokanee because starving fish are less likely to be robust and disease resistant. However, the decomposing carcasses of the spent sockeye would provide nutrients from the sea which may mitigate any negative effects.

Sockeye progeny will likely have eco-niche requirements and behaviour patterns similar to those of kokanee. Thus cross infections are possible. Cross infections may also be possible between salmonids and non-salmonids. However the important question is whether any new pathogens are likely to be introduced. The present pathogen survey is intended to provide answers to this important question but some additional testing and/or studies may be required to deal with the recent finding of *P. minibicornis* in sockeye below the Dam.

ACKNOWLEDGEMENTS

There has been a great number of individuals involved in this project that have made it successful, and the Okanagan Nation Fisheries Commission would like to thank the following people:

Dr. Trevor Evelyn for his continued support through the field season and reviewing and analyzing the vast amounts of data from the laboratories and for his expert editorial help.

Sherry Guest and Tina McCann of the Ministry of Water, Land, and Air Protection Laboratory for working so very hard at processing our samples and re-arranging their schedules to fit our hundreds of fish in.

Garth Traxler and Jon Richard, for processing the sockeye spawners and counting a couple thousand eggs to help out. The photos Garth took are wonderful.

Chris Fisher and Monte Miller of the Colville Confederated Tribes for use of the electrofishing boat to collect our non-salmonids and for making extra trips to come up and complete a session when the weather was not cooperating, ensuring that we always got the fish we needed.

Lee Granberg, Steve Matthews and David Cassidy for their considerable help and cooperation in getting our two-month old kokanee fry for which they do an excellent job of otherwise avoiding.

Chris Bull for his guidance and words of wisdom throughout the project.

And finally, the Staff at the Summerland Hatchery – Mark Siemans, Klaus Wolff and Chantel Weston -- for helping in the field and laboratory, and for making the process go smoothly and efficiently.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
ACKNOWLEDGEMENTS iii
TABLE OF CONTENTS iv
LIST OF FIGURES AND TABLES v
LIST OF PHOTOS v

1.0 INTRODUCTION 1
1.1 Project Background 1
1.2 Project Area 1
1.3 Project Objectives 3

2.0 METHODS 3
2.1 Field Sampling Methods 5
2.2 Live box testing for Myxobolus cerebralis and Ceratomyxa shasta 6
2.3 Laboratory methods used by Fisheries and Oceans Canada 8
2.3.1 Virology 8
2.3.2 Parasitology 8
2.4 Laboratory methods used by the Ministry of Water, Land and Air Protection 9
2.4.1 Virology 9
2.4.2 Parasitology 9

3.0 RESULTS 10
3.1 Whirling disease live box exposures 10
3.2 Fisheries and Oceans Canada laboratory results 12
3.3 Ministry of Water, Land and Air Protection laboratory results 12

4.0 DISCUSSION OF RESULTS 12
4.1 Pathogen Survey 12
4.2 Effect of Water Quality on Pathogens 15
4.3 Risk to Resident Fish 16

5.0 CONCLUSION 17

6.0 REFERENCES 18

APPENDIX A Whirling disease Results Fall 2001
APPENDIX B Whirling disease exposure daily temperature data and site photos Spring 2002
APPENDIX C Fisheries and Oceans Canada laboratory results
APPENDIX D Ministry of Water, Land and Air Protection laboratory results
APPENDIX E Findings from Year 2002 pathogen survey and summary data tables for years 2000, 2001, and 2002

LIST OF FIGURES AND TABLES

Figure 1. Overview of areas sampled and type of fish targeted 2
Figure 2. Whirling disease live-box exposure sites 7

Table 1. Disease risk assessment sampling plan 2002 4
Table 2. Disease risk summary of sampling results.....11

LIST OF PHOTOS

Photo 1. Processing of sockeye spawners with DFO.....5
Photo 2. Collection of kokanee fry with MoWLAP 5
Photo 3. WD7 site.....7
Photo 4. WD5 site.....7
Photo 5. WD3 site.....7
Photo 6. WD1 site.....7

1.0 INTRODUCTION

1.1 Project Background

The Okanagan Nation Fisheries Commission (ONFC) has been investigating the risks involved in re-introducing sockeye salmon into Skaha Lake. This report summarizes the findings from YEAR 3 of 3 of the disease risk assessment.

The disease risk assessment compares disease infection status of salmonids and non-salmonids above and below McIntyre Dam. The disease agents identified that are of concern and examined this year are:

- infectious pancreatic necrosis virus (IPNV),
- infectious haematopoietic necrosis virus, type 2 (IHNV, type 2),
- the whirling disease agent (*Myxobolus cerebralis*), and
- the ceratomyxosis agent (*Ceratomyxa shasta*)

The salmonid samples consisted of kokanee and some whitefish above McIntyre Dam and sockeye and some whitefish below McIntyre Dam. The non-salmonids were also collected both above and below the dam and consisted of as many species as possible. Salmonids were tested for all of the above disease agents except for kokanee and whitefish which were not tested for *M. cerebralis*. The whirling disease agent was specifically tested for by exposing susceptible rainbow trout, held in live-boxes, to suspect water. These rainbow trout were also tested for *C. shasta*. The non-salmonids collected above and below the Dam were tested only for IPNV and IHNV.

1.2 Project Area

As in the previous two years, samples were taken above and below McIntyre Dam within the Okanagan Basin, specifically from Okanagan Lake to Osoyoos Lake to determine if the fish below the dam are carrying infectious agents not present in fish above the dam. Figure 1 shows the sampling locations and indicates the type and life stage of the fish targeted.

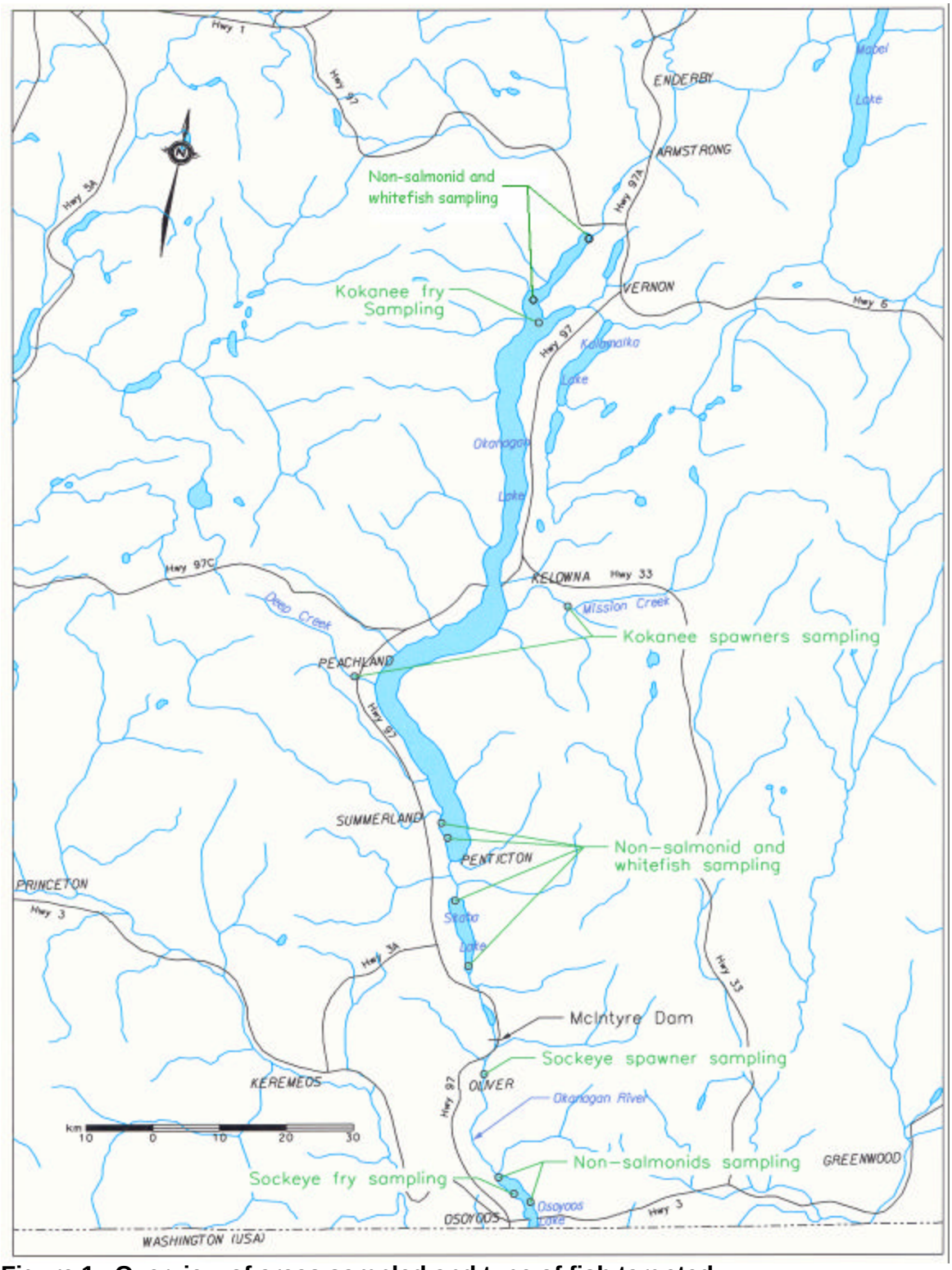


Figure 1. Overview of areas sampled and type of fish targeted

1.3 Project Objectives

The project objectives are outlined below:

1. Compare the disease and infection status of fish above and below the dam,
2. Determine if there are environmental conditions specific to the lakes in question that would either put fish at extraordinary risk for developing disease or that would maintain introduced infectious agents, and
3. Assess the opportunity for re-introduced fish to interact with susceptible resident fish or to extend the distribution of important pathogens.
4. It was requested at the sampling review meeting in YEAR 2 (March 1st, 2002) that an extra 60 non-salmonid fish be collected below the dam

2.0 METHODS

Sampling protocol was originally designed by Dr. Larry Hammel and Dr. Trevor Evelyn and was modified, as deemed appropriate, at the end of every sampling year at a multi-agency workshop hosted by the ONFC and the Colville Confederated Tribes (CCT). Field sampling was conducted by the ONFC and laboratory analyses were carried out by the BC MoWLAP for non-anadromous fish and by DFO for anadromous fish.

A review meeting was held on March 1st, 2002 and it was decided that sampling for YEAR 3 duplicate YEAR 2 with the following exceptions:

- discontinue blood smear collection and examinations (i.e.,sampling for Erythrocytic Inclusion Body Syndrome Virus (EIBSV)). The reason: EIBSV was shown in 2001 and 2002 to be widely distributed in fish both above and below the dam.

- collect an additional 60 non-salmonids below McIntyre Dam. The reason: to make up for a shortfall in the numbers of non-salmonids sampled below the dam in the years prior to 2002.

The collection of at least 720 fish from above the McIntyre Dam sampling region was duplicated from YEAR 2. The collection of at least 780 fish from below the dam sampling region was completed. Of the 720 fish from above the dam 360 were to be salmonids at various life stages and 360 were to be non-salmonids representing as many species as possible with no single species accounting for more than 25% of the sample (see Table 1). The sample below the dam was to consist of 360 sockeye at various ages and 420 non-salmonids with the same requirements as for the non-salmonids above the dam.

Table 1. Disease risk assessment sampling plan 2002

ABOVE MCINTYRE DAM

Fish species		Laboratory Responsible	Number of fish recommended	Test for	Sampling details
Salmonids, mostly kokanee salmon	Recent post-spawners	MOWLAP	150	IPNV, IHNV, and *C.shasta*	Make up the total with other salmonids if necessary
	2-month old fry	MOWLAP	150	IPNV, IHNV, and *C. shasta*	
	all ages (whitefish)	MOWLAP	60	IPNV, IHNV, and *C. shasta*	
Non-salmonids	Migratory & Non-migratory fish	MOWLAP	360	IPNV, IHNV	Collect as many species and age groups as possible from as many areas as possible. No single species should represent more than 25% of the sample.
TOTAL			**720**		

BELOW MCINTYRE DAM

Fish species		Laboratory Responsible	Number of fish recommended	Test for	Comments
Salmonids, mostly sockeye salmon	Recent post-spawners	DFO	180	IPNV, IHNV, *C.shasta* and *M. cerebralis*	Make up the total with other salmonids if necessary
	2-month old fry	DFO	180	IPNV, IHNV, *C. shasta*	
Non-salmonids	Migratory & Non-migratory fish	MOWLAP	420	IPNV, IHNV	Collect as many species and age groups as possible from as many areas as possible. No single species should represent more than 25% of the sample.
TOTAL			**780**		

2.1 Field Sampling Methods

Samples were collected by the ONFC and sent to the provincial and federal laboratories. Resident salmonids and non-salmonids were sent to the MoWLAP laboratory Fish Health Unit and anadromous salmonids were sent to the DFO laboratory at the Pacific Biological Station. Samples were usually received at the laboratory on the day following field collection.

All non-salmonids were collected using a boat electroshocker at selected sites in Okanagan, Skaha and Osoyoos Lakes. The Smith-root model 7.5 GPP electrofishing boat was supplied and operated by the Colville Confederated Tribes.

Kokanee spawners were collected as post-spawners on the spawning grounds of Deep Creek and Mission Creek, tributaries to Okanagan Lake. Kokanee fry were caught by a local commercial Mysid shrimp operator in conjunction with MoWLAP at north end of Okanagan Lake. It did not prove feasible to collect kokanee alevins and emergent fry even though this might have enhanced the detecting of any IPNV present. However, had this virus been present, it should also have been detected using kokanee spawners. Sockeye spawners were collected on the spawning grounds downstream of McIntyre Dam in the Okanagan River by gill netting. Sockeye fry were collected by trawling in Osoyoos Lake.

Photo 1. Processing of sockeye spawners with DFO

Photo 2. Collection of kokanee fry with MoWLAP

2.2 Live box testing for Myxobolus cerebralis and Ceratomyxa Shasta

Testing for the presence of *M. cerebralis* and *C. shasta* in waters above and below McIntyre Dam was done by exposing susceptible sentinel fish (rainbow trout) held in live-boxes to suspect water above and below McIntyre Dam. The alternate hosts of *M. cerebralis* (*Tubifex tubifex*) and *C. shasta* (*Manayunkia speciosa*) produce and shed the life-stages (TAMs) of the two parasites that are infectious for salmonids.

Sampling was to be conducted as in YEAR 2, with spring and fall exposures when the temperatures were between 9 and 15 degrees Celsius. The ONFC was able to complete the spring exposure, which occurred from May 6 to May 27, 2002. The fall exposure was not attempted because appropriate-size sentinel fish proved unavailable. It was then decided among the disease experts that a spring 2003 exposure should be conducted to replace the missed fall 2002 exposure. A spring exposure was also considered to be more likely to yield positive results than a fall exposure for biological reasons; in addition, during the first spring exposure, testing for *C. shasta* was overlooked for some kokanee samples and not done. If a spring 2003 exposure is done, the results will not be ready until December 2003. The results will be forwarded as an addendum to this report once completed. The fall 2001 exposure results are being included in the present report as they were not ready at the time the YEAR 2 report went into print.

For the live box exposures, one thousand rainbow trout were used from a stock known to be free of *M. cerebralis* and *C. shasta*. One hundred fish in each of 8 live-boxes were exposed to the test waters and 200 fish were held as unexposed controls in Skaha Hatchery. The fish were approximately 45 days in age.

Figure 2 shows the eight sites in the Okanagan River where the live boxes were placed once temperatures reached 9 degrees Celsius. The live boxes were placed in areas where water flow was sluggish but the oxygen levels adequate to satisfy the needs of the fish. The eight live boxes were separated into four sites above and four sites below McIntyre Dam. We aimed for 25 days of exposure but actual exposures in 2002 lasted only 22 days due to high mortality and rising temperatures. The fish were then grown out in the Skaha Hatchery for 1500 Thermal units when their tissues were sampled and sent to the MoWLAP laboratory for testing.

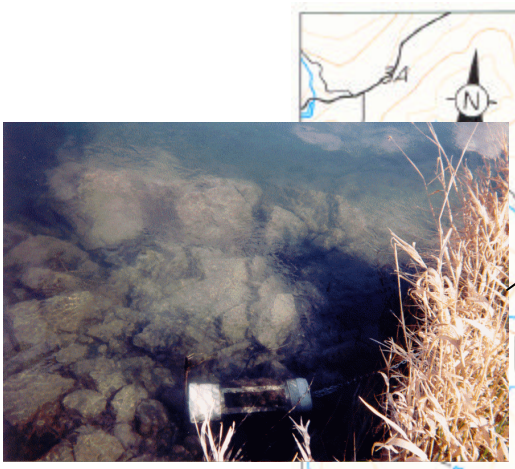


Photo 3. WD7 site

Photo 4. WD5 site

Photo 5. WD3 site

Photo 6. WD1 site

Figure 2. Whirling disease live box exposure sites

2.3 Laboratory methods used by Fisheries and Oceans Canada

In 2002, Fisheries and Oceans Canada (DFO) laboratory processed sockeye fry and spawners. In addition to the required number of sockeye fry and spawners, DFO processed sockeye eggs, alevins and emergent fry. Samples were shipped on ice and processed for virology within 24 hr of arrival at the Pacific Biological Station. If samples could not be processed within a period of 24 hours, they were stored at –80 C until assays were conducted. Dates of collection and assay are noted for each set of samples tested in the laboratory (see tables in Appendix D).

2.3.1 Virology

The majority of the samples were assayed individually using the plaque assay technique in order to determine viral titers present in each fish. If pooling of any samples was done it was recorded on the summary sheets. The following tissues were assayed from the different life stages.

- Eyed eggs
- Emerging fry-whole fish
- Fry (2-4cm)-gills plus viscera
- Adults-reproductive fluid and anterior kidney processed separately

Tissues were homogenized in Earle's balanced salt solution (EBSS) to prepare a 2% w/v solution. The homogenate was centrifuged at 3000 x g for 10 minutes and an additional 10 fold dilution prepared to produce a 0.2% suspension. Ovarian fluid and milt were diluted 1:2 and 1:20 with EBSS. Dilutions prepared from samples were inoculated (0.1ml) into wells containing monolayers of EPC and CHSE-214 cells. The cells were incubated at 15 C and observed 2-3 times per week for a period of 3 weeks for CPE. If CPE occurred supernatant from the affected wells was transferred on to new monolayers and resulting virus isolates were stored at –80 degrees Celsius.

The indirect fluorescent antibody technique (IFAT) was used to confirm the virus isolates as IHNV and to determine if any were IHNV Type II. Cell cultures infected with virus isolates from individual fish were tested with DiagXotics IHN monoclonal antibodies 14D (universal), 105B (Type II specific), and IPN panspecific monoclonal antibody.

2.3.2 Parasitology

Laboratory tests for the detection of *M. cerebralis* and *C. shasta* followed the procedures outlined in the procedures for the detection of certain myxosporidian spores as described in the Canadian Fish Health Protection Regulations. *M. cerebralis* - the pepsin/trypsin digest method. *C. shasta* - microscopic examination of smears.

2.4 Laboratory methods used by the Ministry of Water, Land and Air Protection

The MoWLAP laboratory processed all non-salmonid fish and resident salmonid fry and spawners. MoWLAP also processed the sentinel fish used for detecting *M. cerebralis* and *C. shasta.* If the samples could not be processed within 24 hours of arrival at the laboratory they were stored at –80 degrees Celsius.

2.4.1 Virology

All virology assays were conducted on CHSE-214 and EPC cells according to the methods laid out in the Fish Health Protection Regulations Manual of Compliance. Fish were pooled in three's, on average, using the same species and life stage. The following tissues were retained for analysis for the different life stages;

- Fry (2-4cm): retain gills, but discard head anterior to gills and tail posterior to the vent,
- Fingerlings (4-10cm): remove and retain the gills, gastro-intestinal tract, kidney, spleen and liver,
- Fingerlings (>10cm): remove and retain the kidney, spleen, pyloric ceaca, pancreas and gills.

Tissue homogenates were then inoculated onto the CHSE-214 and EPC cells and incubated for one hour and then over-laid with Hepes Minimum Essential Medium with 10% fetal bovine serum. Assays ran in an incubator for 3 weeks. Assays were examined three times a week for possible CPE. All suspect positives were re-inoculated onto CHSE-214 cells grown on circular glass cover slips. Once CPE developed, cover slips were fixed and stained using IFAT procedures to identify the virus. Samples with CPE were tested with IHNV and IPNV antisera.

2.4.2 Parasitology

Laboratory tests for the detection of C. *shasta* used the PCR method described by K.K. Peters, Boxeman Fish Health Center, Bozeman MT. Fish were pooled in groups of five. In addition, wet mounts for the detection of *C. shasta* spores were prepared to be used for confirmation if required. *C. shasta* testing was conducted on salmonids only.
Detection of *M. cerebralis* was done using the Pepsin-Trypsin Digest Method according to methods described in the American Fisheries Society Bluebook, "Suggested procedures for the detection and identification of certain finfish and shellfish pathogens, fourth edition, 1994". Fish were pooled in groups of five or less within each test group. *M. cerebralis* testing was done only on the sentinel rainbow trout used in the live box exposures.

3.0 RESULTS

The field season began in February and ended in November 2002. Above McIntyre Dam the ONFC was able to collect the required number of non-salmonids and two-month old kokanee fry. This year, it proved difficult to obtain all the required whitefish above the dam so an additional 10 spawning kokanee were collected, which when added together met the salmonid requirement. Below McIntyre Dam all of the sockeye salmon life stages required for the year, plus additional samples of sockeye eggs, alevins and emergent fry, were collected. Due to a clerical error that was caught too late to correct, ONFC was unable to collect the required number of non-salmonids below the dam. It came close to the usual annual target for non-salmonids (349 fish collected instead of 360) but it fell short of the 420 fish hoped for in 2002. The pathogen findings by the DFO and the MoWLAP laboratories on the sampled fish are given in Appendix C and Appendix D, respectively. Table 2 provides information on the number of fish and species collected, and on when the fish were collected for analysis.

3.1 Whirling disease live box exposures

The fall 2001 results are presented in this report because they were not available in time to be included in the YEAR 2 report. As described in the YEAR 2 report, the water temperatures decreased over the 25-day exposure period, which was expected for this time of year. The water temperatures ranged from approximately 20 degrees Celsius to 5 degrees Celsius. Over the 25day exposure, fish mortality was low and no vandalism occurred. The laboratory analysis showed none of the controls to be positive for *M. cerebralis* or *C. shasta*. In addition, none of the exposed fish were positive for *M. cerebralis*. However, a number of fish from exposure site 2 were positive for *C. shasta*. Site 2 was one of four sites located below McIntyre Dam. Details of the findings are given in Appendix A.

In 2002, the live box exposure was performed only in the spring (May 6 to May 27, 2002), for reasons outlined earlier. Temperatures collected while live boxes were in the river ranged from 8.9 to 18.8 degrees Celsius and are presented in Appendix B. During the spring exposure, conditions proved stressful and unsuitable for the sentinel fish. At sites 5 and 1 mortality was 100%, while the rest of the live boxes had fairly high mortality. Due to mortality and rising temperatures, the traps were pulled 3 days earlier than planned (i.e., in 22 rather than 25 days). Results will be included in an addendum to this report later in 2003.

Table 2. Disease risk summary of sampling results

ABOVE MCINTYRE DAM

Fish species		Number of fish recommended	Fish Collected	Collection details	Collection times
Salmonids: Kokanee	Recent post-spawners	150	161	Collected from Mission Creek & Deep Creek spawning channels (10 from Skaha Lake)	Sept. & Nov. 2002
	2 month old fry	150	150	Mysid shrimp harvest boat in the North basin on Okanagan Lake	July 2002
Whitefish	various ages	60	50	Electrofishing boat collected in Okanagan and Skaha Lake	3 fish - April 16 fish - August 31 fish - Nov.
Non-salmonids	yellow perch, northern pike minnow, suckers, peamouth chub, prickley sculpin, pumpkin seed, smallmouth bass and red side shiner	360	364	Electrofishing boat collected in Okanagan and Skaha Lake	72 fish - April 228 fish –June 64 fish - August
TOTAL		**720**	**725**		

BELOW MCINTYRE DAM

Fish species		Number of fish recommended	Fish collected	Collection details	Collection times
Salmonids mostly sockeye	Recent post-spawners	180	180SK 8 KO	Collect from Okanagan River Channel near Oliver with DFO	Oct. 2002
	2-4 month old fry	180	184	trawling in Osoyoos Lake ONFC	June 2002 August2002
	Eggs	Undetermined	40SK	Hydraulic sampling ONFC	February 2002
	alevins	Undetermined	260SK	Hydraulic sampling ONFC	Feb. & March 2002
Whitefish	Emergent fry Various ages	Undetermined 60	120SK 77WF	Emergence fyke netting ONFC	April 2002
Non-salmonids	Yellow perch, smallmouth bass, largemouth bass, northern pike minnow, blue gill, prickley sculpin, pumpkinseed, black crappie, suckers, and peamouth chub	420	349	Electrofishing boat in Osoyoos Lake	151 fish - April 125 fish – June 150 fish - August.
TOTAL		**420**	**1218**		

3.2 Fisheries and Oceans Canada laboratory results

The DFO laboratory processed 180 sockeye spawners and 184 sockeye fry (two - four months old). In addition the laboratory also processed sockeye eggs (40), alevins (260) and emergent fry (120).

There was no indication of either IHNV or IPNV present in the sockeye eggs, alevins, emergent fry or the two-month old sockeye fry. IHN virus was detected only in the sockeye spawners (see Appendix C for details). Tests of the sockeye spawners for *M. cerebralis and C. shasta* proved negative (see Appendix C for the detailed results).

As part of another study unrelated to the present one, DFO also tested a number of sockeye spawners for the myxosporidian parasite, *Parvicapsular minibicornis*. Kidney samples of sockeye collected in 2001 and 2002 from the Okanagan River below McIntyre Dam, proved positive for the parasite using a PCR technique specific for the parasite. In 2001, 8 of 40 sockeye sampled were positive while in 2002 28 of 40 sockeye sampled were positive.

3.3 Ministry of Water, Land and Air Protection laboratory results

The MoWLAP laboratory processed 151 kokanee spawners and 150 two-month old kokanee fry for IHNV, IPNV and *C. shasta*. IHNV was the only virus detected in these fish and it occurred only in the spawners. Tests on these fish for *C. shasta* proved negative (see Table 3, Appendix D for details).

All whitefish caught and processed were tested for IHNV, IPNV and *C. shasta* whether they came from above or below McIntyre Dam. All whitefish proved to be negative for the three pathogens (see Table 3, Appendix D for details).

The MoWLAP laboratory received 349 non-salmonids for processing and testing for IHNV and IPNV. No virus was detected in any of the non-salmonids sampled. See Table 3, Appendix D for detailed results.

4.0 DISCUSSION OF RESULTS

4.1 Pathogen Survey

As in past years, fish sample collecting during year 2002 went off well. The sampling commenced, as planned, in February (with the collection of sockeye eggs and yolk sac sockeye) and ended in November (with the collection of kokanee post-spawners). This year, it was also possible to accomplish live box exposures for detecting the presence of *M. cerebralis* and *C. shasta*. However, only one of the two such exposures was possible (the spring exposure). The planned fall exposure had to be aborted when suitable age sentinel rainbow trout proved unavailable. To make up for this, a spring 2003 exposure is planned, the results of which will be reported later in 2003 in an addendum to this report. The numbers of fish samples collected this 2002 met and even exceeded the

360 fish target for salmonids above and below McIntyre Dam (see Tables 1, 3, and 5, Appendix E, which summarize the collections not only for year 2002 but also for years 2000, 2001, 2002). The same was true for the number of non-salmonids collected above the Dam (Tables 3 and 4, Appendix E). Unfortunately, however, for reasons mentioned earlier in this report, it was not possible to collect the required number of non-salmonids below the Dam (Tables 1 and 2, Appendix E). The collections came close to the usual annual target for non-salmonids (349 fish collected instead of 360) but fell short of the 420 fish hoped for in 2002, a 60 fish increase over the usual target that was intended to make up for an overall shortfall in non-salmonids collected in the preceding two years (Table 7, Appendix E). This shortfall in sample size slightly reduces the confidence that one can put in conclusions drawn from the below-the-Dam non-salmonid sample.

With non-salmonids, eight species were collected above the Dam and ten species below (Tables 4 and 2, Appendix E). This is in contrast to collections in years 2000 and 2001, when the numbers of fish taxa collected above the Dam were greater than those collected below the Dam (compare data in Tables 6 and 7, Appendix E). A goal was to have no single species account for more than 25% of the sample. This year, this goal was essentially met for the non-salmonid species collected above and below the Dam (yellow perch collected below the Dam actually exceeded the limit by a trifle: 25.5% instead of 25%) (based on data in Table 2, Appendix E).

Initial sampling plans called for migratory non-salmonids to constitute 75% of the non-salmonids collected because such fish were more likely to gain access to Skaha and Okanagan lakes once the barriers to migration were removed. However, it proved difficult to achieve consensus on which species are migratory and which are non-migratory. For this reason it was decided in March, 2002, to drop the 75% requirement for migratory species when sampling non-salmonids. However, if the species/groups collected below the Dam to date are rated as active migrators on the basis of their known ability to migrate upstream to spawn or on the ability to live in lotic situations (see Scott and Crossman, 1973), 8 of the 14 (or 57%) species/groups sampled during the 2000 to 2002 fish collections would have been rated as potentially migratory (see Table 7, Appendix E). Even sculpins would have qualified as migratory. How many of the species would qualify as “jumpers” is another relevant question, particularly as it appears likely that some form of barrier permitting the migration of sockeye but not of walleye would have to be put in place. Walleye occur downstream of McIntyre Dam but have yet to reach Osoyoos Lake. Because of their piscivorous nature, their presence in Osoyoos Lake and in the watershed above Osoyoos Lake would be contraindicated.

A final problem with the non-salmonid sampling program is that species of non-salmonids known or suspected to be present below the Dam were again not represented in the year 2002 samples. For example, tench, which are reported to occur below the Dam, were not represented. It seems likely that the sampling methods used and the locations sampled should have shown their presence. It is possible, therefore, that tench occur in relatively low numbers below the Dam and that this explains their absence in the samples.

Based on the results obtained from the fish samples processed in 2002, only one known viral fish pathogen, IHNV (almost certainly type I) was isolated and it occurred only in sockeye and kokanee (see Tables 1,2, 3, and 4, Appendix E). The identification protocol indicates that the IHNV isolates were not type II but it did not rule out the possibility that

they were type III. This possibility is, however, regarded as remote because type III is usually found in chinook salmon and its range is in southern Oregon and northern California. IHNV type I is not one of the "pathogens of concern" because it is already known to occur in salmonids above McIntyre Dam. As in the two previous sampling years, during the 2002 survey the virus was found in salmonid samples obtained from both below and above McIntyre Dam and was detected, not unexpectedly, in fish at the spawning and post-spawning stage. The virus was not detected in juvenile salmon -- not even in sockeye eggs, yolk sac fry, or emergent fry -- probably indicating that the virus is not vertically transmitted.

In 2002, no samples were taken for EIBS testing because it had been shown during 2000 and 2001 samplings to be widely distributed in fish both above and below McIntyre Dam. In 2001 the condition was detected in one salmonid (a whitefish) and six species of non-salmonids. In year 2000, it was found in all three species of salmonids tested and in seven species of non-salmonids. These findings were presented in last year's report.

In year 2002, all sockeye tested for *C. shasta* and *M. cerebralis* proved negative for these pathogens (Table 1, Appendix E). A similar result was obtained for sockeye collected in years 2000 and 2001. Results for *C. shasta* testing of kokanee and whitefish collected in years 2000 and 2001 were delayed by an equipment failure but are now available (see Tables 1 and 2, Appendix D, for details or Table 8, Appendix E, for a summary). They showed whitefish in both years to be negative for *C. shasta*; however, 11 adult kokanee from above the Dam were positive for *C. shasta* in 2000. Tests for *C. shasta* on samples of kokanee and whitefish from above and below the Dam during 2002 all proved negative for the pathogen (Tables 3 and 1, Appendix E). Testing for *M. cerebralis* in the fall of 2001 using live box-exposed rainbow trout failed to detect the pathogen in fish exposed to waters below and above McIntyre Dam (see Appendix A). In these tests, *C. shasta* was not detected in fish exposed to waters above the Dam but it was detected in fish at a live-box exposure site (site #2) below the Dam (see Appendix A for details). It is hoped that positive PCR-based results for *C. shasta* can be reinforced in the future by observing spores typical of *C. shasta).* Results for the live-box exposures done in the spring of 2002 are not yet available and so they will also be included in the addendum to this report, to be ready later in 2003. The available results to date suggest that *M. cerebralis* does not occur in the sample areas above and below the Dam, and indicate that sockeye are not likely to be "vectors" of this pathogen which is known to occur in the Columbia River system. On the basis of available data, it appears that *C. shasta* occurs both above and below the Dam.

Samples of sockeye spawners, collected in 2001 and 2002 in the Okanagan River below McIntyre Dam as part of an unrelated study, proved positive for a myxosporidian parasite, *Parvicapsula minibicornis.* This parasite was not included in the list of "disease agents of particular concern" because it has only recently given cause for concern (it recently caused significant pre-spawning mortalities in sockeye in the Fraser River). Whether the parasite also occurs in fish above McIntyre Dam is unkown, but its presence in sockeye below the Dam, taken together with its pathogenicity potential, will have to be considered when making a decision on whether to proceed with the introduction of sockeye into Skaha Lake. Certainly, it would appear that some additional sampling to determine whether the parasite also occurs above the Dam would be in order. At this stage, not much is known about the life cycle of the parasite. It is not known, for example, whether the parasite requires an alternate host (as do *M. cerebralis* and *C. shasta*) to complete its life cycle. If it does, and if the alternate host does not

occur in the Okanagan watershed, the parasite would not be able to infect fish within the watershed. In which case, its presence in the sockeye would be of little concern should one wish to proceed with a test introduction of sockeye into Skaha Lake. On the other hand, if an alternate host is not required, direct fish-to-fish infections would be possible and thus any introductions of returning sockeye adults into Skaha Lake would be contraindicated unless it was found that the parasite already exists above the Dam. It is known, however, that myxosporidians affecting salmonids are not transmitted via salmonid eggs. Thus, if one wished to proceed with a test introduction of sockeye into Skaha Lake to study its interactions with kokanee and mysids, this could be immediately achieved without risk of spreading the parasite by planting sockeye fry derived from eggs collected from the returning sockeye adults. In going about this, however, well-known precautions would have to be taken to reduce the likelihood of fry losses due to IHN virus which the sockeye adults are known to harbour.

At this stage of the pathogen survey, there is no evidence to indicate that the fish populations above and below the Dam differ with respect to the "disease agents of concern" that they carry. Thus, for the moment, none of these agents presents a reason for not proceeding with a test introduction of sockeye into Skaha Lake. On the other hand, the recent finding of the myxosporidian parasite, *P. minibicornis,* in sockeye spawners below the Dam would contraindicate any such introductions of returning sockeye adults until the distribution of the parasite in the watershed was better known. Such an introduction would only be reasonable if the parasite was already known to occur above McIntyre Dam. However, while efforts are being made to determine this, test introductions of sockeye (using fry hatched from eggs collected from the returning sockeye adults) would be permissible because such fry would pose no risk of spreading the parasite.

4.2 Effect of Water Quality on Pathogens

An examination of limnological data for Okanagan and Skaha lakes reveals no obvious environmental factors likely to pose an extraordinary risk of causing disease in salmonids or non-salmonids. Both lakes appear to undergo the classic stratification cycle for northern lakes, with a warm epilimnion and a cooler hypolimnion in summer followed by an overturn. Temperature regimes in the lakes are such that salmonids should be able to reside in water of non-stressful temperatures all year long. Brief entries into the epilimnion, for feeding, even during its warmest periods (where temperatures may be less than ideal for salmonids), are not likely to be stressful enough to cause disease because they are unlikely to induce chronic stress, the type of stress most conducive to disease. Likewise, oxygen concentrations in the hypolimnion appear normally to be at levels that are non-stressful to salmonids, although in Skaha Lake, which is much smaller and shallower than Okanagan Lake, oxygen concentrations in the hypolimnion may decline to levels that may be slightly stressful to salmonids in very warm years.

Populations of kokanee in the above lakes have declined drastically ever since anthropogenic nutrient input into the lakes was reduced and mysids, competitors for zooplankton needed by kokanee, were introduced. One might speculate, therefore, that the introduction of sockeye to these lakes would add to the competition for an already limiting food supply. Because starving fish are not likely to be as robust and disease resistant as well-fed fish, one might predict that the introduced sockeye would contribute to the poor health of kokanee and other fish in the lakes depending on zooplankton for

their food. However, introduced sockeye will also be providing the lakes with nutrients brought back from the sea in the form of spawning sockeye adults. Once sockeye runs return to their earlier healthy levels, these nutrients, released from the decomposing carcasses of the spent sockeye, may mitigate and perhaps even neutralise any negative effects resulting from the "extra (sockeye) mouths to be fed".

It is probably a given that any microbial fish pathogen introduced above the McIntyre Dam with sockeye or other fishes that are allowed to migrate there, will eventually establish infections in resident fish, if not disease. Most microbial pathogens are not highly host-specific, but rather can infect a variety of fish species. In addition, once released from infected fish, most of these pathogens can survive in water for significant periods. The virus responsible for IPN, for example, has a particularly wide host range, and its long-term persistence in water has been well documented. In addition, IPNV is considered to be a vertically transmitted pathogen (i.e., it can be transmitted from parent to progeny via the egg). It thus has the ability to persist in generation after generation of any introduced species, which can then serve as a constant potential source of infection for other fish sharing the same water.

With myxosporidian pathogens such as *M. cerebralis* and *C. shasta,* their persistence in a system following introduction is dependent on whether their alternate hosts are also present in the system. At the moment, it is not known if the alternate host for *M. cerebralis* occurs in the Okanagan drainage. However, in the case of *C. shasta* its presence below and above the Dam, as evidenced by positive PCR tests in adult kokanee and sentinel rainbow trout, would suggest that the alternate host for this parasite does indeed occur in the Okanagan watershed – both above and below the Dam.

4.3 Risk to Resident Fish

It seems very likely that the progeny of introduced sockeye will have very similar eco-niche requirements as resident kokanee and that their behaviour patterns will be very similar. It follows, therefore, that this will increase the chances of interactions between these fishes, thus increasing the chances that any pathogens carried by one or other of these fishes will cause cross infections. These factors will likely also hold true for cross infections between introduced and resident non-salmonid species. In addition, because of the survival of many microbial fish pathogens in water, cross infections between salmonids and non-salmonids will also be possible (e.g.,with IPNV). Range extensions of fish pathogens are therefore a distinct possibility when fish carrying exotic pathogens move into new areas. However, in the present study, the important question is whether any new (i.e., exotic) pathogens are likely to be introduced. The present pathogen survey is intended to provide answers to this important question.

5.0 CONCLUSION

Data from three years of sampling suggest that none of the "disease agents of particular concern" present any reason for preventing a test introduction of sockeye into Skaha Lake. If this is borne out by results still to come, the risks posed by an introduction of sockeye into Skaha Lake would have to be based mainly on considerations of factors other than fish pathogens. The recent unexpected finding of *P. minibicornis* in sockeye salmon below the Dam will, however, almost certainly affect decisions about introducing sockeye into Skaha Lake, given the parasite's recently recognized potential as a fish pathogen. Factors to be considered with respect to a sockeye introduction as a result of the *P. minibicornis* finding have been discussed above.

There are no indications that Okanagan and Skaha Lakes pose an extraordinary risk of causing disease in fish. Competition between kokanee and sockeye could conceivably add to a starvation problem which would make resident fish less robust and more susceptible to disease, but nutrients from decomposing sockeye carcasses may mitigate any such negative effects. It seems likely that any exotic pathogen introduced above McIntyre Dam by fish migrating from below the Dam would likely persist in its new location and over time lead to infections (and perhaps even disease) in fish above the Dam. It is important, therefore, that the barriers to fish migration from Osoyoos Lake into Skaha and Okanagan lakes be maintained until firm conclusions about the pathogens (including *P. minibicornis*) present in fish above and below the Dam are possible, and until the benefits and risks of removing the barriers are thoroughly considered.

6.0 REFERENCES

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin 184. Fisheries Research Board of Canada. 966 p.

APPENDIX A

Whirling disease Results Fall 2001

ONFC Live Box Study - Case # 2002-1025 Control Group #1				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	1-5	Mar-12-02	Neg	Neg
2	6-10	Mar-12-02	Neg	Neg
3	11-15	Mar-12-02	Neg	Neg
4	16-20	Mar-12-02	Neg	Neg
5	21-25	Mar-12-02	Neg	Neg
6	26-30	Mar-12-02	Neg	Neg
7	31-35	Mar-12-02	Neg	Neg
8	36-40	Mar-12-02	Neg	Neg
9	41-45	Mar-12-02	Neg	Neg
10	46-50	Mar-12-02	Neg	Neg
11	51-55	Mar-12-02	Neg	Neg
12	56-60	Mar-12-02	Neg	Neg
13	61-65	Mar-12-02	Neg	Neg
14	66-70	Mar-12-02	Neg	Neg
15	71-75	Mar-12-02	Neg	Neg
16	76-80	Mar-12-02	Neg	Neg
17	81-85	Mar-12-02	Neg	Neg
18	86-90	Mar-12-02	Neg	Neg
19	91-93	Mar-12-02	Neg	Neg

ONFC Live Box Study - Case # 2002-1026 Control Group #2				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	94-98	Mar-12-02	Neg	Neg
2	99-103	Mar-12-02	Neg	Neg
3	104-108	Mar-12-02	Neg	Neg
4	109-113	Mar-12-02	Neg	Neg
5	114-118	Mar-12-02	Neg	Neg
6	119-123	Mar-12-02	Neg	Neg
7	124-128	Mar-12-02	Neg	Neg
8	129-133	Mar-12-02	Neg	Neg
9	134-138	Mar-12-02	Neg	Neg
10	139-143	Mar-12-02	Neg	Neg
11	144-148	Mar-12-02	Neg	Neg
12	149-153	Mar-12-02	Neg	Neg
13	154-158	Mar-12-02	Neg	Neg
14	159-163	Mar-12-02	Neg	Neg
15	164-168	Mar-12-02	Neg	Neg
16	169-173	Mar-12-02	Neg	Neg
17	174-178	Mar-12-02	Neg	Neg
18	179-183	Mar-12-02	Neg	Neg

ONFC Live Box Study - Case # 2002-1027 Experimental Site #1				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	184-188	Mar-12-02	Neg	Neg
2	189-193	Mar-12-02	Neg	Neg
3	194-198	Mar-12-02	Neg	Neg
4	199-203	Mar-12-02	Neg	Neg
5	204-208	Mar-12-02	Neg	Neg
6	209-213	Mar-12-02	Neg	Neg
7	214-218	Mar-12-02	Neg	Neg
8	219-223	Mar-12-02	Neg	Neg
9	224-228	Mar-12-02	Neg	Neg
10	229-233	Mar-12-02	Neg	Neg
11	234-238	Mar-12-02	Neg	Neg

ONFC Live Box Study - Case # 2002-1028 Experimental Site #2				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	239-243	Mar-13-02	Neg	Neg
2	244-248	Mar-13-02	Neg	Neg
3	249-253	Mar-13-02	Neg	Neg
4	254-258	Mar-13-02	Neg	Neg
5	259-263	Mar-13-02	261	Neg
6	264-268	Mar-13-02	Neg	Neg
7	269-273	Mar-13-02	269, 270, 271	Neg
8	274-278	Mar-13-02	275, 276, 278	Neg
9	279-283	Mar-13-02	Neg	Neg
10	284-288	Mar-13-02	Neg	Neg
11	289-293	Mar-13-02	Neg	Neg
12	294-298	Mar-13-02	295, 296	Neg
13	299-303	Mar-13-02	300, 302	Neg
14	304-307	Mar-13-02	307	Neg

ONFC Live Box Study - Case # 2002-1029 Experimental Site #3				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	308-312	Mar-13-02	Neg	Neg
2	313-317	Mar-13-02	Neg	Neg
3	318-322	Mar-13-02	Neg	Neg
4	323-327	Mar-13-02	Neg	Neg
5	328-332	Mar-13-02	Neg	Neg
6	333-337	Mar-13-02	Neg	Neg
7	338-342	Mar-13-02	Neg	Neg
8	343-347	Mar-13-02	Neg	Neg

ONFC Live Box Study - Case # 2002-1030 Experimental Site #4				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	348-352	Mar-13-02	Neg	Neg
2	353-357	Mar-13-02	Neg	Neg
3	358-362	Mar-13-02	Neg	Neg
4	363-367	Mar-13-02	Neg	Neg
5	368-372	Mar-13-02	Neg	Neg
6	373-377	Mar-13-02	Neg	Neg
7	378-382	Mar-13-02	Neg	Neg
8	383-387	Mar-13-02	Neg	Neg
9	388-392	Mar-13-02	Neg	Neg
10	393-397	Mar-13-02	Neg	Neg
11	398-402	Mar-13-02	Neg	Neg
12	403-407	Mar-13-02	Neg	Neg
13	408-412	Mar-13-02	Neg	Neg
14	413-417	Mar-13-02	Neg	Neg
15	418-422	Mar-13-02	Neg	Neg

ONFC Live Box Study - Case # 2002-1031 Experimental Site #5				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	423-427	Mar-13-02	Neg	Neg
2	428-432	Mar-13-02	Neg	Neg
3	433-437	Mar-13-02	Neg	Neg
4	438-442	Mar-13-02	Neg	Neg
5	443-447	Mar-13-02	Neg	Neg
6	448-452	Mar-13-02	Neg	Neg
7	453-457	Mar-13-02	Neg	Neg
8	458-462	Mar-13-02	Neg	Neg
9	463-467	Mar-13-02	Neg	Neg
10	468-472	Mar-13-02	Neg	Neg
11	473-477	Mar-13-02	Neg	Neg
12	478-482	Mar-13-02	Neg	Neg
13	483-484	Mar-13-02	Neg	Neg

ONFC Live Box Study - Case # 2002-1032 Experimental Site #6				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	485-489	Mar-13-02	Neg	Neg
2	490-494	Mar-13-02	Neg	Neg
3	495-499	Mar-13-02	Neg	Neg
4	500-504	Mar-13-02	Neg	Neg
5	505-509	Mar-13-02	Neg	Neg
6	510-514	Mar-13-02	Neg	Neg
7	515-519	Mar-13-02	Neg	Neg
8	520-524	Mar-13-02	Neg	Neg
9	525-529	Mar-13-02	Neg	Neg
10	530-534	Mar-13-02	Neg	Neg
11	535-539	Mar-13-02	Neg	Neg
12	540-543	Mar-13-02	Neg	Neg

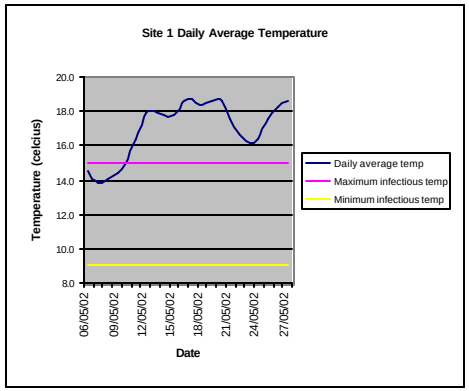
ONFC Live Box Study - Case # 2002-1033 Experimental Site #7				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	544-548	Mar-14-02	Neg	Neg
2	549-553	Mar-14-02	Neg	Neg
3	554-558	Mar-14-02	Neg	Neg
4	559-563	Mar-14-02	Neg	Neg
5	564-568	Mar-14-02	Neg	Neg
6	569-573	Mar-14-02	Neg	Neg
7	574-578	Mar-14-02	Neg	Neg
8	579-583	Mar-14-02	Neg	Neg
9	584-588	Mar-14-02	Neg	Neg
10	589-593	Mar-14-02	Neg	Neg
11	594-596	Mar-14-02	Neg	Neg
12	597-599	Mar-14-02	Neg	Neg

ONFC Live Box Study - Case # 2002-1034 Experimental Site #8				
Pool Number	**Fish Number**	**Sample Date**	***C. shasta* Positive Fish**	***M. cerebralis* Positive Fish**
1	600-604	Mar-14-02	Neg	Neg
2	605-609	Mar-14-02	Neg	Neg
3	610-614	Mar-14-02	Neg	Neg
4	615-619	Mar-14-02	Neg	Neg
5	620-624	Mar-14-02	Neg	Neg
6	625-629	Mar-14-02	Neg	Neg
7	630-634	Mar-14-02	Neg	Neg
8	635-639	Mar-14-02	Neg	Neg
9	640-644	Mar-14-02	Neg	Neg
10	645-649	Mar-14-02	Neg	Neg
11	650-654	Mar-14-02	Neg	Neg
12	655-659	Mar-14-02	Neg	Neg
13	660-664	Mar-14-02	Neg	Neg
14	665-669	Mar-14-02	Neg	Neg
15	670-672	Mar-14-02	Neg	Neg

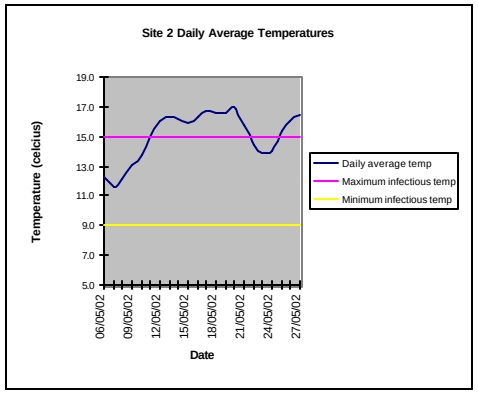
APPENDIX B

Whirling disease exposure daily temperature data and site photos Spring 2002

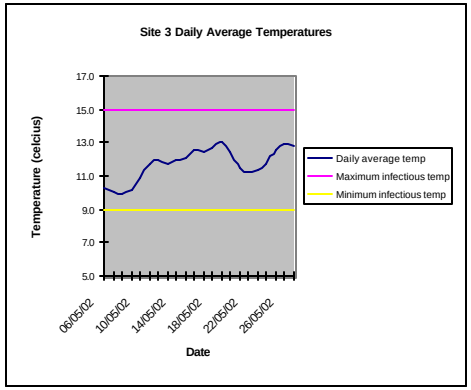
Date 2002	Daily Avg Temp. (C) Site 1
06-May	14.5
07-May	13.9
08-May	14.1
09-May	14.4
10-May	15.0
11-May	16.4
12-May	17.9
13-May	18.0
14-May	17.8
15-May	17.7
16-May	18.7
17-May	18.8
18-May	18.4
19-May	18.6
20-May	18.6
21-May	17.6
22-May	16.6
23-May	16.1
24-May	16.4
25-May	17.6
26-May	18.3
27-May	18.6
Average	17.0



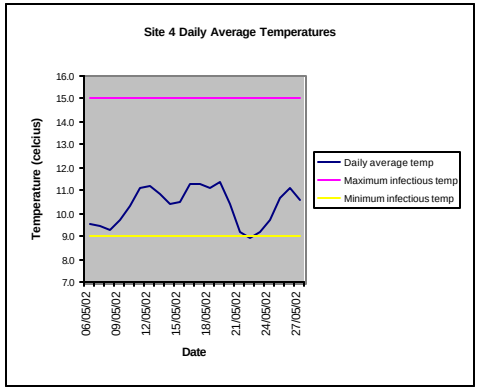
Date 2002	Daily Avg Temp. Site 2
06-May	12.2
07-May	11.6
08-May	12.2
09-May	13.1
10-May	13.7
11-May	14.9
12-May	16.1
13-May	16.3
14-May	16.1
15-May	15.9
16-May	16.3
17-May	16.7
18-May	16.6
19-May	16.6
20-May	16.9
21-May	15.7
22-May	14.4
23-May	13.9
24-May	14.1
25-May	15.3
26-May	16.0
27-May	16.4
Average	15.1



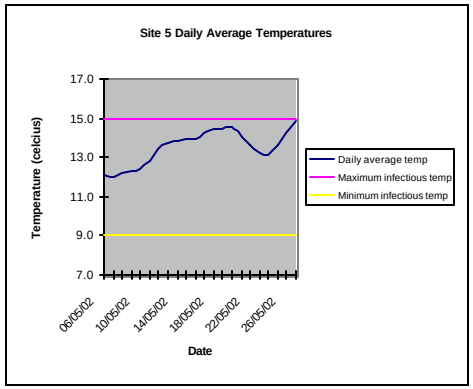
Date 2002	Daily Avg Temp. (C) Site 3
06-May	10.3
07-May	10.0
08-May	9.9
09-May	10.2
10-May	10.9
11-May	11.8
12-May	12.0
13-May	11.8
14-May	11.9
15-May	12.0
16-May	12.6
17-May	12.5
18-May	12.7
19-May	13.0
20-May	12.4
21-May	11.5
22-May	11.2
23-May	11.3
24-May	11.8
25-May	12.6
26-May	12.9
27-May	12.8
Average	11.7



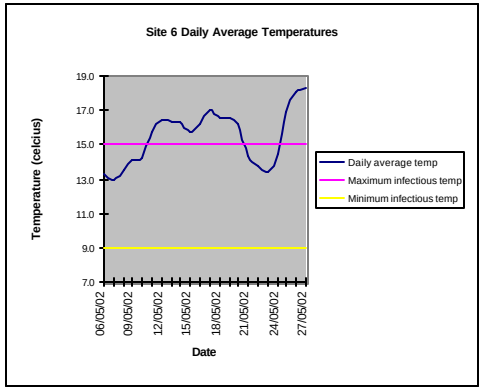
Date 2002	Daily Avg Temp. Site 4
06-May	9.6
07-May	9.4
08-May	9.3
09-May	9.7
10-May	10.3
11-May	11.1
12-May	11.2
13-May	10.9
14-May	10.4
15-May	10.5
16-May	11.2
17-May	11.3
18-May	11.1
19-May	11.4
20-May	10.4
21-May	9.2
22-May	8.9
23-May	9.2
24-May	9.7
25-May	10.6
26-May	11.1
27-May	10.6
Average	10.3



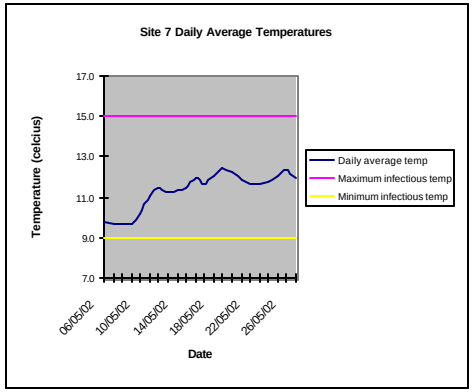
Date 2002	Daily Avg Temp. (C) Site 5
06-May	12.1
07-May	12.0
08-May	12.2
09-May	12.3
10-May	12.4
11-May	12.8
12-May	13.4
13-May	13.8
14-May	13.9
15-May	13.9
16-May	13.9
17-May	14.2
18-May	14.4
19-May	14.5
20-May	14.6
21-May	14.1
22-May	13.6
23-May	13.3
24-May	13.1
25-May	13.6
26-May	14.3
27-May	14.8
Average	13.5



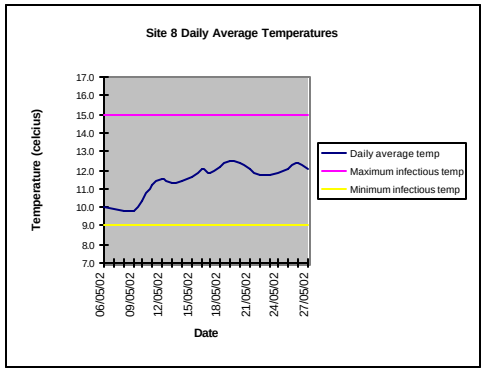
Date 2002	Daily Avg Temp. Site 6
06-May	13.3
07-May	12.9
08-May	13.5
09-May	14.1
10-May	14.2
11-May	15.7
12-May	16.4
13-May	16.3
14-May	16.3
15-May	15.7
16-May	16.3
17-May	17.0
18-May	16.6
19-May	16.6
20-May	16.2
21-May	14.3
22-May	13.7
23-May	13.4
24-May	14.5
25-May	16.8
26-May	18.1
27-May	18.3
Average	15.5



Date 2002	Daily Avg Temp. (C) Site 7
06-May	9.8
07-May	9.7
08-May	9.6
09-May	9.6
10-May	10.2
11-May	11.0
12-May	11.4
13-May	11.2
14-May	11.4
15-May	11.5
16-May	11.9
17-May	11.7
18-May	12.0
19-May	12.4
20-May	12.3
21-May	11.9
22-May	11.7
23-May	11.6
24-May	11.8
25-May	12.0
26-May	12.4
27-May	11.9
Average	11.3



Date 2002	Daily Avg Temp. Site 8
06-May	10.0
07-May	9.9
08-May	9.8
09-May	9.8
10-May	10.3
11-May	11.1
12-May	11.5
13-May	11.3
14-May	11.5
15-May	11.6
16-May	12.1
17-May	11.8
18-May	12.1
19-May	12.5
20-May	12.4
21-May	12.0
22-May	11.8
23-May	11.7
24-May	11.8
25-May	12.1
26-May	12.4
27-May	12.0
Average	11.4



Whirling Disease Site 8

Whirling Disease Site 6

Whirling Disease Site 4

Whirling Disease Site 2

APPENDIX C

Fisheries and Oceans Canada laboratory results

Collection Site-Okanagan River
Collection Date-Feb. 12, 2002
Sample-eggs, alevins
sockeye salmon
Assay Date-Feb. 13, 2002
(samples not frozen)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results	Remarks
1	2	nvd *	alevins
2	2	nvd	alevins
3	2	nvd	alevins
4	2	nvd	alevins
5	2	nvd	alevins
6	2	nvd	alevins
7	2	nvd	alevins
8	2	nvd	alevins
9	2	nvd	alevins
10	2	nvd	alevins
11	2	nvd	eyed eggs
12	2	nvd	eyed eggs
13	2	nvd	eyed eggs
14	2	nvd	eyed eggs
15	2	nvd	eyed eggs
16	2	nvd	eyed eggs
17	2	nvd	eyed eggs
18	2	nvd	eyed eggs
19	2	nvd	eyed eggs
20	2	nvd	eyed eggs
21	2	nvd	eyed eggs
22	2	nvd	eyed eggs
23	2	nvd	eyed eggs
24	2	nvd	eyed eggs
25	2	nvd	eyed eggs
26	2	nvd	eyed eggs
27	2	nvd	eyed eggs
28	2	nvd	eyed eggs
29	2	nvd	eyed eggs
30	2	nvd	eyed eggs
Total	**20 alevin**	**0/20**	
	40 eggs	**0/40**	

Collection Site-Okanagan River
Collection Date-Feb. 19, 2002
Sample-alevins
sockeye salmon
Assay Date-Feb. 20, 2002
(samples not frozen)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd*
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
16	2	nvd
17	2	nvd
18	2	nvd
19	2	nvd
20	2	nvd
21	2	nvd
22	2	nvd
23	2	nvd
24	2	nvd
25	2	nvd
26	2	nvd
27	2	nvd
28	2	nvd
29	2	nvd
30	2	nvd
Total	**60**	**0/60**

Collection Site-Okanagan River
Collection Date-Feb. 26, 2002
Sample-alevins
sockeye salmon
Assay Date-Feb. 27, 2002
(sample not frozen)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd*
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
16	2	nvd
17	2	nvd
18	2	nvd
19	2	nvd
20	2	nvd
21	2	nvd
22	2	nvd
23	2	nvd
24	2	nvd
25	2	nvd
26	2	nvd
27	2	nvd
28	2	nvd
29	2	nvd
30	2	nvd
Total	**60**	**0/60**

Collection Site-Okanagan River
Collection Date-March 5, 2002
Sample-alevins
sockeye salmon
Assay Date-March 7, 2002
(sample not frozen)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd*
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
16	2	nvd
17	2	nvd
18	2	nvd
19	2	nvd
20	2	nvd
21	2	nvd
22	2	nvd
23	2	nvd
24	2	nvd
25	2	nvd
26	2	nvd
27	2	nvd
28	2	nvd
29	2	nvd
30	2	nvd
Total	**60**	**0/60**

Collection Site-Okanagan River
Collection Date-March 12, 2002
Sample-alevins
sockeye salmon
Assay Date-March 15, 2002
(samples frozen at -80)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd*
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
16	2	nvd
17	2	nvd
18	2	nvd
19	2	nvd
20	2	nvd
21	2	nvd
22	2	nvd
23	2	nvd
24	2	nvd
25	2	nvd
26	2	nvd
27	2	nvd
28	2	nvd
29	2	nvd
30	2	nvd
Total	**60**	**0/60**

nvd* - no virus detected

Collection Site-Okanagan River
Collection Date-April 17, 2002
Sample-fry
sockeye salmon
Assay Date-April 18, 2002
(samples not frozen)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd *
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
16	2	nvd
17	2	nvd
18	2	nvd
19	2	nvd
20	2	nvd
21	2	nvd
22	2	nvd
23	2	nvd
24	2	nvd
25	2	nvd
26	2	nvd
27	2	nvd
28	2	nvd
29	2	nvd
30	2	nvd
Total	**60 fish**	**0/60**

Collection Site-Okanagan River
Collection Date-April 23, 2002
Sample-fry
sockeye salmon
Assay Date-April 25, 2002
(samples not frozen)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd *
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
16	2	nvd
17	2	nvd
18	2	nvd
19	2	nvd
20	2	nvd
21	2	nvd
22	2	nvd
23	2	nvd
24	2	nvd
25	2	nvd
26	2	nvd
27	2	nvd
28	2	nvd
29	2	nvd
30	2	nvd
Total	**60 fish**	**0/60**

Collection Site-Osoyoos Lake
Collection Date-June 12, 2002
Sample-fry
sockeye salmon
Assay Date-July 31, 2002
(samples frozen at -80)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd *
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
Total	**30 fish**	**0/30**

Collection Site-Osoyoos Lake
Collection Date-June 24, 2002
Sample-fry
sockeye salmon
Assay Date-Aug. 13, 2002
(samples frozen at -80)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd *
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
Total	**30 fish**	**0/30**

nvd* - no virus detected

Collection Site-Osoyoos Lake
Collection Date-June 25, 2002
Sample-fry
sockeye salmon
Assay Date-July 31, 2002
(samples frozen at -80)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd *
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
Total	**30 fish**	**0/30**

Collection Site-Osoyoos Lake
Collection Date-June 25, 2002
Sample-fry
sockeye salmon
Assay Date-Aug. 13, 2002
(samples frozen at -80)
Cell lines-EPC and CHSE-214

Pool No.	Number of fish/pool	Virology Results
1	2	nvd *
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
Total	**30 fish**	**0/30**

Collection Site-Osoyoos Lake
Collection Date-Aug. 27, 2002
Sample-fry
sockeye salmon
Assay Date-Dec. 20, 2002
(samples frozen at -80)
Cell Lines-EPC and CHSE-214

Pool Number	Number of fish/pool	Virology Results
1	2	nvd*
2	2	nvd
3	2	nvd
4	2	nvd
5	2	nvd
6	2	nvd
7	2	nvd
8	2	nvd
9	2	nvd
10	2	nvd
11	2	nvd
12	2	nvd
13	2	nvd
14	2	nvd
15	2	nvd
16	2	nvd
17	2	nvd
18	2	nvd
19	2	nvd
20	2	nvd
21	2	nvd
22	2	nvd
23	2	nvd
24	2	nvd
25	2	nvd
26	2	nvd
27	2	nvd
28	2	nvd
29	2	nvd
30	2	nvd
Total	**60 fish**	**0/60**

Disease risk assessment - Sockeye spawner

Collection Site- Okanagan River
Collection Date-October 15-18, 2002
Sample180 sockeye adults post-spawners plus 8 kokanee post-spawners
Assay Date-October 23-November 27, 2002 (samples frozen)
Cell lines-EPC and CHSE

Virology Fish Number	Number of fish/pool	Sex	Virology Results pfu/ml		*Myxobolus cerebralis*	*Ceratomyxa shasta*	Virus Isolate tested by IFAT
			Reprod Fl	Kidney			
1	1	F	*nvd	nvd	negative	negative	
2	1	F	nvd	nvd	negative	negative	
3	1	M	nvd	nvd	negative	negative	
4	1	M	nvd	nvd	negative	negative	
5	1	M	nvd	nvd	negative	negative	
6	1	M	nvd	nvd	negative	negative	
7	1	M	nvd	10^3	negative	negative	
8	1	M	nvd	nvd	negative	negative	
9	1	M	nvd	nvd	negative	negative	
10	1	M	nvd	nvd	negative	negative	
11	1	F	nvd	nvd	negative	negative	
12	1	F	nvd	nvd	negative	negative	
13	1	F	nvd	nvd	negative	negative	
14	1	M	nvd	nvd	negative	negative	
15	1	M	nvd	nvd	negative	negative	
16	1	M	nvd	nvd	negative	negative	
17	1	M	nvd	nvd	negative	negative	
18	1	M	nvd	nvd	negative	negative	
19	1	M	nvd	nvd	negative	negative	
20	1	M	nvd	nvd	negative	negative	
21	1	M	nvd	nvd	negative	negative	
22	1	M	nvd	nvd	negative	negative	
23	1	M	nvd	nvd	negative	negative	
24 kok	1	M	nvd	nvd	negative	negative	
25 kok	1	M	nvd	nvd	negative	negative	
26 kok	1	M	no sample	nvd	negative	negative	
27 kok	1	M	nvd	nvd	negative	negative	
28 kok	1	M	nvd	nvd	negative	negative	
29kok	1	M	nvd	nvd	negative	negative	
30 kok	1	M	nvd	nvd	negative	negative	
31 kok	1	M	nvd	nvd	negative	negative	
32	1	F	nvd	nvd	negative	negative	
33	1	F	nvd	nvd	negative	negative	
34	1	F	nvd	10^4	negative	negative	
35	1	M	nvd	nvd	negative	negative	
36	1	M	nvd	nvd	negative	negative	
37	1	M	nvd	nvd	negative	negative	
38	1	M	nvd	nvd	negative	negative	
39	1	M	nvd	nvd	negative	negative	
40	1	F	10^6	10^6	negative	negative	** react with Mab 14D

Collection Site- Okanagan River
Collection Date-October 15-18, 2002
Sample180 sockeye adults post-spawners plus 8 kokanee post-spawners
Assay Date-October 23-November 27, 2002 (samples frozen)
Cell lines-EPC and CHSE

Virology Fish Number	Number of fish/pool	Sex	Virology Results pfu/ml		*Myxobolus cerebralis*	*Ceratomyxa shasta*	Virus Isolate tested by IFAT
			Reprod Fl	Kidney			
41	1	M	nvd	nvd	negative	negative	
42	1	M	nvd	nvd	negative	negative	
43	1	F	nvd	nvd	negative	negative	
44	1	F	nvd	nvd	negative	negative	
45	1	F	nvd	nvd	negative	negative	
46	1	M	nvd	nvd	negative	negative	
47	1	M	nvd	nvd	negative	negative	
48	1	M	nvd	nvd	negative	negative	
49	1	M	nvd	nvd	negative	negative	
50	1	F	nvd	nvd	negative	negative	
51	1	F	nvd	nvd	negative	negative	
52	1	F	nvd	10^4	negative	negative	
53	1	F	nvd	nvd	negative	negative	
54	1	M	nvd	nvd	negative	negative	
55	1	M	nvd	nvd	negative	negative	
56	1	M	nvd	nvd	negative	negative	
57	1	M	nvd	nvd	negative	negative	
58	1	M	nvd	nvd	negative	negative	
59	1	M	nvd	nvd	negative	negative	
60	1	M	nvd	10^3	negative	negative	
61	1	M	nvd	nvd	negative	negative	
62	1	M	nvd	nvd	negative	negative	
63	1	M	nvd	nvd	negative	negative	
64	1	M	nvd	nvd	negative	negative	
65	1	M	nvd	nvd	negative	negative	
66	1	M	nvd	nvd	negative	negative	
67	1	M	nvd	nvd	negative	negative	
68	1	M	nvd	10^4	negative	negative	
69	1	M	nvd	nvd	negative	negative	
70	1	F	10^2	10^6	negative	negative	react with Mab 14D
71	1	F	nvd	10^5	negative	negative	
72	1	F	nvd	nvd	negative	negative	
73	1	F	10^2	10^3	negative	negative	react with Mab 14D
74	1	F	nvd	nvd	negative	negative	
75	1	F	nvd	nvd	negative	negative	
76	1	M	nvd	10^3	negative	negative	
77	1	M	nvd	nvd	negative	negative	
78	1	M	nvd	nvd	negative	negative	
79	1	M	nvd	nvd	negative	negative	
80	1	M	nvd	nvd	negative	negative	
81	1	M	nvd	nvd	negative	negative	

Collection Site- Okanagan River
Collection Date-October 15-18, 2002
Sample180 sockeye adults post-spawners plus 8 kokanee post-spawners
Assay Date-October 23-November 27, 2002 (samples frozen)
Cell lines-EPC and CHSE

Virology Fish Number	Number of fish/pool	Sex	Virology Results pfu/ml		*Myxobolus cerebralis*	*Ceratomyxa shasta*	Virus Isolate tested by IFAT
			Reprod Fl	Kidney			
82	1	M	nvd	nvd	negative	negative	
83	1	M	nvd	nvd	negative	negative	
84	1	M	nvd	nvd	negative	negative	
85	1	M	nvd	nvd	negative	negative	
86	1	M	nvd	nvd	negative	negative	
87	1	F	nvd	nvd	negative	negative	
88	1	F	nvd	nvd	negative	negative	
89	1	F	nvd	nvd	negative	negative	
90	1	F	nvd	nvd	negative	negative	
91	1	F	nvd	nvd	negative	negative	
92	1	F	nvd	nvd	negative	negative	
93	1	M	nvd	nvd	negative	negative	
94	1	M	nvd	nvd	negative	negative	
95	1	M	nvd	nvd	negative	negative	
96	1	F	nvd	nvd	negative	negative	
97	1	F	nvd	nvd	negative	negative	
98	1	F	nvd	nvd	negative	negative	
99	1	F	nvd	nvd	negative	negative	
100	1	F	nvd	nvd	negative	negative	
101	1	M	nvd	nvd	negative	negative	
102	1	M	nvd	nvd	negative	negative	
103	1	M	nvd	nvd	negative	negative	
104	1	M	nvd	nvd	negative	negative	
105	1	M	nvd	nvd	negative	negative	
106	1	M	nvd	nvd	negative	negative	
107	1	M	nvd	10^4	negative	negative	
108	1	M	nvd	nvd	negative	negative	
109	1	M	nvd	nvd	negative	negative	
110	1	M	nvd	nvd	negative	negative	
111	1	M	nvd	nvd	negative	negative	
112	1	M	nvd	nvd	negative	negative	
113	1	M	nvd	nvd	negative	negative	
114	1	M	nvd	nvd	negative	negative	
115	1	M	nvd	nvd	negative	negative	
116	1	F	nvd	nvd	negative	negative	
117	1	M	nvd	nvd	negative	negative	
118	1	F	nvd	nvd	negative	negative	
119	1	M	nvd	nvd	negative	negative	
120	1	M	nvd	nvd	negative	negative	
121	1	M	nvd	nvd	negative	negative	
122	1	M	nvd	nvd	negative	negative	

Collection Site- Okanagan River
Collection Date-October 15-18, 2002
Sample180 sockeye adults post-spawners plus 8 kokanee post-spawners
Assay Date-October 23-November 27, 2002 (samples frozen)
Cell lines-EPC and CHSE

Virology Fish Number	Number of fish/pool	Sex	Virology Results pfu/ml		*Myxobolus cerebralis*	*Ceratomyxa shasta*	Virus Isolate tested by IFAT
			Reprod Fl	Kidney			
123	1	M	nvd	nvd	negative	negative	
124	1	M	nvd	nvd	negative	negative	
125	1	M	nvd	nvd	negative	negative	
126	1	F	nvd	10^4	negative	negative	
127	1	F	nvd	nvd	negative	negative	
128	1	F	nvd	nvd	negative	negative	
129	1	F	nvd	nvd	negative	negative	
130	1	M	nvd	nvd	negative	negative	
131	1	M	nvd	nvd	negative	negative	
132	1	M	nvd	nvd	negative	negative	
133	1	M	nvd	nvd	negative	negative	
134	1	M	nvd	nvd	negative	negative	
135	1	M	nvd	nvd	negative	negative	
136	1	M	nvd	nvd	negative	negative	
137	1	M	nvd	nvd	negative	negative	
138	1	M	nvd	nvd	negative	negative	
139	1	M	nvd	10^4	negative	negative	
140	1	M	nvd	nvd	negative	negative	
141	1	M	nvd	nvd	negative	negative	
142	1	M	nvd	nvd	negative	negative	
143	1	F	nvd	nvd	negative	negative	
144	1	F	no sample	nvd	negative	negative	
145	1	F	nvd	nvd	negative	negative	
146	1	M	nvd	nvd	negative	negative	
147	1	M	nvd	nvd	negative	negative	
148	1	M	nvd	nvd	negative	negative	
149	1	M	nvd	nvd	negative	negative	
150	1	M	nvd	nvd	negative	negative	
151	1	F	nvd	nvd	negative	negative	
152	1	F	nvd	nvd	negative	negative	
153	1	F	nvd	nvd	negative	negative	
154	1	F	nvd	nvd	negative	negative	
155	1	M	nvd	nvd	negative	negative	
156	1	M	nvd	nvd	negative	negative	
157	1	M	nvd	nvd	negative	negative	
158	1	M	nvd	nvd	negative	negative	
159	1	M	nvd	nvd	negative	negative	
160	1	F	no sample	nvd	negative	negative	
161	1	F	no sample	nvd	negative	negative	
162	1	F	no sample	nvd	negative	negative	

Collection Site- Okanagan River
Collection Date-October 15-18, 2002
Sample180 sockeye adults post-spawners plus 8 kokanee post-spawners
Assay Date-October 23-November 27, 2002 (samples frozen)
Cell lines-EPC and CHSE

Virology Fish Number	Number of fish/pool	Sex	Virology Results pfu/ml		*Myxobolus cerebralis*	*Ceratomyxa shasta*	Virus Isolate tested by IFAT
			Reprod Fl	Kidney			
163	1	F	no sample	nvd	negative	negative	
164	1	F	no sample	nvd	negative	negative	
165	1	F	nvd	nvd	negative	negative	
166	1	F	nvd	nvd	negative	negative	
167	1	F	no sample	nvd	negative	negative	
168	1	F	no sample	nvd	negative	negative	
169	1	F	no sample	nvd	negative	negative	
170	1	F	no sample	nvd	negative	negative	
171	1	F	nvd	nvd	negative	negative	
172	1	M	nvd	nvd	negative	negative	
173	1	M	nvd	nvd	negative	negative	
174	1	F	nvd	nvd	negative	negative	
175	1	F	no sample	nvd	negative	negative	
176	1	F	nvd	10^4	negative	negative	
177	1	F	no sample	nvd	negative	negative	
178	1	F	nvd	nvd	negative	negative	
179	1	F	nvd	nvd	negative	negative	
180	1	M	nvd	nvd	negative	negative	
181	1	F	10^4	10^6	negative	negative	react with Mab 14D
182	1	F	nvd	nvd	negative	negative	
183	1	F	nvd	nvd	negative	negative	
184	1	F	10^4	10^4	negative	negative	react with Mab 14D
185	1	F	nvd	nvd	negative	negative	
186	1	F	nvd	nvd	negative	negative	
187	1	F	nvd	nvd	negative	negative	
188	1	F	nvd	nvd	negative	negative	

	Virology Results pfu/ml		*Myxobolus cerebralis*	*Ceratomyxa shasta*	Virus Isolate tested by IFAT
	Reprod Fl	Kidney			
Total	5/180	16/180	0/180	0/180	0/5
Prevalence	2.8%	8.9%	0%	0%	0%

Total kokanee	0/8	0/8	0/8	0/8	
Prevalence	0%	0%	0%	0%	

*nvd-no virus detected
**-virus isolate reacted positive with MAb 14D the universal antibody for IHNV and did not react with MAb 105B the type 2 specific antibody

APPENDIX D

Ministry of Water, Land and Air Protection laboratory results

Table 1. PCR-based data on *Ceratomyxa shasta* in kokanee and whitefish collected from above and below McIntyre Dam in Year 2000

Fish Number	Date Sampled 2000	Lake	Species	Age	*C. shasta* PCR results
404	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
405	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
406	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
407	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
408	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
409	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
410	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
411	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
412	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
413	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
414	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
415	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
416	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
417	11-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
418	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
419	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
420	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
421	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
422	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
423	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	intestines not taken, fish too small
424	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	intestines not taken, fish too small
425	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
426	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
427	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	intestines not taken, fish too small
428	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
429	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	intestines not taken, fish too small
430	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
431	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	intestines not taken, fish too small
432	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
433	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
434	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
435	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
436	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
437	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
438	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
439	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	intestines not taken, fish too small
440	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	Negative
441	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	intestines not taken, fish too small
442	13-Jul	Okanagan Lk	Kokanee	Fry - 3 to 4 months	intestines not taken, fish too small
482	21-Aug	Okanagan Lk	Whitefish		Negative
483	21-Aug	Okanagan Lk	Whitefish		Negative
484	21-Aug	Okanagan Lk	Whitefish		Negative
485	21-Aug	Okanagan Lk	Whitefish		Negative
487	21-Aug	Okanagan Lk	Whitefish		Negative
488	21-Aug	Okanagan Lk	Whitefish		Negative
492	21-Aug	Okanagan Lk	Whitefish		Negative
498	21-Aug	Okanagan Lk	Whitefish		Negative
655	23-Aug	Osoyoos Lk	Whitefish		Negative
656	23-Aug	Osoyoos Lk	Whitefish		Negative
657	23-Aug	Osoyoos Lk	Whitefish		Negative
800	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
801	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
802	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
803	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
804	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
805	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
806	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
807	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
808	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
809	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
810	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative

Table 1. PCR-based data on *Ceratomyxa shasta* in kokanee and whitefish collected from above and below McIntyre Dam in Year 2000

Fish Number	Date Sampled 2000	Lake	Species	Age	*C. shasta* PCR results
811	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
812	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
813	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
814	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
815	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
816	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
817	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
818	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
819	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
820	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
821	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
822	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
823	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
824	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
825	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
826	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
827	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
828	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
829	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
830	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
831	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
832	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
833	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
834	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
835	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
836	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
837	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
838	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
839	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
840	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
841	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
842	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
843	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
844	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
845	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
846	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
847	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
848	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
849	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
850	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
851	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
852	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
853	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
854	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
855	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
856	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
857	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
858	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
859	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
860	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
861	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
862	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
863	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
864	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
865	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
866	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
867	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
868	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
869	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
870	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
871	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative

Table 1. PCR-based data on *Ceratomyxa shasta* in kokanee and whitefish collected from above and below McIntyre Dam in Year 2000

Fish Number	Date Sampled 2000	Lake	Species	Age	*C. shasta* PCR results
872	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
873	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
874	12-Sep	Okanagan Lk	Kokanee	Fry - 6 months	Negative
877	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
878	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
879	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
880	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
881	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
882	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
883	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
884	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
885	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
886	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
887	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
888	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
889	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
890	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
891	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
892	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
893	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
894	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
895	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
896	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
897	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
898	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
899	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
900	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
901	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
902	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
903	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
904	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
905	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
906	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
907	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
908	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
909	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
910	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
911	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
912	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
913	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
914	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
915	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
916	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
917	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
918	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
919	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
920	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
921	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
922	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
923	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
924	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
925	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
926	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
927	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
928	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
929	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
930	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
931	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
932	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
933	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
934	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative

Table 1. PCR-based data on *Ceratomyxa shasta* in kokanee and whitefish collected from above and below McIntyre Dam in Year 2000

Fish Number	Date Sampled 2000	Lake	Species	Age	*C. shasta* PCR results
935	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
936	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
937	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
938	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
939	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
940	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
941	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
942	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
943	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
944	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
945	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
946	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
947	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
948	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
949	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
950	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
951	14-Sep	N. Okanagan Lk	Kokanee	Fry - 6 months	Negative
952	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
953	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
954	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
955	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
956	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
957	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
958	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
959	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
960	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
961	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
962	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
963	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
964	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
965	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
966	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
967	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
968	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
969	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
970	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
971	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
972	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
973	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
974	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
975	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
976	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
977	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
978	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
979	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
980	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
981	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
982	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
983	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
984	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
985	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
986	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
987	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
988	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
989	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
990	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
991	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
992	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
993	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
994	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
995	19-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative

Table 1. PCR-based data on *Ceratomyxa shasta* in kokanee and whitefish collected from above and below McIntyre Dam in Year 2000

Fish Number	Date Sampled 2000	Lake	Species	Age	*C. shasta* PCR results
996	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
997	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
998	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
999	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1000	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1001	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1002	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1003	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1004	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1005	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1006	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1007	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1008	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1009	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1010	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1011	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1012	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1013	20-Sep	Deep Cr.	Kokanee	Adult-spawner	Negative
1020	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1021	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Positive
1022	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1023	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Positive
1024	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Positive
1025	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Positive
1026	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1027	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Positive
1028	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1029	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1030	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1031	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1032	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1033	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1034	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1035	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1036	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1037	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1038	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1039	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1040	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1041	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1042	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1043	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1044	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1045	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1046	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1047	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1048	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1049	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1050	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1051	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1052	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1053	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1054	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1055	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1056	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1057	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1058	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1059	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1060	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1061	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1062	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative

Table 1. PCR-based data on *Ceratomyxa shasta* in kokanee and whitefish collected from above and below McIntyre Dam in Year 2000

Fish Number	Date Sampled 2000	Lake	Species	Age	*C. shasta* PCR results
1063	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1064	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1065	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1066	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1067	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1068	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1069	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1070	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1071	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1072	21-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1073	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1074	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1075	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1076	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1077	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1078	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1079	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1080	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1081	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1082	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1083	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1084	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1085	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1086	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1087	24-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1088	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1089	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1090	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1091	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1092	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1093	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1094	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1095	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1096	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1097	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1098	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1099	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1100	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1101	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1102	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1103	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1104	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1105	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1106	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1107	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1108	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1109	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1110	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1111	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1112	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1113	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1114	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1115	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1116	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1117	26-Sep	Mission Cr.	Kokanee	Adult-spawner	Negative
1326	20-Nov	Osoyoos Lk	Whitefish		Negative
1336	20-Nov	Osoyoos Lk	Whitefish		Negative
1379	21-Nov	Osoyoos Lk	Whitefish		Negative
1380	21-Nov	Osoyoos Lk	Whitefish		Negative
2000	6-Nov	Okanagan Lk	Whitefish		Negative
2001	6-Nov	Okanagan Lk	Whitefish		Negative

Table 1. PCR-based data on *Ceratomyxa shasta* in kokanee and whitefish collected from above and below McIntyre Dam in Year 2000

Fish Number	Date Sampled 2000	Lake	Species	Age	*C. shasta* PCR results
2002	6-Nov	Okanagan Lk	Whitefish		Negative
2003	6-Nov	Okanagan Lk	Whitefish		Negative
2004	6-Nov	Okanagan Lk	Whitefish		Negative
2005	6-Nov	Okanagan Lk	Whitefish		Negative
2006	6-Nov	Okanagan Lk	Whitefish		Negative
2007	6-Nov	Okanagan Lk	Whitefish		Negative
2008	6-Nov	Okanagan Lk	Whitefish		Negative
2009	6-Nov	Okanagan Lk	Whitefish		Negative
2010	6-Nov	Okanagan Lk	Whitefish		Negative
2011	6-Nov	Okanagan Lk	Whitefish		Negative
2012	6-Nov	Okanagan Lk	Whitefish		Negative
2013	6-Nov	Okanagan Lk	Whitefish		Negative
2014	6-Nov	Okanagan Lk	Whitefish		Negative
2015	6-Nov	Okanagan Lk	Whitefish		Negative
2016	6-Nov	Okanagan Lk	Whitefish		Negative
2017	6-Nov	Okanagan Lk	Whitefish		Negative
2018	6-Nov	Okanagan Lk	Whitefish		Negative
2019	6-Nov	Okanagan Lk	Whitefish		Negative
2020	6-Nov	Okanagan Lk	Whitefish		Negative
2021	6-Nov	Okanagan Lk	Whitefish		Negative
2022	6-Nov	Okanagan Lk	Whitefish		Negative
2023	6-Nov	Okanagan Lk	Whitefish		Negative
2024	6-Nov	Okanagan Lk	Whitefish		Negative
2025	6-Nov	Okanagan Lk	Whitefish		Negative
2026	6-Nov	Okanagan Lk	Whitefish		Negative
2027	6-Nov	Okanagan Lk	Whitefish		Negative
2028	6-Nov	Okanagan Lk	Whitefish		Negative
2029	6-Nov	Okanagan Lk	Whitefish		Negative

Table 2. PCR-based data on Ceratomyxa shasta in kokanee and whitefish collected from above and below McIntyre Dam in Year 2001

Fish Number	Date Sampled 2001	Lake	Species	Age	*C. shasta* PCR results
3001	23-Apr	Okanagan Lk	Whitefish		negative
3002	23-Apr	Okanagan Lk	Whitefish		negative
3003	23-Apr	Okanagan Lk	Whitefish		negative
3004	23-Apr	Okanagan Lk	Whitefish		negative
3005	23-Apr	Okanagan Lk	Whitefish		negative
3006	23-Apr	Okanagan Lk	Whitefish		negative
3007	23-Apr	Okanagan Lk	Whitefish		negative
3008	23-Apr	Okanagan Lk	Whitefish		negative
3009	23-Apr	Okanagan Lk	Whitefish		negative
3010	23-Apr	Okanagan Lk	Whitefish		negative
3011	23-Apr	Okanagan Lk	Whitefish		negative
3012	23-Apr	Okanagan Lk	Whitefish		negative
3013	23-Apr	Okanagan Lk	Whitefish		negative
3014	23-Apr	Okanagan Lk	Whitefish		negative
3015	23-Apr	Okanagan Lk	Whitefish		negative
3016	23-Apr	Okanagan Lk	Whitefish		negative
3017	23-Apr	Okanagan Lk	Whitefish		negative
3018	23-Apr	Okanagan Lk	Whitefish		negative
3019	23-Apr	Okanagan Lk	Whitefish		negative
3081	23-Apr	Skaha Lk	Whitefish		negative
3082	23-Apr	Skaha Lk	Whitefish		negative
3083	23-Apr	Skaha Lk	Whitefish		negative
3084	23-Apr	Skaha Lk	Whitefish		negative
3085	23-Apr	Skaha Lk	Whitefish		negative
3086	23-Apr	Skaha Lk	Whitefish		negative
3156	26-Apr	Osoyoos Lk	Whitefish		negative
3157	26-Apr	Osoyoos Lk	Whitefish		negative
3158	26-Apr	Osoyoos Lk	Whitefish		negative
3159	26-Apr	Osoyoos Lk	Whitefish		negative
3161	26-Apr	Osoyoos Lk	Whitefish		negative
3162	26-Apr	Osoyoos Lk	Whitefish		negative
3165	26-Apr	Osoyoos Lk	Whitefish		negative
3299	3-Jun	Okanagan Lk	Whitefish		negative
3300	3-Jun	Okanagan Lk	Whitefish		negative
3301	3-Jun	Okanagan Lk	Whitefish		negative
3302	3-Jun	Okanagan Lk	Whitefish		negative
3303	3-Jun	Okanagan Lk	Whitefish		negative
3304	3-Jun	Okanagan Lk	Whitefish		negative
3305	3-Jun	Okanagan Lk	Whitefish		negative
3454	5-Jun	Osoyoos Lk	Whitefish		negative
3455	5-Jun	Osoyoos Lk	Whitefish		negative
3456	5-Jun	Osoyoos Lk	Whitefish		negative
4001	21-Aug	Okanagan Lk	Whitefish		negative
4002	21-Aug	Okanagan Lk	Whitefish		negative
4003	21-Aug	Okanagan Lk	Whitefish		negative
4004	21-Aug	Okanagan Lk	Whitefish		negative
4005	21-Aug	Okanagan Lk	Whitefish		negative
4006	21-Aug	Okanagan Lk	Whitefish		negative
4007	21-Aug	Okanagan Lk	Whitefish		negative
4008	21-Aug	Okanagan Lk	Whitefish		negative
4009	21-Aug	Okanagan Lk	Whitefish		negative
4010	21-Aug	Okanagan Lk	Whitefish		negative
4011	21-Aug	Okanagan Lk	Whitefish		negative
4012	21-Aug	Okanagan Lk	Whitefish		negative
4013	21-Aug	Okanagan Lk	Whitefish		negative
4014	21-Aug	Okanagan Lk	Whitefish		negative
4015	21-Aug	Okanagan Lk	Whitefish		negative
4016	21-Aug	Okanagan Lk	Whitefish		negative
4017	21-Aug	Okanagan Lk	Whitefish		negative
4344	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4345	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative

Table 2. PCR-based data on Ceratomyxa shasta in kokanee and whitefish collected from above and below McIntyre Dam in Year 2001

Fish Number	Date Sampled 2001	Lake	Species	Age	*C. shasta* PCR results
4346	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4347	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4348	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4349	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4350	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4351	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4352	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4353	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4354	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4355	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4356	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4357	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4358	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4359	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4360	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4361	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4362	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4363	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4364	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4365	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4366	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4367	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4368	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4369	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4370	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4371	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4372	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4373	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4374	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4375	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4376	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4377	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4378	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4379	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4380	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4381	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4382	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4383	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4384	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4385	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4386	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4387	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4388	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4389	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4390	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4391	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4392	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4393	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4394	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4395	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4396	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4397	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4398	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4399	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4400	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4401	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4402	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4403	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4404	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4405	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4406	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative

Table 2. PCR-based data on Ceratomyxa shasta in kokanee and whitefish collected from above and below McIntyre Dam in Year 2001

Fish Number	Date Sampled 2001	Lake	Species	Age	*C. shasta* PCR results
4407	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4408	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4409	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4410	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4411	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4412	24-Sep	Okanagan Lk-Mission Cr	Kokanee	Adult-spawner	negative
4413	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4414	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4415	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4416	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4417	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4418	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4419	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4420	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4421	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4422	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4423	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4424	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4425	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4426	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4427	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4428	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4429	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4430	27-Sep	Okanagan Lk-Deep Cr	Kokanee	Adult-spawner	negative
4431	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4432	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4433	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4434	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4435	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4436	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4437	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4438	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4439	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4440	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4441	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4442	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4443	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4444	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4445	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4446	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4447	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4448	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4449	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4450	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4451	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4452	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4453	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4454	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4455	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4456	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4457	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4458	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4459	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4460	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4461	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4462	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4463	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4464	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4465	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4466	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4467	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative

Table 2. PCR-based data on Ceratomyxa shasta in kokanee and whitefish collected from above and below McIntyre Dam in Year 2001

Fish Number	Date Sampled 2001	Lake	Species	Age	*C. shasta* PCR results
4468	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4469	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4470	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4471	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4472	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4473	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4474	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4475	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4476	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4477	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4478	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4479	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4480	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4481	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4482	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4483	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4484	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4485	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4486	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4487	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4488	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4489	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4490	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4491	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4492	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4493	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4494	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4495	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4496	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4497	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4498	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4499	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4500	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4501	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4502	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4503	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4504	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4505	2-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4506	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4507	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4508	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4509	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4510	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4511	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4512	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4513	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4514	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4515	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4516	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4517	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4518	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4519	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4520	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4521	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4522	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4523	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4524	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4525	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4526	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4527	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4528	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative

Table 2. PCR-based data on Ceratomyxa shasta in kokanee and whitefish collected from above and below McIntyre Dam in Year 2001

Fish Number	Date Sampled 2001	Lake	Species	Age	*C. shasta* PCR results
4529	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4530	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4531	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4532	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4533	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4534	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4535	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4536	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4537	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4538	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4539	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4540	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4541	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4542	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4543	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4544	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4545	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4546	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4547	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4548	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4549	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4550	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4551	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4552	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4553	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4554	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4555	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4556	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4557	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4558	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4559	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4560	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4561	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4562	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4563	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4564	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4565	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4566	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4567	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4568	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4569	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4570	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4571	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4572	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4573	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4574	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4575	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4576	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4577	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4578	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4579	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4580	15-Oct	Okanagan Lk	Kokanee	fry - 6 months	negative
4581	13-Nov	Okanagan Lk	Whitefish		negative
4582	13-Nov	Okanagan Lk	Whitefish		negative
4583	13-Nov	Okanagan Lk	Whitefish		negative
4584	13-Nov	Okanagan Lk	Whitefish		negative
4585	13-Nov	Okanagan Lk	Whitefish		negative
4586	13-Nov	Okanagan Lk	Whitefish		negative
4587	13-Nov	Okanagan Lk	Whitefish		negative
4588	13-Nov	Okanagan Lk	Whitefish		negative
4589	13-Nov	Okanagan Lk	Whitefish		negative

Table 2. PCR-based data on Ceratomyxa shasta in kokanee and whitefish collected from above and below McIntyre Dam in Year 2001

Fish Number	Date Sampled 2001	Lake	Species	Age	*C. shasta* PCR results
4590	13-Nov	Okanagan Lk	Whitefish		negative
4591	13-Nov	Okanagan Lk	Whitefish		negative
4592	13-Nov	Okanagan Lk	Whitefish		negative
4593	14-Nov	Osoyoos Lk	Whitefish		negative
4594	14-Nov	Osoyoos Lk	Whitefish		negative
4595	14-Nov	Osoyoos Lk	Whitefish		negative
4596	14-Nov	Osoyoos Lk	Whitefish		negative
4606	14-Nov	Osoyoos Lk	Whitefish		negative
4607	14-Nov	Osoyoos Lk	Whitefish		negative
4608	14-Nov	Osoyoos Lk	Whitefish		negative
4609	14-Nov	Osoyoos Lk	Whitefish		negative
4610	14-Nov	Osoyoos Lk	Whitefish		negative
4611	14-Nov	Osoyoos Lk	Whitefish		negative
4612	14-Nov	Osoyoos Lk	Whitefish		negative
4613	14-Nov	Osoyoos Lk	Whitefish		negative
4614	14-Nov	Osoyoos Lk	Whitefish		negative
4615	14-Nov	Osoyoos Lk	Whitefish		negative
4616	14-Nov	Osoyoos Lk	Whitefish		negative
4617	14-Nov	Osoyoos Lk	Whitefish		negative
4618	14-Nov	Osoyoos Lk	Whitefish		negative
4619	14-Nov	Osoyoos Lk	Whitefish		negative
4620	14-Nov	Osoyoos Lk	Whitefish		negative
4621	14-Nov	Osoyoos Lk	Whitefish		negative
4622	14-Nov	Osoyoos Lk	Whitefish		negative
4623	14-Nov	Osoyoos Lk	Whitefish		negative
4624	14-Nov	Osoyoos Lk	Whitefish		negative
4625	14-Nov	Osoyoos Lk	Whitefish		negative
4626	14-Nov	Osoyoos Lk	Whitefish		negative
4627	14-Nov	Osoyoos Lk	Whitefish		negative
4628	14-Nov	Osoyoos Lk	Whitefish		negative
4629	14-Nov	Osoyoos Lk	Whitefish		negative
4630	14-Nov	Osoyoos Lk	Whitefish		negative

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5001	15-Apr	Skaha Lake	WF		26.6		imm F	NVD	NVD	Neg	
5002	15-Apr	Skaha Lake	WF		30.1		imm M	NVD	NVD	Neg	
5003	15-Apr	Skaha Lake	WF		32.4		imm F	NVD	NVD	Neg	
5004	15-Apr	Skaha Lake	PMB		7.7		imm	NVD	NVD		
5005	15-Apr	Skaha Lake	PMB		11.5		imm	NVD	NVD		
5006	15-Apr	Skaha Lake	PMB		8.6		imm	NVD	NVD		
5007	15-Apr	Skaha Lake	PMB		11.9		imm	NVD	NVD		
5008	15-Apr	Skaha Lake	PMB		13.0		imm	NVD	NVD		
5009	15-Apr	Skaha Lake	PMB		9.7		imm	NVD	NVD		
5010	15-Apr	Skaha Lake	NSC		24.2		imm	NVD	NVD		
5011	15-Apr	Skaha Lake	NSC		38.5		imm F ?	NVD	NVD		eye problems
5012	15-Apr	Skaha Lake	NSC		37.8		imm M?	NVD	NVD		
5013	15-Apr	Skaha Lake	NSC		42.5		imm M?	NVD	NVD		
5014	15-Apr	Skaha Lake	NSC		37.6		imm M?	NVD	NVD		
5015	15-Apr	Skaha Lake	NSC		46.5		imm F?	NVD	NVD		
5016	15-Apr	Skaha Lake	SU		38.4		imm M	NVD	NVD		
5017	15-Apr	Skaha Lake	SU		41.7		imm F	NVD	NVD		
5018	15-Apr	Skaha Lake	SU		36.9		imm M	NVD	NVD		
5019	15-Apr	Skaha Lake	SU		36.2		imm	NVD	NVD		
5020	15-Apr	Skaha Lake	SU		36.4		imm	NVD	NVD		
5021	15-Apr	Skaha Lake	SU		39.0		imm F	NVD	NVD		
5022	15-Apr	Skaha Lake	SMB		16.6		imm	NVD	NVD		
5023	15-Apr	Skaha Lake	SMB		22.4		imm	NVD	NVD		
5024	15-Apr	Skaha Lake	SMB		15.2		imm	NVD	NVD		
5025	15-Apr	Skaha Lake	SMB		27.6		imm F	NVD	NVD		
5026	15-Apr	Skaha Lake	SMB		15.3		imm	NVD	NVD		
5027	15-Apr	Skaha Lake	SMB		14.8		imm	NVD	NVD		
5028	15-Apr	Skaha Lake	SMB		26.2		imm F	NVD	NVD		
5029	15-Apr	Skaha Lake	SMB		14.8		imm	NVD	NVD		
5030	15-Apr	Skaha Lake	SMB		7.9		imm	NVD	NVD		
5031	15-Apr	Skaha Lake	SMB		26.1		imm	NVD	NVD		
5032	15-Apr	Skaha Lake	SMB		28.3		imm	NVD	NVD		
5033	15-Apr	Skaha Lake	SMB		17.5		imm	NVD	NVD		
5034	15-Apr	Skaha Lake	SMB		25.0		imm F	NVD	NVD		
5035	15-Apr	Skaha Lake	SMB		33.0		imm F	NVD	NVD		
5036	15-Apr	Skaha Lake	SMB		21.6		imm	NVD	NVD		
5037	15-Apr	Skaha Lake	SMB		8.2		imm	NVD	NVD		Photo 22 w/ HA
5038	15-Apr	Skaha Lake	SMB		8.0		imm	NVD	NVD		Photo 21
5039	15-Apr	Skaha Lake	SMB		30.0		imm	NVD	NVD		
5040	15-Apr	Skaha Lake	SMB		27.9		imm	NVD	NVD		
5041	15-Apr	Skaha Lake	SMB		16.2		imm	NVD	NVD		
5042	15-Apr	Skaha Lake	SMB		14.1		imm	NVD	NVD		
5043	15-Apr	Skaha Lake	SMB		8.5		imm	NVD	NVD		
5044	15-Apr	Skaha Lake	SMB		14.2		imm	NVD	NVD		
5045	15-Apr	Skaha Lake	SMB		7.4		imm	NVD	NVD		
5046	15-Apr	Skaha Lake	SMB		16.0		imm	NVD	NVD		
5047	15-Apr	Skaha Lake	SMB		8.4		imm	NVD	NVD		
5048	15-Apr	Skaha Lake	SMB		14.7		imm	NVD	NVD		
5049	15-Apr	Skaha Lake	SMB		8.3		imm	NVD	NVD		
5050	15-Apr	Skaha Lake	SMB		14.0		imm	NVD	NVD		
5051	15-Apr	Skaha Lake	SMB		15.6		imm	NVD	NVD		
5052	15-Apr	Skaha Lake	SMB		7.4		imm	NVD	NVD		
5053	15-Apr	Skaha Lake	SMB		14.6		imm	NVD	NVD		
5054	15-Apr	Skaha Lake	SMB		14.6		imm	NVD	NVD		
5055	15-Apr	Skaha Lake	SMB		14.4		imm	NVD	NVD		
5056	15-Apr	Skaha Lake	SMB		14.5		imm	NVD	NVD		
5057	15-Apr	Skaha Lake	SMB		7.8		imm	NVD	NVD		
5058	15-Apr	Skaha Lake	SMB		15.7		imm	NVD	NVD		
5059	15-Apr	Skaha Lake	SMB		16.1		imm	NVD	NVD		
5060	15-Apr	Skaha Lake	SMB		16.6		imm	NVD	NVD		
5061	15-Apr	Skaha Lake	SMB		15.3		imm	NVD	NVD		
5062	15-Apr	Skaha Lake	SMB		14.5		imm	NVD	NVD		
5063	15-Apr	Skaha Lake	SMB		15.2		imm	NVD	NVD		
5064	15-Apr	Skaha Lake	SMB		7.8		imm	NVD	NVD		
5065	15-Apr	Skaha Lake	SMB		8.0		imm	NVD	NVD		
5066	15-Apr	Skaha Lake	SMB		8.0		imm	NVD	NVD		
5067	15-Apr	Skaha Lake	SMB		10.9		imm	NVD	NVD		
5068	15-Apr	Skaha Lake	SMB		8.1		imm	NVD	NVD		
5069	15-Apr	Skaha Lake	SMB		8.3		imm	NVD	NVD		
5070	15-Apr	Skaha Lake	SMB		7.7		imm	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5071	15-Apr	Skaha Lake	SMB		8.2		imm	NVD	NVD		
5072	15-Apr	Skaha Lake	SMB		8.4		imm	NVD	NVD		
5073	15-Apr	Skaha Lake	CAS		6.7		imm F	NVD	NVD		
5074	15-Apr	Skaha Lake	CAS		6.9		imm F	NVD	NVD		
5075	15-Apr	Skaha Lake	CAS		8.0		imm F	NVD	NVD		
5076	17-Apr	Osoyoos Lake	WF		13.7		imm	NVD	NVD	Neg	
5077	17-Apr	Osoyoos Lake	WF		13.8		imm	NVD	NVD	Neg	
5078	17-Apr	Osoyoos Lake	WF		15.8		imm	NVD	NVD	Neg	
5079	17-Apr	Osoyoos Lake	WF		15.6		imm	NVD	NVD	Neg	
5080	17-Apr	Osoyoos Lake	WF		16.0		imm	NVD	NVD	Neg	
5081	17-Apr	Osoyoos Lake	WF		14.3		imm	NVD	NVD	Neg	
5082	17-Apr	Osoyoos Lake	WF		15.2		imm	NVD	NVD	Neg	
5083	17-Apr	Osoyoos Lake	WF		15.6		imm	NVD	NVD	Neg	
5084	17-Apr	Osoyoos Lake	WF		15.1		imm	NVD	NVD	Neg	
5085	17-Apr	Osoyoos Lake	WF		16.1		imm	NVD	NVD	Neg	
5086	17-Apr	Osoyoos Lake	WF		24.5		imm F	NVD	NVD	Neg	
5087	17-Apr	Osoyoos Lake	WF		26.6		imm M	NVD	NVD	Neg	
5088	17-Apr	Osoyoos Lake	NSC		38.1		imm	NVD	NVD		
5089	17-Apr	Osoyoos Lake	NSC		35.0		imm	NVD	NVD		
5090	17-Apr	Osoyoos Lake	NSC		14.6		imm	NVD	NVD		
5091	17-Apr	Osoyoos Lake	SU		26.2		imm	NVD	NVD		
5092	17-Apr	Osoyoos Lake	SU		42.0		imm	NVD	NVD		
5093	17-Apr	Osoyoos Lake	SU		44.5		imm	NVD	NVD		
5094	17-Apr	Osoyoos Lake	SU		21.2		imm	NVD	NVD		
5095	17-Apr	Osoyoos Lake	SU		24.8		imm	NVD	NVD		
5096	17-Apr	Osoyoos Lake	SU		42.1		imm	NVD	NVD		
5097	17-Apr	Osoyoos Lake	SU		48.2		imm F	NVD	NVD		
5098	17-Apr	Osoyoos Lake	SU		50.4		imm F	NVD	NVD		
5099	17-Apr	Osoyoos Lake	SU		42.1		imm F	NVD	NVD		
5100	17-Apr	Osoyoos Lake	NSC		13.1		imm	NVD	NVD		
5101	17-Apr	Osoyoos Lake	NSC		48.2		imm F	NVD	NVD		
5102	17-Apr	Osoyoos Lake	NSC		51.5		imm F	NVD	NVD		
5103	17-Apr	Osoyoos Lake	YP		9.8		Sp M	NVD	NVD		
5104	17-Apr	Osoyoos Lake	YP		9.6		Sp M	NVD	NVD		
5105	17-Apr	Osoyoos Lake	YP		11.6		Sp M	NVD	NVD		
5106	17-Apr	Osoyoos Lake	YP		7.6		Sp M	NVD	NVD		
5107	17-Apr	Osoyoos Lake	YP		11.3		Sp M	NVD	NVD		
5108	17-Apr	Osoyoos Lake	YP		12.1		Sp M	NVD	NVD		
5109	17-Apr	Osoyoos Lake	YP		11.0		Sp M	NVD	NVD		
5110	17-Apr	Osoyoos Lake	YP		10.8		Sp M	NVD	NVD		
5111	17-Apr	Osoyoos Lake	YP		10.9		Sp M	NVD	NVD		
5112	17-Apr	Osoyoos Lake	YP		14.9		Sp M	NVD	NVD		
5113	17-Apr	Osoyoos Lake	YP		13.5		Sp M	NVD	NVD		
5114	17-Apr	Osoyoos Lake	YP		11.2		Sp M	NVD	NVD		
5115	17-Apr	Osoyoos Lake	YP		12.2		Sp M	NVD	NVD		
5116	17-Apr	Osoyoos Lake	YP		11.3						
5117	17-Apr	Osoyoos Lake	YP		14.1		Sp M	NVD	NVD		
5118	17-Apr	Osoyoos Lake	YP		17.9		Sp M	NVD	NVD		
5119	17-Apr	Osoyoos Lake	YP		11.0		Sp M	NVD	NVD		
5120	17-Apr	Osoyoos Lake	YP		15.2		Sp M	NVD	NVD		
5121	17-Apr	Osoyoos Lake	YP		13.6		Sp M	NVD	NVD		
5122	17-Apr	Osoyoos Lake	YP		12.1		Sp M	NVD	NVD		
5123	17-Apr	Osoyoos Lake	YP		11.4		Sp M	NVD	NVD		
5124	17-Apr	Osoyoos Lake	YP		16.8		Sp M	NVD	NVD		
5125	17-Apr	Osoyoos Lake	YP		15.9		Sp M	NVD	NVD		
5126	17-Apr	Osoyoos Lake	YP		19.9		Sp M	NVD	NVD		
5127	17-Apr	Osoyoos Lake	YP		10.6		Sp M	NVD	NVD		
5128	17-Apr	Osoyoos Lake	YP		9.9		Sp M	NVD	NVD		
5129	17-Apr	Osoyoos Lake	YP		10.7		Sp M	NVD	NVD		
5130	17-Apr	Osoyoos Lake	YP		10.1		Sp M	NVD	NVD		
5131	17-Apr	Osoyoos Lake	YP		11.2		Sp M	NVD	NVD		
5132	17-Apr	Osoyoos Lake	YP		9.8		Sp M	NVD	NVD		
5133	17-Apr	Osoyoos Lake	YP		9.7		Sp M	NVD	NVD		
5134	17-Apr	Osoyoos Lake	YP		12.2		Sp M	NVD	NVD		
5135	17-Apr	Osoyoos Lake	YP		11.2		Sp M	NVD	NVD		
5136	17-Apr	Osoyoos Lake	YP		11.0		imm	NVD	NVD		
5137	17-Apr	Osoyoos Lake	YP		11.3		Sp M	NVD	NVD		
5138	17-Apr	Osoyoos Lake	YP		12.1		Sp M	NVD	NVD		
5139	17-Apr	Osoyoos Lake	YP		10.6		Sp M	NVD	NVD		
5140	17-Apr	Osoyoos Lake	YP		11.2		Sp M	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5141	17-Apr	Osoyoos Lake	YP		12.6		Sp M	NVD	NVD		
5142	17-Apr	Osoyoos Lake	YP		11.4		Sp M	NVD	NVD		
5143	17-Apr	Osoyoos Lake	YP		12.8		Sp M	NVD	NVD		
5144	17-Apr	Osoyoos Lake	YP		15.3		Sp M	NVD	NVD		
5145	17-Apr	Osoyoos Lake	YP		15.3		Sp M	NVD	NVD		
5146	17-Apr	Osoyoos Lake	YP		12.6		Sp M	NVD	NVD		
5147	17-Apr	Osoyoos Lake	YP		10.4		Sp M	NVD	NVD		
5148	17-Apr	Osoyoos Lake	YP		12.9		Sp M	NVD	NVD		
5149	17-Apr	Osoyoos Lake	YP		12.5		Sp M	NVD	NVD		
5150	17-Apr	Osoyoos Lake	YP		16.2		Sp M	NVD	NVD		
5150	18-Apr	Osoyoos Lake	WF		13.5		imm	NVD	NVD	Neg	
5151	18-Apr	Osoyoos Lake	WF		15.3		imm	NVD	NVD	Neg	
5152	18-Apr	Osoyoos Lake	WF		15.0		imm	NVD	NVD	Neg	
5153	18-Apr	Osoyoos Lake	WF		12.5		imm	NVD	NVD	Neg	
5154	18-Apr	Osoyoos Lake	WF		14.8		imm	NVD	NVD	Neg	
5155	18-Apr	Osoyoos Lake	WF		14.8		imm	NVD	NVD	Neg	
5156	18-Apr	Osoyoos Lake	WF		17.4		imm	NVD	NVD	Neg	
5157	18-Apr	Osoyoos Lake	WF		16.2		imm	NVD	NVD	Neg	
5158	18-Apr	Osoyoos Lake	WF		13.2		imm	NVD	NVD	Neg	
5159	18-Apr	Osoyoos Lake	WF		14.3		imm	NVD	NVD	Neg	
5160	18-Apr	Osoyoos Lake	WF		17.9		imm	NVD	NVD	Neg	
5161	18-Apr	Osoyoos Lake	WF		16.7		imm	NVD	NVD	Neg	
5162	18-Apr	Osoyoos Lake	WF		14.3		imm	NVD	NVD	Neg	
5163	18-Apr	Osoyoos Lake	WF		14.5		imm	NVD	NVD	Neg	
5164	18-Apr	Osoyoos Lake	WF		16.7		imm	NVD	NVD	Neg	
5165	18-Apr	Osoyoos Lake	WF		13.3		imm	NVD	NVD	Neg	
5166	18-Apr	Osoyoos Lake	WF		14.3		imm	NVD	NVD	Neg	
5167	18-Apr	Osoyoos Lake	WF		14.6		imm	NVD	NVD	Neg	
5168	18-Apr	Osoyoos Lake	WF		18.0		imm	NVD	NVD	Neg	
5169	18-Apr	Osoyoos Lake	WF		15.0		imm	NVD	NVD	Neg	
5170	18-Apr	Osoyoos Lake	WF		13.8		imm	NVD	NVD	Neg	
5171	18-Apr	Osoyoos Lake	WF		14.7		imm	NVD	NVD	Neg	
5172	18-Apr	Osoyoos Lake	WF		15.3		imm	NVD	NVD	Neg	
5173	18-Apr	Osoyoos Lake	WF		12.4		imm	NVD	NVD	Neg	
5174	18-Apr	Osoyoos Lake	WF		18.3		imm	NVD	NVD	Neg	
5175	18-Apr	Osoyoos Lake	WF		23.3		imm	NVD	NVD	Neg	
5176	18-Apr	Osoyoos Lake	WF		32.3		imm M	NVD	NVD	Neg	
5177	18-Apr	Osoyoos Lake	WF		35.0		imm F	NVD	NVD	Neg	
5178	18-Apr	Osoyoos Lake	PCC		27.4		imm	NVD	NVD		
5179	18-Apr	Osoyoos Lake	PCC		23.1		F	NVD	NVD		
5180	18-Apr	Osoyoos Lake	PCC		23.9		imm	NVD	NVD		
5181	18-Apr	Osoyoos Lake	NSC		20.5		imm	NVD	NVD		
5182	18-Apr	Osoyoos Lake	NSC		34.1		M	NVD	NVD		
5183	18-Apr	Osoyoos Lake	NSC		32.1		M	NVD	NVD		
5184	18-Apr	Osoyoos Lake	NSC		35.5		imm	NVD	NVD		
5185	18-Apr	Osoyoos Lake	NSC		41.9		imm	NVD	NVD		
5186	18-Apr	Osoyoos Lake	NSC		42.5		F	NVD	NVD		
5187	18-Apr	Osoyoos Lake	SU		39.1		F	NVD	NVD		
5188	18-Apr	Osoyoos Lake	SU		23.6		imm	NVD	NVD		
5189	18-Apr	Osoyoos Lake	SU		24.0		imm	NVD	NVD		
5190	18-Apr	Osoyoos Lake	SU		22.9		imm	NVD	NVD		
5191	18-Apr	Osoyoos Lake	SU		32.5		M	NVD	NVD		
5192	18-Apr	Osoyoos Lake	SU		35.0		imm	NVD	NVD		
5193	18-Apr	Osoyoos Lake	SU		34.0		imm	NVD	NVD		
5194	18-Apr	Osoyoos Lake	SU		43.5		M	NVD	NVD		
5195	18-Apr	Osoyoos Lake	SU		43.0		imm	NVD	NVD		
5196	18-Apr	Osoyoos Lake	SU		46.8		F	NVD	NVD		
5197	18-Apr	Osoyoos Lake	YP		12.2		Sp M	NVD	NVD		
5198	18-Apr	Osoyoos Lake	YP		10.8		Sp M	NVD	NVD		
5199	18-Apr	Osoyoos Lake	YP		11.1		Sp M	NVD	NVD		
5200	18-Apr	Osoyoos Lake	YP		10.4		Sp M	NVD	NVD		
5201	18-Apr	Osoyoos Lake	YP		10.7		Sp M	NVD	NVD		
5202	18-Apr	Osoyoos Lake	YP		11.0		Sp M	NVD	NVD		
5203	18-Apr	Osoyoos Lake	YP		11.1		Sp M	NVD	NVD		
5204	18-Apr	Osoyoos Lake	YP		11.6		Sp M	NVD	NVD		
5205	18-Apr	Osoyoos Lake	YP		11.9		Sp M	NVD	NVD		
5206	18-Apr	Osoyoos Lake	YP		12.4		Sp M	NVD	NVD		
5207	18-Apr	Osoyoos Lake	YP		10.3		Sp M	NVD	NVD		
5208	18-Apr	Osoyoos Lake	YP		11.8		imm	NVD	NVD		
5209	18-Apr	Osoyoos Lake	YP		11.3		Sp M	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5210	18-Apr	Osoyoos Lake	YP		11.3		Sp M	NVD	NVD		
5211	18-Apr	Osoyoos Lake	YP		11.0		Sp M	NVD	NVD		
5212	18-Apr	Osoyoos Lake	YP		11.5		Sp M	NVD	NVD		
5213	18-Apr	Osoyoos Lake	YP		10.8		imm	NVD	NVD		
5214	18-Apr	Osoyoos Lake	YP		11.0		Sp M	NVD	NVD		
5215	18-Apr	Osoyoos Lake	YP		10.0		Sp M	NVD	NVD		
5216	18-Apr	Osoyoos Lake	YP		12.1		Sp M	NVD	NVD		
5217	18-Apr	Osoyoos Lake	YP		10.5		imm	NVD	NVD		
5218	18-Apr	Osoyoos Lake	YP		12.2		imm	NVD	NVD		
5219	18-Apr	Osoyoos Lake	YP		12.8		Sp M	NVD	NVD		
5220	18-Apr	Osoyoos Lake	YP		13.8		Sp M	NVD	NVD		
5221	18-Apr	Osoyoos Lake	YP		12.8		Sp M	NVD	NVD		
5222	18-Apr	Osoyoos Lake	YP		18.2		Sp M	NVD	NVD		
5223	18-Apr	Osoyoos Lake	YP		17.4		Sp M	NVD	NVD		
5224	18-Apr	Osoyoos Lake	YP		17.6		Sp M	NVD	NVD		
5225	18-Apr	Osoyoos Lake	YP		17.2		Sp M	NVD	NVD		
5263	16/17-June	Okanagan Lake	YP		18.0		Mat M	NVD	NVD		
5264	16/17-June	Okanagan Lake	YP		17.9		Mat M	NVD	NVD		
5265	16/17-June	Okanagan Lake	YP		18.6		Mat M	NVD	NVD		
5266	16/17-June	Okanagan Lake	YP		18.8		Mat M	NVD	NVD		
5267	16/17-June	Okanagan Lake	YP		20.0		Mat M	NVD	NVD		
5268	16/17-June	Okanagan Lake	YP		34.0		Mat M	NVD	NVD		
5269	16/17-June	Okanagan Lake	YP		11.0		Mat M	NVD	NVD		
5270	16/17-June	Okanagan Lake	YP		19.5		Mat M	NVD	NVD		
5271	16/17-June	Okanagan Lake	YP		18.0		Mat M	NVD	NVD		
5272	16/17-June	Okanagan Lake	YP		16.3		Mat M	NVD	NVD		
5273	16/17-June	Okanagan Lake	YP		15.5		Mat M	NVD	NVD		
5274	16/17-June	Okanagan Lake	YP		17.5		Mat M	NVD	NVD		
5275	16/17-June	Okanagan Lake	YP		16.5		Mat M	NVD	NVD		
5276	16/17-June	Okanagan Lake	YP		10.9		Mat M	NVD	NVD		
5277	16/17-June	Okanagan Lake	PCC		14.0		Juv	NVD	NVD		
5278	16/17-June	Okanagan Lake	PCC		13.0		Juv	NVD	NVD		
5279	16/17-June	Okanagan Lake	PCC		11.3		Juv	NVD	NVD		
5280	16/17-June	Okanagan Lake	PCC		13.2		Juv	NVD	NVD		
5281	16/17-June	Okanagan Lake	PCC		15.3		Juv	NVD	NVD		
5282	16/17-June	Okanagan Lake	PCC		11.8		Juv	NVD	NVD		
5283	16/17-June	Okanagan Lake	NSC		10.6		Juv	NVD	NVD		
5284	16/17-June	Okanagan Lake	PCC		11.0		Juv	NVD	NVD		
5285	16/17-June	Okanagan Lake	NSC		10.6		Juv	NVD	NVD		
5286	16/17-June	Okanagan Lake	PCC		16.4		Juv	NVD	NVD		
5287	16/17-June	Okanagan Lake	NSC		12.6		Juv	NVD	NVD		
5288	16/17-June	Okanagan Lake	NSC		11.0		Juv	NVD	NVD		
5289	16/17-June	Okanagan Lake	NSC		6.6		Juv	NVD	NVD		
5290	16/17-June	Okanagan Lake	NSC		12.5		Juv	NVD	NVD		
5291	16/17-June	Okanagan Lake	NSC		17.1		Juv	NVD	NVD		
5292	16/17-June	Okanagan Lake	NSC		12.0		Juv	NVD	NVD		
5293	16/17-June	Okanagan Lake	NSC		12.8		Juv	NVD	NVD		
5294	16/17-June	Okanagan Lake	PCC		13.0		Juv	NVD	NVD		External lesion (LHS) ~1cm wide between anus and lateral line
5295	16/17-June	Okanagan Lake	PCC		16.1		Juv	NVD	NVD		
5296	16/17-June	Okanagan Lake	PCC		12.0		Juv	NVD	NVD		
5297	16/17-June	Okanagan Lake	NSC		11.7		Juv	NVD	NVD		
5298	16/17-June	Okanagan Lake	NSC		19.0		Juv	NVD	NVD		
5299	16/17-June	Okanagan Lake	PCC		9.7		Juv	NVD	NVD		
5300	16/17-June	Okanagan Lake	NSC		12.4		Juv	NVD	NVD		
5301	16/17-June	Okanagan Lake	PCC		10.9		Juv	NVD	NVD		
5302	16/17-June	Okanagan Lake	NSC		27.5		Juv	NVD	NVD		
5303	16/17-June	Okanagan Lake	NSC		26.3		Juv	NVD	NVD		
5304	16/17-June	Okanagan Lake	NSC		34.0		Juv	NVD	NVD		
5305	16/17-June	Okanagan Lake	PCC		6.1		Juv	NVD	NVD		
5306	16/17-June	Okanagan Lake	SU		15.0		Imm	NVD	NVD		
5307	16/17-June	Okanagan Lake	SU		13.5		Imm	NVD	NVD		
5308	16/17-June	Okanagan Lake	SU		14.2		Imm	NVD	NVD		
5309	16/17-June	Okanagan Lake	SU		14.0		Imm	NVD	NVD		
5310	16/17-June	Okanagan Lake	PCC		11.6		Juv	NVD	NVD		
5311	16/17-June	Okanagan Lake	SU		13.5		Imm	NVD	NVD		
5312	16/17-June	Okanagan Lake	SU		13.0		Imm	NVD	NVD		
5313	16/17-June	Okanagan Lake	SU		17.5		Imm	NVD	NVD		
5314	16/17-June	Okanagan Lake	SU		29.3		Imm	NVD	NVD		
5315	16/17-June	Okanagan Lake	SU		31.1		Imm	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5316	16/17-June	Okanagan Lake	SU		47.2		Imm M	NVD	NVD		
5317	16/17-June	Okanagan Lake	SU		28.3		M	NVD	NVD		
5318	16/17-June	Okanagan Lake	SU		30.5		M	NVD	NVD		
5319	16/17-June	Okanagan Lake	SU		39.6		Imm F	NVD	NVD		
5320	16/17-June	Okanagan Lake	SU		32.3		Sp F	NVD	NVD		
5321	16/17-June	Okanagan Lake	SU		44.7		Imm	NVD	NVD		
5322	16/17-June	Okanagan Lake	SU		43.9		Imm	NVD	NVD		
5323	16/17-June	Okanagan Lake	SU		15.0		Imm	NVD	NVD		
5324	16/17-June	Okanagan Lake	SU		12.4		Imm	NVD	NVD		
5325	16/17-June	Okanagan Lake	SU		17.4		Imm	NVD	NVD		
5326	16/17-June	Okanagan Lake	SU		20.3		Imm	NVD	NVD		
5327	16/17-June	Okanagan Lake	SU		17.9		Imm	NVD	NVD		
5328	16/17-June	Okanagan Lake	SU		14.3		Imm	NVD	NVD		
5329	16/17-June	Okanagan Lake	SU		11.5		Imm	NVD	NVD		
5330	16/17-June	Okanagan Lake	SU		12.4		Imm	NVD	NVD		
5331	16/17-June	Okanagan Lake	SU		26.0		Imm	NVD	NVD		
5332	16/17-June	Okanagan Lake	SU		31.1		M	NVD	NVD		
5333	16/17-June	Okanagan Lake	SU		28.4		M	NVD	NVD		
5334	16/17-June	Okanagan Lake	SU		32.2		M	NVD	NVD		
5335	16/17-June	Okanagan Lake	SU		29.5		M	NVD	NVD		
5336	16/17-June	Okanagan Lake	SU		32.6		M	NVD	NVD		
5337	16/17-June	Okanagan Lake	SU		19.2		Imm	NVD	NVD		
5338	17-Jun	Skaha Lake	PMB		8.4		Mat F	NVD	NVD		
5339	17-Jun	Skaha Lake	PMB		12.3		Mat M	NVD	NVD		
5340	17-Jun	Skaha Lake	PMB		13.4		Mat F	NVD	NVD		
5341	17-Jun	Skaha Lake	PMB		14.8		Mat F	NVD	NVD		
5342	17-Jun	Skaha Lake	PMB		15.3		M	NVD	NVD		
5343	17-Jun	Skaha Lake	PMB		16.4		Mat F	NVD	NVD		
5344	17-Jun	Skaha Lake	PCC		10.4		Imm	NVD	NVD		
5345	17-Jun	Skaha Lake	PCC		7.6		Imm	NVD	NVD		
5346	17-Jun	Skaha Lake	NSC		10.1		Juv	NVD	NVD		
5347	17-Jun	Skaha Lake	NSC		10.7		Juv	NVD	NVD		
5348	17-Jun	Skaha Lake	NSC		28.6		M	NVD	NVD		
5349	17-Jun	Skaha Lake	SMB		15.1		Imm M	NVD	NVD		
5350	17-Jun	Skaha Lake	SMB		17.1		Imm	NVD	NVD		
5351	17-Jun	Skaha Lake	SMB		15.6		Imm M	NVD	NVD		
5352	17-Jun	Skaha Lake	SMB		14.6		Imm	NVD	NVD		
5353	17-Jun	Skaha Lake	SMB		15.5		Imm	NVD	NVD		
5354	17-Jun	Skaha Lake	SMB		9.9		Imm	NVD	NVD		
5355	17-Jun	Skaha Lake	SMB		14.9		Imm	NVD	NVD		
5356	17-Jun	Skaha Lake	SMB		18.3		Imm M	NVD	NVD		
5357	17-Jun	Skaha Lake	SMB		18.2		Imm M	NVD	NVD		
5358	17-Jun	Skaha Lake	SMB		17.9		Imm	NVD	NVD		
5359	17-Jun	Skaha Lake	SMB		18.1		M	NVD	NVD		
5360	17-Jun	Skaha Lake	SMB		15.0		Imm m	NVD	NVD		
5361	17-Jun	Skaha Lake	SMB		22.7		Imm M	NVD	NVD		
5362	17-Jun	Skaha Lake	SMB		21.2		Imm F	NVD	NVD		
5363	17-Jun	Skaha Lake	SMB		23.7		ImmM	NVD	NVD		
5364	17-Jun	Skaha Lake	SMB		23.8		ImmM	NVD	NVD		
5365	17-Jun	Skaha Lake	SMB		22.8		ImmM	NVD	NVD		
5366	17-Jun	Skaha Lake	SMB		23.0		ImmM	NVD	NVD		
5367	17-Jun	Skaha Lake	SMB		24.3		ImmM	NVD	NVD		
5368	17-Jun	Skaha Lake	SMB		22.9		ImmM	NVD	NVD		
5369	17-Jun	Skaha Lake	SMB		24.6		Mat M	NVD	NVD		
5370	17-Jun	Skaha Lake	SMB		24.2		Imm M	NVD	NVD		
5371	17-Jun	Skaha Lake	SMB		28.2		Mat M	NVD	NVD		
5372	17-Jun	Skaha Lake	SMB		27.5		Mat M	NVD	NVD		
5373	17-Jun	Skaha Lake	SMB		28.6		Mat M	NVD	NVD		
5374	17-Jun	Skaha Lake	SMB		29.4		Imm M	NVD	NVD		
5375	17-Jun	Skaha Lake	SMB		32.1		Mat F	NVD	NVD		
5376	17-Jun	Skaha Lake	NSC		13.2		Juv	NVD	NVD		
5377	17-Jun	Skaha Lake	NSC		22.6		M	NVD	NVD		
5378	17-Jun	Skaha Lake	NSC		19.1		Imm	NVD	NVD		
5379	17-Jun	Skaha Lake	NSC		15.8		Imm	NVD	NVD		
5380	17-Jun	Skaha Lake	NSC		21.5		M	NVD	NVD		
5381	17-Jun	Skaha Lake	NSC		16.4		Imm	NVD	NVD		
5382	17-Jun	Skaha Lake	SU		42.2		Imm	NVD	NVD		
5383	17-Jun	Skaha Lake	SU		39.2		M	NVD	NVD		
5384	17-Jun	Skaha Lake	SU		44.9		Mat F	NVD	NVD		
5385	17-Jun	Skaha Lake	SU		38.5		M	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5386	17-Jun	Skaha Lake	SU		39.7		Imm F	NVD	NVD		
5387	17-Jun	Skaha Lake	SU		37.1		Imm	NVD	NVD		
5388	17-Jun	Skaha Lake	SU		34.2		Imm	NVD	NVD		
5389	17-Jun	Skaha Lake	SU		35.7		Imm M	NVD	NVD		
5390	17-Jun	Skaha Lake	SU		36.7		Imm M	NVD	NVD		
5391	17-Jun	Skaha Lake	SU		37.0		F	NVD	NVD		
5392	17-Jun	Skaha Lake	SU		34.3		Imm M	NVD	NVD		
5393	17-Jun	Skaha Lake	SU		41.0		F	NVD	NVD		
5394	17-Jun	Skaha Lake	PCC		28.6		Imm F	NVD	NVD		
5395	17-Jun	Skaha Lake	YP		18.2		M	NVD	NVD		
5396	17-Jun	Skaha Lake	YP		10.2		Juv	NVD	NVD		
5397	17-Jun	Skaha Lake	YP		8.8		Juv	NVD	NVD		
5398	17-Jun	Skaha Lake	SU		40.6		Mat F	NVD	NVD		
5399	17-Jun	Skaha Lake	SU		44.1		Mat F	NVD	NVD		
5400	17-Jun	Skaha Lake	SU		47.3		Imm F	NVD	NVD		
5401	17-Jun	Skaha Lake	SU		42.6		Mat F	NVD	NVD		
5402	17-Jun	Skaha Lake	SU		38.3		Imm F	NVD	NVD		
5403	17-Jun	Skaha Lake	SU		36.3		M	NVD	NVD		Lesions
5404	17-Jun	Skaha Lake	SU		44.4		Imm M	NVD	NVD		Spawning colors
5405	17-Jun	Skaha Lake	SU		39.6		Imm F	NVD	NVD		Parasite/Bumps under skin
5406	17-Jun	Skaha Lake	SU		38.4		Imm M	NVD	NVD		Parasite/Bumps under skin
5407	17-Jun	Skaha Lake	SU		37.9		Mat F	NVD	NVD		
5408	17-Jun	Skaha Lake	SU		38.9		Imm	NVD	NVD		
5409	17-Jun	Skaha Lake	SU		40.1		Imm M	NVD	NVD		
5410	17-Jun	Skaha Lake	CAS		8.0		Imm F	NVD	NVD		
5411	17-Jun	Skaha Lake	CAS		6.8		Imm F	NVD	NVD		
5412	17-Jun	Skaha Lake	CAS		5.9		Imm F	NVD	NVD		
5413	17-Jun	Skaha Lake	CAS		6.7		Imm	NVD	NVD		
5414	17-Jun	Skaha Lake	CAS		7.4		Imm	NVD	NVD		
5415	17-Jun	Skaha Lake	CAS		8.6		Imm	NVD	NVD		
5417	19-Jun	Osoyoos Lake	WF		7.4		Juv	NVD	NVD	Neg	
5418	19-Jun	Osoyoos Lake	WF		5.3		Juv	NVD	NVD	Neg	
5419	19-Jun	Osoyoos Lake	WF		16.3		Imm	NVD	NVD	Neg	
5420	19-Jun	Osoyoos Lake	WF		15.9		Imm	NVD	NVD	Neg	
5421	19-Jun	Osoyoos Lake	WF		16.2		Imm	NVD	NVD	Neg	
5422	19-Jun	Osoyoos Lake	WF		17.5		Imm	NVD	NVD	Neg	
5423	19-Jun	Osoyoos Lake	WF		17.4		Imm	NVD	NVD	Neg	
5424	19-Jun	Osoyoos Lake	WF		16.3		Imm	NVD	NVD	Neg	
5425	19-Jun	Osoyoos Lake	WF		16.7		Imm	NVD	NVD	Neg	
5426	19-Jun	Osoyoos Lake	WF		18.6		Imm	NVD	NVD	Neg	
5427	19-Jun	Osoyoos Lake	WF		17.9		Imm	NVD	NVD	Neg	
5428	19-Jun	Osoyoos Lake	WF		19.0		Imm	NVD	NVD	Neg	Scarring
5429	19-Jun	Osoyoos Lake	WF		18.3		Imm	NVD	NVD	Neg	
5430	19-Jun	Osoyoos Lake	WF		17.6		Imm	NVD	NVD	Neg	
5431	19-Jun	Osoyoos Lake	WF		17.2		Imm	NVD	NVD	Neg	
5432	19-Jun	Osoyoos Lake	WF		19.5		Imm	NVD	NVD	Neg	
5433	19-Jun	Osoyoos Lake	PCC		17.3		Imm	NVD	NVD		Was misidentified in field as a WF
5434	19-Jun	Osoyoos Lake	WF		19.1		Imm	NVD	NVD	Neg	
5435	19-Jun	Osoyoos Lake	WF		18.7		Imm	NVD	NVD	Neg	
5436	19-Jun	Osoyoos Lake	WF		18.7		Imm	NVD	NVD	Neg	
5437	19-Jun	Osoyoos Lake	WF		20.2		Imm	NVD	NVD	Neg	
5438	19-Jun	Osoyoos Lake	YP		8.7		Imm	NVD	NVD		
5439	19-Jun	Osoyoos Lake	YP		8.8		Imm	NVD	NVD		
5440	19-Jun	Osoyoos Lake	YP		10.4		Imm	NVD	NVD		
5441	19-Jun	Osoyoos Lake	YP		8.3		Imm	NVD	NVD		
5442	19-Jun	Osoyoos Lake	YP		10.8		Imm	NVD	NVD		
5443	19-Jun	Osoyoos Lake	YP		11.2		Imm	NVD	NVD		
5444	19-Jun	Osoyoos Lake	YP		10.3		Imm	NVD	NVD		
5445	19-Jun	Osoyoos Lake	YP		11.4		Imm	NVD	NVD		
5446	19-Jun	Osoyoos Lake	YP		11.1		Imm	NVD	NVD		
5447	19-Jun	Osoyoos Lake	YP		12.3		Imm	NVD	NVD		
5448	19-Jun	Osoyoos Lake	YP		11.9		Imm	NVD	NVD		
5449	19-Jun	Osoyoos Lake	YP		21.0		Imm	NVD	NVD		
5450	19-Jun	Osoyoos Lake	YP		6.5		Imm	NVD	NVD		
5451	19-Jun	Osoyoos Lake	SMB		9.9		Imm	NVD	NVD		
5452	19-Jun	Osoyoos Lake	SMB		15.2		Imm	NVD	NVD		
5453	19-Jun	Osoyoos Lake	SMB		21.3		F	NVD	NVD		
5454	19-Jun	Osoyoos Lake	SMB		29.4		F	NVD	NVD		
5455	19-Jun	Osoyoos Lake	SMB		34.0		M	NVD	NVD		
5456	19-Jun	Osoyoos Lake	SMB		36.1		F	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5457	19-Jun	Osoyoos Lake	SMB		32.6		F	NVD	NVD		
5458	19-Jun	Osoyoos Lake	SU		13.1		M	NVD	NVD		
5459	19-Jun	Osoyoos Lake	SU		14.8		Imm F	NVD	NVD		Circular soft spot
5460	19-Jun	Osoyoos Lake	SU		12.7		Imm M	NVD	NVD		
5461	19-Jun	Osoyoos Lake	SU		13.7		Imm	NVD	NVD		
5462	19-Jun	Osoyoos Lake	SU		12.5		M	NVD	NVD		Bleeding from pectoral fin
5463	19-Jun	Osoyoos Lake	SU		15.0		M	NVD	NVD		
5464	19-Jun	Osoyoos Lake	SU		24.5		Imm M	NVD	NVD		
5465	19-Jun	Osoyoos Lake	SU		23.0		Imm M	NVD	NVD		
5466	19-Jun	Osoyoos Lake	SU		22.2		Mat M	NVD	NVD		
5467	19-Jun	Osoyoos Lake	SU		19.0		Imm	NVD	NVD		
5468	19-Jun	Osoyoos Lake	CAS		9.6		Imm	NVD	NVD		
5469	19-Jun	Osoyoos Lake	CAS		6.3		Imm	NVD	NVD		
5470	19-Jun	Osoyoos Lake	CAS		5.5		ImmF	NVD	NVD		
5471	19-Jun	Osoyoos Lake	SU		20.5		Mat m	NVD	NVD		
5472	19-Jun	Osoyoos Lake	SU		22.0		Imm M	NVD	NVD		Red lips
5473	19-Jun	Osoyoos Lake	SU		22.6		Imm M	NVD	NVD		Cut on belly
5474	19-Jun	Osoyoos Lake	SU		22.0		Imm	NVD	NVD		Red marks on body
5475	19-Jun	Osoyoos Lake	SU		23.1		Mat M	NVD	NVD		
5476	19-Jun	Osoyoos Lake	SU		26.5		Mat M	NVD	NVD		Red marks on lips
5477	19-Jun	Osoyoos Lake	SU		23.5		Mat M	NVD	NVD		
5478	19-Jun	Osoyoos Lake	SU		22.2		M	NVD	NVD		
5479	19-Jun	Osoyoos Lake	SU		21.3		M	NVD	NVD		
5480	19-Jun	Osoyoos Lake	SU		23.5		Imm M	NVD	NVD		
5481	19-Jun	Osoyoos Lake	SU		23.7		Mat M	NVD	NVD		Red marks on body
5482	19-Jun	Osoyoos Lake	SU		45.9		Mat F	NVD	NVD		Skull deformed
5483	19-Jun	Osoyoos Lake	SU		49.2		Mat F	NVD	NVD		
5484	19-Jun	Osoyoos Lake	SU		44.5		Mat F	NVD	NVD		
5485	20-Jun	Osoyoos Lake	WF		15.7		Imm	NVD	NVD	Neg	
5486	20-Jun	Osoyoos Lake	WF		18.0		Imm	NVD	NVD	Neg	
5487	20-Jun	Osoyoos Lake	WF		16.5		Imm	NVD	NVD	Neg	
5488	20-Jun	Osoyoos Lake	WF		18.0		Imm	NVD	NVD	Neg	
5489	20-Jun	Osoyoos Lake	WF		17.0		Imm	NVD	NVD	Neg	
5490	20-Jun	Osoyoos Lake	WF		16.0		Imm	NVD	NVD	Neg	
5491	20-Jun	Osoyoos Lake	WF		15.5		Imm	NVD	NVD	Neg	
5492	20-Jun	Osoyoos Lake	WF		19.2		Imm	NVD	NVD	Neg	
5493	20-Jun	Osoyoos Lake	WF		16.1		Imm	NVD	NVD	Neg	
5494	20-Jun	Osoyoos Lake	WF		16.1		Imm	NVD	NVD	Neg	
5495	20-Jun	Osoyoos Lake	WF		16.0		Imm	NVD	NVD	Neg	
5496	20-Jun	Osoyoos Lake	WF		17.5		Imm	NVD	NVD	Neg	
5497	20-Jun	Osoyoos Lake	WF		18.0		Imm	NVD	NVD	Neg	
5498	20-Jun	Osoyoos Lake	WF		18.5		Imm	NVD	NVD	Neg	
5499	20-Jun	Osoyoos Lake	WF		15.5		Imm	NVD	NVD	Neg	
5500	20-Jun	Osoyoos Lake	WF		19.0		Imm	NVD	NVD	Neg	
5501	20-Jun	Osoyoos Lake	WF		6.5		Imm	NVD	NVD	Neg	
5502	20-Jun	Osoyoos Lake	NSC		14.2		Imm	NVD	NVD		
5503	20-Jun	Osoyoos Lake	NSC		13.5		Imm	NVD	NVD		
5504	20-Jun	Osoyoos Lake	NSC		27.2		M	NVD	NVD		
5505	20-Jun	Osoyoos Lake	NSC		26.0		M	NVD	NVD		Missing left eye
5506	20-Jun	Osoyoos Lake	NSC		42.0		F	NVD	NVD		No left eye, scars
5507	20-Jun	Osoyoos Lake	CAS		10.3		Imm	NVD	NVD		
5508	20-Jun	Osoyoos Lake	CAS		9.5		Imm F	NVD	NVD		
5509	20-Jun	Osoyoos Lake	CAS		6.7		Imm	NVD	NVD		
5510	20-Jun	Osoyoos Lake	CAS		6.5		Imm	NVD	NVD		
5511	20-Jun	Osoyoos Lake	CAS		7.5		Imm	NVD	NVD		
5512	20-Jun	Osoyoos Lake	SU		46.5		F	NVD	NVD		
5513	20-Jun	Osoyoos Lake	SU		25.0		Imm M	NVD	NVD		
5514	20-Jun	Osoyoos Lake	SU		26.5		M	NVD	NVD		
5515	20-Jun	Osoyoos Lake	SU		25.5		Imm M	NVD	NVD		
5516	20-Jun	Osoyoos Lake	SU		21.0		Imm M	NVD	NVD		
5517	20-Jun	Osoyoos Lake	SU		48.5		F	NVD	NVD		
5518	20-Jun	Osoyoos Lake	SU		45.7		F	NVD	NVD		
5519	20-Jun	Osoyoos Lake	SU		44.0		M	NVD	NVD		
5520	20-Jun	Osoyoos Lake	SU		26.0		M	NVD	NVD		
5521	20-Jun	Osoyoos Lake	SU		23.5		Imm	NVD	NVD		
5522	20-Jun	Osoyoos Lake	SU		23.5		Imm	NVD	NVD		
5523	20-Jun	Osoyoos Lake	SU		21.2		Imm	NVD	NVD		
5524	20-Jun	Osoyoos Lake	SU		22.0		Mat M	NVD	NVD		
5525	20-Jun	Osoyoos Lake	SU		20.0		Mat M	NVD	NVD		
5526	20-Jun	Osoyoos Lake	SU		13.7		Imm	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5527	20-Jun	Osoyoos Lake	SU		14.5		Imm	NVD	NVD		
5528	20-Jun	Osoyoos Lake	SU		12.3		Imm	NVD	NVD		
5529	20-Jun	Osoyoos Lake	SMB		20.0		Imm M	NVD	NVD		
5530	20-Jun	Osoyoos Lake	SMB		29.5		Mat M	NVD	NVD		
5531	20-Jun	Osoyoos Lake	SMB		26.5		Mat M	NVD	NVD		
5532	20-Jun	Osoyoos Lake	CAS		6.7		Imm	NVD	NVD		
5533	20-Jun	Osoyoos Lake	SMB		39.0		Mat M	NVD	NVD		
5534	20-Jun	Osoyoos Lake	SMB		31.5		Mat M	NVD	NVD		
5535	20-Jun	Osoyoos Lake	SMB		35.2		Mat M	NVD	NVD		
5536	20-Jun	Osoyoos Lake	SMB		39.0		Mat F	NVD	NVD		
5537	20-Jun	Osoyoos Lake	SMB		36.5		Mat M	NVD	NVD		
5538	20-Jun	Osoyoos Lake	SMB		27.5		Mat F	NVD	NVD		
5539	20-Jun	Osoyoos Lake	SMB		28.0		Mat F	NVD	NVD		
5540	20-Jun	Osoyoos Lake	SMB		19.8		Imm M	NVD	NVD		
5541	20-Jun	Osoyoos Lake	SU		40.0		Mat M	NVD	NVD		
5542	24-Jun	Okanagan Lake	PMB		5.1		Juv	NVD	NVD		
5543	24-Jun	Okanagan Lake	PMB		5.4		Imm	NVD	NVD		
5544	24-Jun	Okanagan Lake	PMB		5.0		Juv	NVD	NVD		
5545	24-Jun	Okanagan Lake	PMB		4.9		Imm	NVD	NVD		
5546	24-Jun	Okanagan Lake	PMB		5.2		Juv	NVD	NVD		
5547	24-Jun	Okanagan Lake	PMB		5.5		Imm	NVD	NVD		
5548	24-Jun	Okanagan Lake	PMB		6.2		Imm	NVD	NVD		
5549	24-Jun	Okanagan Lake	PMB		7.2		Imm	NVD	NVD		
5550	24-Jun	Okanagan Lake	PMB		7.2		Imm	NVD	NVD		
5551	24-Jun	Okanagan Lake	PMB		8.6		F	NVD	NVD		
5552	24-Jun	Okanagan Lake	PMB		9.0		Imm	NVD	NVD		
5553	24-Jun	Okanagan Lake	PMB		10.0		Imm	NVD	NVD		
5554	24-Jun	Okanagan Lake	PMB		9.5		Imm	NVD	NVD		
5555	24-Jun	Okanagan Lake	PMB		9.7		M	NVD	NVD		
5556	24-Jun	Okanagan Lake	PMB		11.0		M	NVD	NVD		
5557	24-Jun	Okanagan Lake	YP		10.0		Imm	NVD	NVD		
5558	24-Jun	Okanagan Lake	YP		11.2		Imm	NVD	NVD		
5559	24-Jun	Okanagan Lake	YP		9.1		Imm	NVD	NVD		
5560	24-Jun	Okanagan Lake	YP		12.2		M	NVD	NVD		
5561	24-Jun	Okanagan Lake	YP		9.9		Imm	NVD	NVD		
5562	24-Jun	Okanagan Lake	YP		11.8		Imm	NVD	NVD		
5563	24-Jun	Okanagan Lake	YP		19.4		M	NVD	NVD		
5564	24-Jun	Okanagan Lake	YP		21.3		M	NVD	NVD		
5565	24-Jun	Okanagan Lake	PCC		12.1		Imm	NVD	NVD		
5566	24-Jun	Okanagan Lake	PCC		12.9		Imm	NVD	NVD		
5567	24-Jun	Okanagan Lake	PCC		15.6		Imm	NVD	NVD		
5568	24-Jun	Okanagan Lake	PCC		12.9		Imm	NVD	NVD		scarred
5569	24-Jun	Okanagan Lake	PCC		14.5		Imm	NVD	NVD		
5570	24-Jun	Okanagan Lake	PCC		18.5		Imm	NVD	NVD		Swollen kidney/red spleen
5571	24-Jun	Okanagan Lake	PCC		19.5		Imm	NVD	NVD		Hemorrhage on lips
5572	24-Jun	Okanagan Lake	PCC		21.5		Imm	NVD	NVD		
5573	24-Jun	Okanagan Lake	RSC		4.7		Imm	NVD	NVD		
5574	24-Jun	Okanagan Lake	RSC		4.8		Imm	NVD	NVD		
5575	24-Jun	Okanagan Lake	RSC		4.9		Imm	NVD	NVD		
5576	24-Jun	Okanagan Lake	RSC		5.7		Imm	NVD	NVD		
5577	24-Jun	Okanagan Lake	RSC		5.5		Imm	NVD	NVD		
5578	24-Jun	Okanagan Lake	RSC		5.3		Imm	NVD	NVD		
5579	24-Jun	Okanagan Lake	RSC		6.4		M	NVD	NVD		
5580	24-Jun	Okanagan Lake	RSC		6.3		Imm	NVD	NVD		
5581	24-Jun	Okanagan Lake	RSC		6.5		Imm	NVD	NVD		
5582	24-Jun	Okanagan Lake	RSC		5.7		Imm	NVD	NVD		
5583	24-Jun	Okanagan Lake	RSC		6.5		Imm	NVD	NVD		
5584	24-Jun	Okanagan Lake	RSC		6.0		Imm	NVD	NVD		
5585	24-Jun	Okanagan Lake	RSC		6.3		Imm	NVD	NVD		
5586	24-Jun	Okanagan Lake	RSC		7.0		Imm	NVD	NVD		
5587	24-Jun	Okanagan Lake	RSC		7.5		Imm	NVD	NVD		
5588	24-Jun	Okanagan Lake	RSC		7.2		F	NVD	NVD		
5589	24-Jun	Okanagan Lake	RSC		7.3		F	NVD	NVD		
5590	24-Jun	Okanagan Lake	RSC		8.3		F	NVD	NVD		
5591	24-Jun	Okanagan Lake	RSC		8.2		F	NVD	NVD		
5592	24-Jun	Okanagan Lake	CAS		5.8		Juv	NVD	NVD		
5593	24-Jun	Okanagan Lake	CAS		6.4		Juv	NVD	NVD		
5594	24-Jun	Okanagan Lake	CAS		6.9		Juv	NVD	NVD		
5595	24-Jun	Okanagan Lake	CAS		9.3		Juv	NVD	NVD		
5596	24-Jun	Okanagan Lake	PCC		12.4		Imm	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5597	24-Jun	Okanagan Lake	NSC		9.7		F	NVD	NVD		
5598	24-Jun	Okanagan Lake	NSC		12.4		Juv	NVD	NVD		
5599	24-Jun	Okanagan Lake	NSC		12.2		Juv	NVD	NVD		
5600	24-Jun	Okanagan Lake	NSC		10.7		M	NVD	NVD		
5601	24-Jun	Okanagan Lake	NSC		12.0		Juv	NVD	NVD		
5602	24-Jun	Okanagan Lake	NSC		12.0		Juv	NVD	NVD		
5603	24-Jun	Okanagan Lake	NSC		10.7		M	NVD	NVD		
5604	24-Jun	Okanagan Lake	NSC		11.7		Juv	NVD	NVD		
5605	24-Jun	Okanagan Lake	NSC		13.8		M	NVD	NVD		
5606	24-Jun	Okanagan Lake	NSC		10.2		Juv	NVD	NVD		
5607	24-Jun	Okanagan Lake	NSC		16.1		Imm	NVD	NVD		
5608	24-Jun	Okanagan Lake	NSC		14.6		Juv	NVD	NVD		
5609	24-Jun	Okanagan Lake	NSC		15.6		Juv	NVD	NVD		
5610	24-Jun	Okanagan Lake	NSC		25.6		Imm	NVD	NVD		
5611	24-Jun	Okanagan Lake	SU		8.1		Imm	NVD	NVD		Hemorrhage and pale
5612	24-Jun	Okanagan Lake	SU		12.7		Imm	NVD	NVD		
5613	24-Jun	Okanagan Lake	SU		13.6		Imm	NVD	NVD		
5614	24-Jun	Okanagan Lake	SU		13.1		Imm	NVD	NVD		
5615	24-Jun	Okanagan Lake	SU		12.5		Imm	NVD	NVD		
5616	24-Jun	Okanagan Lake	SU		39.6		M	NVD	NVD		
5765	02-Jul	Okanagan Lake	KO		6.7	2 months		NVD	NVD	Neg	
5766	02-Jul	Okanagan Lake	KO		4.9	2 months		NVD	NVD	Neg	
5767	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5768	02-Jul	Okanagan Lake	KO		3.1	2 months		NVD	NVD	Neg	
5769	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5770	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5771	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5772	02-Jul	Okanagan Lake	KO		3.8	2 months		NVD	NVD	Neg	
5773	02-Jul	Okanagan Lake	KO		4.1	2 months		NVD	NVD	Neg	
5774	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5775	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5776	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5777	02-Jul	Okanagan Lake	KO		4.8	2 months		NVD	NVD	Neg	
5778	02-Jul	Okanagan Lake	KO		4.8	2 months		NVD	NVD	Neg	
5779	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5780	02-Jul	Okanagan Lake	KO		4.1	2 months		NVD	NVD	Neg	
5781	02-Jul	Okanagan Lake	KO		4.9	2 months		NVD	NVD	Neg	
5782	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5783	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5784	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5785	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5786	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5787	02-Jul	Okanagan Lake	KO		3.7	2 months		NVD	NVD	Neg	
5788	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5789	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5790	02-Jul	Okanagan Lake	KO		4.9	2 months		NVD	NVD	Neg	
5791	02-Jul	Okanagan Lake	KO		3.4	2 months		NVD	NVD	Neg	
5792	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5793	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5794	02-Jul	Okanagan Lake	KO		4.0	2 months		NVD	NVD	Neg	
5795	02-Jul	Okanagan Lake	KO		5.4	2 months		NVD	NVD	Neg	
5796	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5797	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5798	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5799	02-Jul	Okanagan Lake	KO		3.9	2 months		NVD	NVD	Neg	
5800	02-Jul	Okanagan Lake	KO		4.1	2 months		NVD	NVD	Neg	
5801	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5802	02-Jul	Okanagan Lake	KO		4.9	2 months		NVD	NVD	Neg	
5803	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5804	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5805	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5806	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5807	02-Jul	Okanagan Lake	KO		5.0	2 months		NVD	NVD	Neg	
5808	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5809	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5810	02-Jul	Okanagan Lake	KO		4.9	2 months		NVD	NVD	Neg	
5811	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5812	02-Jul	Okanagan Lake	KO		5.2	2 months		NVD	NVD	Neg	
5813	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5814	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5815	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5816	02-Jul	Okanagan Lake	KO		5.1	2 months		NVD	NVD	Neg	
5817	02-Jul	Okanagan Lake	KO		4.8	2 months		NVD	NVD	Neg	
5818	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5819	02-Jul	Okanagan Lake	KO		3.5	2 months		NVD	NVD	Neg	
5820	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5821	02-Jul	Okanagan Lake	KO		5.3	2 months		NVD	NVD	Neg	
5822	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5823	02-Jul	Okanagan Lake	KO		5.0	2 months		NVD	NVD	Neg	
5824	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5825	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5826	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5827	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5828	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5829	02-Jul	Okanagan Lake	KO		5.2	2 months		NVD	NVD	Neg	
5830	02-Jul	Okanagan Lake	KO		4.8	2 months		NVD	NVD	Neg	
5831	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5832	02-Jul	Okanagan Lake	KO		3.0	2 months		NVD	NVD	Neg	
5833	02-Jul	Okanagan Lake	KO		4.8	2 months		NVD	NVD	Neg	
5834	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5835	02-Jul	Okanagan Lake	KO		4.8	2 months		NVD	NVD	Neg	
5836	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5837	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5838	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5839	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5840	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5841	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5842	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5843	02-Jul	Okanagan Lake	KO		4.0	2 months		NVD	NVD	Neg	
5844	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5845	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5846	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5847	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5848	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5849	02-Jul	Okanagan Lake	KO		4.8	2 months		NVD	NVD	Neg	
5850	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5851	02-Jul	Okanagan Lake	KO		5.5	2 months		NVD	NVD	Neg	
5852	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5853	02-Jul	Okanagan Lake	KO		3.2	2 months		NVD	NVD	Neg	
5854	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5855	02-Jul	Okanagan Lake	KO		4.8	2 months		NVD	NVD	Neg	
5856	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5857	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5858	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5859	02-Jul	Okanagan Lake	KO		3.6	2 months		NVD	NVD	Neg	
5860	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5861	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5862	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5863	02-Jul	Okanagan Lake	KO		5.2	2 months		NVD	NVD	Neg	
5864	02-Jul	Okanagan Lake	KO		4.0	2 months		NVD	NVD	Neg	
5865	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5866	02-Jul	Okanagan Lake	KO		2.9	2 months		NVD	NVD	Neg	
5867	02-Jul	Okanagan Lake	KO		4.1	2 months		NVD	NVD	Neg	
5868	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5869	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5870	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5871	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5872	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5873	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5874	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5875	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5876	02-Jul	Okanagan Lake	KO		4.0	2 months		NVD	NVD	Neg	
5877	02-Jul	Okanagan Lake	KO		4.1	2 months		NVD	NVD	Neg	
5878	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5879	02-Jul	Okanagan Lake	KO		3.3	2 months		NVD	NVD	Neg	
5880	02-Jul	Okanagan Lake	KO		5.5	2 months		NVD	NVD	Neg	
5881	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5882	02-Jul	Okanagan Lake	KO		4.9	2 months		NVD	NVD	Neg	
5883	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5884	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5885	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5886	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5887	02-Jul	Okanagan Lake	KO		5.2	2 months		NVD	NVD	Neg	
5888	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5889	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5890	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5891	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5892	02-Jul	Okanagan Lake	KO		4.1	2 months		NVD	NVD	Neg	
5893	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5894	02-Jul	Okanagan Lake	KO		3.8	2 months		NVD	NVD	Neg	
5895	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5896	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5897	02-Jul	Okanagan Lake	KO		3.9	2 months		NVD	NVD	Neg	
5898	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5899	02-Jul	Okanagan Lake	KO		3.5	2 months		NVD	NVD	Neg	
5900	02-Jul	Okanagan Lake	KO		3.9	2 months		NVD	NVD	Neg	
5901	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5902	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5903	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5904	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5905	02-Jul	Okanagan Lake	KO		4.5	2 months		NVD	NVD	Neg	
5906	02-Jul	Okanagan Lake	KO		4.4	2 months		NVD	NVD	Neg	
5907	02-Jul	Okanagan Lake	KO		4.3	2 months		NVD	NVD	Neg	
5908	02-Jul	Okanagan Lake	KO		4.0	2 months		NVD	NVD	Neg	
5909	02-Jul	Okanagan Lake	KO		4.7	2 months		NVD	NVD	Neg	
5910	02-Jul	Okanagan Lake	KO		4.6	2 months		NVD	NVD	Neg	
5911	02-Jul	Okanagan Lake	KO		3.8	2 months		NVD	NVD	Neg	
5912	02-Jul	Okanagan Lake	KO		4.2	2 months		NVD	NVD	Neg	
5913	02-Jul	Okanagan Lake	KO		4.0	2 months		NVD	NVD	Neg	
5914	02-Jul	Okanagan Lake	KO		4.0	2 months		NVD	NVD	Neg	
5915	26-Aug	Okanagan Lake	WF		10.3		Juv	NVD	NVD	Neg	
5916	26-Aug	Okanagan Lake	WF		11.1		Juv	NVD	NVD	Neg	
5917	26-Aug	Okanagan Lake	WF		9.4		Juv	NVD	NVD	Neg	
5918	26-Aug	Okanagan Lake	RSC		6.9		M	NVD	NVD		
5919	26-Aug	Okanagan Lake	WF		10.4		Juv	NVD	NVD	Neg	
5920	26-Aug	Okanagan Lake	WF		10.2		Juv	NVD	NVD	Neg	
5921	26-Aug	Okanagan Lake	WF		9.4		Juv	NVD	NVD	Neg	
5922	26-Aug	Okanagan Lake	RSC		7.0		Juv	NVD	NVD		
5923	26-Aug	Okanagan Lake	RSC		6.1		Juv	NVD	NVD		
5924	26-Aug	Okanagan Lake	RSC		7.1		Imm M	NVD	NVD		
5925	26-Aug	Okanagan Lake	RSC		6.3		Imm	NVD	NVD		
5926	26-Aug	Okanagan Lake	RSC		4.7		Juv	NVD	NVD		
5927	26-Aug	Okanagan Lake	WF		9.6		Juv	NVD	NVD	Neg	
5928	26-Aug	Okanagan Lake	WF		10.0		Juv	NVD	NVD	Neg	
5929	26-Aug	Okanagan Lake	WF		10.9		Juv	NVD	NVD	Neg	
5930	26-Aug	Okanagan Lake	RSC		7.0		Imm	NVD	NVD		
5931	26-Aug	Okanagan Lake	RSC		7.6		M Juv	NVD	NVD		
5932	26-Aug	Okanagan Lake	RSC		7.1		M	NVD	NVD		
5933	26-Aug	Okanagan Lake	RSC		6.4		M	NVD	NVD		
5934	26-Aug	Okanagan Lake	RSC		5.1		Juv	NVD	NVD		
5935	26-Aug	Okanagan Lake	WF		18.9		Juv	NVD	NVD	Neg	Red marks near pelvic fins
5936	26-Aug	Okanagan Lake	WF		11.0		Juv	NVD	NVD	Neg	
5937	26-Aug	Okanagan Lake	WF		10.2		Juv	NVD	NVD	Neg	
5938	26-Aug	Okanagan Lake	WF		9.7		Juv	NVD	NVD	Neg	
5939	26-Aug	Okanagan Lake	WF		9.6		Juv	NVD	NVD	Neg	
5940	26-Aug	Okanagan Lake	YP		6.8		M	NVD	NVD		
5941	26-Aug	Okanagan Lake	RSC		6.3		Juv	NVD	NVD		
5942	26-Aug	Okanagan Lake	WF		19.2		Juv	NVD	NVD	Neg	
5943	26-Aug	Okanagan Lake	WF		10.5		M	NVD	NVD	Neg	
5944	26-Aug	Okanagan Lake	RSC		8.0		M	NVD	NVD		
5945	26-Aug	Okanagan Lake	RSC		5.9		M	NVD	NVD		
5946	26-Aug	Okanagan Lake	RSC		7.9		M	NVD	NVD		
5947	26-Aug	Okanagan Lake	RSC		5.5		Imm	NVD	NVD		
5948	26-Aug	Okanagan Lake	RSC		5.2		Imm	NVD	NVD		
5949	26-Aug	Okanagan Lake	RSC		4.7		Juv	NVD	NVD		
5950	26-Aug	Okanagan Lake	PCC		18.3		Juv	NVD	NVD		
5951	26-Aug	Okanagan Lake	NSC		6.6		Juv	NVD	NVD		
5952	26-Aug	Okanagan Lake	NSC		7.1		Juv	NVD	NVD		
5953	26-Aug	Okanagan Lake	NSC		8.2		Juv	NVD	NVD		
5954	26-Aug	Okanagan Lake	NSC		9.9		Juv	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
5955	26-Aug	Okanagan Lake	NSC		7.4		Juv	NVD	NVD		
5956	26-Aug	Okanagan Lake	NSC		8.6		Juv	NVD	NVD		
5957	26-Aug	Okanagan Lake	NSC		11.4		Juv	NVD	NVD		
5958	26-Aug	Okanagan Lake	PCC		11.6		Juv	NVD	NVD		
5959	26-Aug	Okanagan Lake	NSC		7.7		Juv	NVD	NVD		
5960	26-Aug	Okanagan Lake	NSC		7.3		Juv	NVD	NVD		
5961	26-Aug	Okanagan Lake	NSC		12.5		Juv	NVD	NVD		
5962	26-Aug	Okanagan Lake	NSC		16.8		Juv	NVD	NVD		
5963	26-Aug	Okanagan Lake	NSC		18.8		Juv	NVD	NVD		
5964	26-Aug	Okanagan Lake	PCC		15.8		Juv	NVD	NVD		
5965	26-Aug	Okanagan Lake	NSC		6.6		Juv	NVD	NVD		
5966	26-Aug	Okanagan Lake	NSC		13.1		Juv	NVD	NVD		
5967	26-Aug	Okanagan Lake	NSC		13.0		Juv	NVD	NVD		
5968	26-Aug	Okanagan Lake	NSC		20.1		Juv	NVD	NVD		
5969	26-Aug	Okanagan Lake	NSC		7.7		Juv	NVD	NVD		
5970	26-Aug	Okanagan Lake	NSC		7.7		Juv	NVD	NVD		
5971	26-Aug	Okanagan Lake	NSC		7.8		Juv	NVD	NVD		
5972	26-Aug	Okanagan Lake	NSC		7.4		Juv	NVD	NVD		
5973	26-Aug	Okanagan Lake	NSC		7.2		Juv	NVD	NVD		
5974	26-Aug	Okanagan Lake	NSC		12.1		Juv	NVD	NVD		
5975	26-Aug	Okanagan Lake	PCC		8.9		Juv	NVD	NVD		
5976	26-Aug	Okanagan Lake	YP		14.8		M	NVD	NVD		
5977	26-Aug	Okanagan Lake	RSC		7.5		Juv	NVD	NVD		
5978	26-Aug	Okanagan Lake	CAS		6.5		Juv	NVD	NVD		
5979	26-Aug	Okanagan Lake	CAS		6.5		Juv	NVD	NVD		
5980	26-Aug	Okanagan Lake	NSC		14.0		Juv	NVD	NVD		
5981	26-Aug	Okanagan Lake	NSC		11.6		Juv	NVD	NVD		
5982	26-Aug	Okanagan Lake	PCC		9.2		Juv	NVD	NVD		
5983	26-Aug	Okanagan Lake	PCC		13.0		M	NVD	NVD		
5984	26-Aug	Okanagan Lake	PCC		11.9		Juv	NVD	NVD		
5985	26-Aug	Okanagan Lake	YP		17.0		M	NVD	NVD		
5986	26-Aug	Okanagan Lake	NSC		6.4		Juv	NVD	NVD		
5987	26-Aug	Okanagan Lake	NSC		7.3		Juv	NVD	NVD		
5988	26-Aug	Okanagan Lake	NSC		7.0		Juv	NVD	NVD		
5989	26-Aug	Okanagan Lake	CAS		7.0		Juv	NVD	NVD		
5990	26-Aug	Okanagan Lake	CAS		6.0		Juv	NVD	NVD		
5991	26-Aug	Okanagan Lake	CAS		7.0		Juv	NVD	NVD		
5992	26-Aug	Okanagan Lake	PCC		18.0		M	NVD	NVD		
5993	26-Aug	Okanagan Lake	YP		17.4		M	NVD	NVD		
5994	26-Aug	Okanagan Lake	NSC		40.0		Imm	NVD	NVD		
6000	28-Aug	Osoyoos Lake	BGB		10.1		Imm	NVD	NVD		
6001	28-Aug	Osoyoos Lake	BGB		10.4		Imm	NVD	NVD		
6002	28-Aug	Osoyoos Lake	BGB		12.2		M	NVD	NVD		
6003	28-Aug	Osoyoos Lake	BGB		10.6		M	NVD	NVD		
6004	28-Aug	Osoyoos Lake	PMB		10.4		Mat F	NVD	NVD		
6005	28-Aug	Osoyoos Lake	PMB		9.9		Mat F	NVD	NVD		
6006	28-Aug	Osoyoos Lake	BCB		8.7		Imm	NVD	NVD		
6007	28-Aug	Osoyoos Lake	BCB		8.3		Imm	NVD	NVD		
6008	28-Aug	Osoyoos Lake	BGB		8.7		M	NVD	NVD		
6009	28-Aug	Osoyoos Lake	BGB		7.7		F	NVD	NVD		
6010	28-Aug	Osoyoos Lake	BCB		7.9		Imm	NVD	NVD		
6011	28-Aug	Osoyoos Lake	BGB		8.0		Imm	NVD	NVD		
6012	28-Aug	Osoyoos Lake	BGB		8.9		Imm F	NVD	NVD		
6013	28-Aug	Osoyoos Lake	BGB		9.8		Imm M	NVD	NVD		
6014	28-Aug	Osoyoos Lake	BCB		8.1		Imm	NVD	NVD		
6015	28-Aug	Osoyoos Lake	BCB		7.1		Imm	NVD	NVD		
6016	28-Aug	Osoyoos Lake	BGB		9.0		Imm F	NVD	NVD		
6017	28-Aug	Osoyoos Lake	BGB		8.9		M	NVD	NVD		
6018	28-Aug	Osoyoos Lake	BGB		9.4		Imm	NVD	NVD		
6019	28-Aug	Osoyoos Lake	BCB		6.1		Imm	NVD	NVD		
6020	28-Aug	Osoyoos Lake	BCB		8.2		Imm	NVD	NVD		
6021	28-Aug	Osoyoos Lake	BCB		8.6		Imm	NVD	NVD		
6022	28-Aug	Osoyoos Lake	BCB		5.6		Juv	NVD	NVD		
6023	28-Aug	Osoyoos Lake	BCB		6.8		Imm	NVD	NVD		
6024	28-Aug	Osoyoos Lake	BCB		5.3		Imm	NVD	NVD		
6025	28-Aug	Osoyoos Lake	BCB		5.9		Imm	NVD	NVD		
6026	28-Aug	Osoyoos Lake	BCB		5.4		Imm	NVD	NVD		
6027	28-Aug	Osoyoos Lake	BCB		5.7		Juv	NVD	NVD		
6028	28-Aug	Osoyoos Lake	BCB		5.5		Imm	NVD	NVD		
6029	28-Aug	Osoyoos Lake	BCB		6.2		Juv	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
6030	28-Aug	Osoyoos Lake	BGB		9.4		M	NVD	NVD		
6031	28-Aug	Osoyoos Lake	BCB		8.1		Imm	NVD	NVD		
6032	28-Aug	Osoyoos Lake	BCB		7.2		Imm	NVD	NVD		
6033	28-Aug	Osoyoos Lake	BCB		7.0		Imm	NVD	NVD		
6034	28-Aug	Osoyoos Lake	BCB		6.7		Imm	NVD	NVD		
6035	28-Aug	Osoyoos Lake	BCB		5.0		Imm	NVD	NVD		
6036	28-Aug	Osoyoos Lake	BCB		5.0		Imm	NVD	NVD		
6037	28-Aug	Osoyoos Lake	BCB		4.6		Imm	NVD	NVD		
6038	28-Aug	Osoyoos Lake	BGB		3.3		Imm	NVD	NVD		
6039	28-Aug	Osoyoos Lake	PMB		3.9		Juv	NVD	NVD		
6040	28-Aug	Osoyoos Lake	PMB		3.7		Juv	NVD	NVD		
6041	28-Aug	Osoyoos Lake	SMB		7.1		Imm	NVD	NVD		
6042	28-Aug	Osoyoos Lake	SMB		8.0		Imm	NVD	NVD		
6043	28-Aug	Osoyoos Lake	SMB		7.0		Imm	NVD	NVD		
6044	28-Aug	Osoyoos Lake	SMB		10.0		Imm	NVD	NVD		
6045	28-Aug	Osoyoos Lake	SMB		16.9		Imm	NVD	NVD		
6046	28-Aug	Osoyoos Lake	SMB		17.4		M	NVD	NVD		
6047	28-Aug	Osoyoos Lake	SMB		22.1		M	NVD	NVD		
6048	28-Aug	Osoyoos Lake	SMB		26.1		Imm	NVD	NVD		
6049	28-Aug	Osoyoos Lake	LMB		12.6		M	NVD	NVD		
6050	28-Aug	Osoyoos Lake	LMB		37.5		Imm	NVD	NVD		
6051	28-Aug	Osoyoos Lake	LMB		10.5		Imm	NVD	NVD		
6052	28-Aug	Osoyoos Lake	LMB		10.9		Imm	NVD	NVD		
6053	28-Aug	Osoyoos Lake	LMB		9.6		Imm	NVD	NVD		
6054	28-Aug	Osoyoos Lake	LMB		8.3		Imm	NVD	NVD		
6055	28-Aug	Osoyoos Lake	LMB		7.6		Imm	NVD	NVD		
6056	28-Aug	Osoyoos Lake	LMB		7.7		Imm	NVD	NVD		
6057	28-Aug	Osoyoos Lake	LMB		5.6		Imm	NVD	NVD		
6058	28-Aug	Osoyoos Lake	LMB		7.3		Imm	NVD	NVD		
6059	28-Aug	Osoyoos Lake	LMB		7.6		Imm	NVD	NVD		
6060	28-Aug	Osoyoos Lake	LMB		6.3		Imm	NVD	NVD		
6061	28-Aug	Osoyoos Lake	LMB		8.0		Imm	NVD	NVD		
6062	28-Aug	Osoyoos Lake	LMB		6.8		Imm	NVD	NVD		
6063	28-Aug	Osoyoos Lake	LMB		5.5		Imm	NVD	NVD		
6064	28-Aug	Osoyoos Lake	LMB		6.0		Imm	NVD	NVD		
6065	28-Aug	Osoyoos Lake	CAS		7.3		Imm	NVD	NVD		
6066	28-Aug	Osoyoos Lake	CAS		7.8		Imm	NVD	NVD		
6067	28-Aug	Osoyoos Lake	CAS		8.7		Imm	NVD	NVD		
6068	28-Aug	Osoyoos Lake	CAS		6.9		Imm	NVD	NVD		
6069	28-Aug	Osoyoos Lake	CAS		7.8		Imm	NVD	NVD		
6070	28-Aug	Osoyoos Lake	CAS		8.2		Imm	NVD	NVD		
6071	28-Aug	Osoyoos Lake	CAS		7.4		Imm	NVD	NVD		
6072	28-Aug	Osoyoos Lake	NSC		24.8		F	NVD	NVD		
6073	28-Aug	Osoyoos Lake	NSC		21.2		M	NVD	NVD		
6074	28-Aug	Osoyoos Lake	NSC		19.6		M	NVD	NVD		
6075	04-Sep	Osoyoos Lake	CAS		8.3		Juv	NVD	NVD		
6076	04-Sep	Osoyoos Lake	CAS		7.5		Juv	NVD	NVD		
6077	04-Sep	Osoyoos Lake	CAS		7.4		Juv	NVD	NVD		
6078	04-Sep	Osoyoos Lake	CAS		7.3		Juv	NVD	NVD		
6079	04-Sep	Osoyoos Lake	CAS		9.9		Juv	NVD	NVD		
6080	04-Sep	Osoyoos Lake	CAS		8.8		Juv	NVD	NVD		
6081	04-Sep	Osoyoos Lake	PMB		10.2		F	NVD	NVD		
6082	04-Sep	Osoyoos Lake	PMB		10.1		F	NVD	NVD		
6083	04-Sep	Osoyoos Lake	BGB		4.7		Imm	NVD	NVD		
6084	04-Sep	Osoyoos Lake	BGB		10.9		F	NVD	NVD		
6085	04-Sep	Osoyoos Lake	BGB		10.6		F	NVD	NVD		
6086	04-Sep	Osoyoos Lake	BGB		6.6		Imm	NVD	NVD		
6087	04-Sep	Osoyoos Lake	BGB		8.9		M	NVD	NVD		
6088	04-Sep	Osoyoos Lake	BGB		4.2		Imm	NVD	NVD		
6089	04-Sep	Osoyoos Lake	BGB		7.9		Imm	NVD	NVD		
6090	04-Sep	Osoyoos Lake	BGB		8.0		Imm	NVD	NVD		
6091	04-Sep	Osoyoos Lake	BGB		9.5		Imm	NVD	NVD		
6092	04-Sep	Osoyoos Lake	BGB		7.8		Imm	NVD	NVD		
6093	04-Sep	Osoyoos Lake	BGB		8.1		Imm	NVD	NVD		
6094	04-Sep	Osoyoos Lake	BGB		9.5		Imm	NVD	NVD		
6095	04-Sep	Osoyoos Lake	BGB		8.0		Imm	NVD	NVD		
6096	04-Sep	Osoyoos Lake	BGB		6.7		Imm	NVD	NVD		
6097	04-Sep	Osoyoos Lake	BGB		4.8		Imm	NVD	NVD		
6098	04-Sep	Osoyoos Lake	BCB		9.7		Juv	NVD	NVD		
6099	04-Sep	Osoyoos Lake	BCB		9.1		Juv	NVD	NVD		

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
6100	04-Sep	Osoyoos Lake	BCB		9.0		Juv	NVD	NVD		
6101	04-Sep	Osoyoos Lake	BCB		9.0		Juv	NVD	NVD		
6102	04-Sep	Osoyoos Lake	BCB		8.2		Juv	NVD	NVD		
6103	04-Sep	Osoyoos Lake	BCB		8.6		Juv	NVD	NVD		
6104	04-Sep	Osoyoos Lake	BCB		9.0		Juv	NVD	NVD		
6105	04-Sep	Osoyoos Lake	BCB		8.2		Juv	NVD	NVD		
6106	04-Sep	Osoyoos Lake	BCB		8.5		Juv	NVD	NVD		
6107	04-Sep	Osoyoos Lake	BCB		6.7		Juv	NVD	NVD		
6108	04-Sep	Osoyoos Lake	BCB		8.8		Juv	NVD	NVD		
6109	04-Sep	Osoyoos Lake	BCB		6.5		Juv	NVD	NVD		
6110	04-Sep	Osoyoos Lake	BCB		7.8		Juv	NVD	NVD		
6111	04-Sep	Osoyoos Lake	BCB		9.4		Juv	NVD	NVD		
6112	04-Sep	Osoyoos Lake	BCB		7.4		Juv	NVD	NVD		
6113	04-Sep	Osoyoos Lake	BCB		8.8		Juv	NVD	NVD		
6114	04-Sep	Osoyoos Lake	BCB		6.8		Juv	NVD	NVD		
6115	04-Sep	Osoyoos Lake	LMB		11.0		Imm	NVD	NVD		
6116	04-Sep	Osoyoos Lake	LMB		10.0		Imm	NVD	NVD		
6117	04-Sep	Osoyoos Lake	LMB		7.5		Imm	NVD	NVD		
6118	04-Sep	Osoyoos Lake	LMB		10.0		Imm	NVD	NVD		
6119	04-Sep	Osoyoos Lake	LMB		7.5		Imm	NVD	NVD		
6120	04-Sep	Osoyoos Lake	LMB		10.6		Imm	NVD	NVD		
6121	04-Sep	Osoyoos Lake	LMB		6.8		Imm	NVD	NVD		
6122	04-Sep	Osoyoos Lake	LMB		6.4		Imm	NVD	NVD		
6123	04-Sep	Osoyoos Lake	LMB		7.5		Imm	NVD	NVD		
6124	04-Sep	Osoyoos Lake	LMB		11.6		Imm	NVD	NVD		
6125	04-Sep	Osoyoos Lake	LMB		6.9		Imm	NVD	NVD		
6126	04-Sep	Osoyoos Lake	LMB		6.6		Imm	NVD	NVD		
6127	04-Sep	Osoyoos Lake	LMB		7.3		Imm	NVD	NVD		
6128	04-Sep	Osoyoos Lake	LMB		7.0		Imm	NVD	NVD		
6129	04-Sep	Osoyoos Lake	LMB		7.4		Imm	NVD	NVD		
6130	04-Sep	Osoyoos Lake	LMB		6.4		Imm	NVD	NVD		
6131	04-Sep	Osoyoos Lake	LMB		7.7		Imm	NVD	NVD		
6132	04-Sep	Osoyoos Lake	LMB		7.0		Imm	NVD	NVD		
6133	04-Sep	Osoyoos Lake	SMB		6.9		Imm	NVD	NVD		
6134	04-Sep	Osoyoos Lake	SMB		7.4		Imm	NVD	NVD		
6135	04-Sep	Osoyoos Lake	SMB		6.9		Imm	NVD	NVD		
6136	04-Sep	Osoyoos Lake	SMB		7.1		Imm	NVD	NVD		
6137	04-Sep	Osoyoos Lake	SMB		7.1		Imm	NVD	NVD		
6138	04-Sep	Osoyoos Lake	SMB		7.4		Imm	NVD	NVD		
6139	04-Sep	Osoyoos Lake	SMB		7.9		Imm	NVD	NVD		
6140	04-Sep	Osoyoos Lake	SMB		9.1		Imm	NVD	NVD		
6141	04-Sep	Osoyoos Lake	SMB		7.8		Imm	NVD	NVD		
6142	04-Sep	Osoyoos Lake	SMB		7.5		Imm	NVD	NVD		
6143	04-Sep	Osoyoos Lake	SMB		7.0		Imm	NVD	NVD		
6144	04-Sep	Osoyoos Lake	SMB		6.7		Imm	NVD	NVD		
6145	04-Sep	Osoyoos Lake	SMB		8.4		Imm	NVD	NVD		
6146	04-Sep	Osoyoos Lake	SMB		8.6		Imm	NVD	NVD		
6147	04-Sep	Osoyoos Lake	SMB		8.4		Imm	NVD	NVD		
6148	04-Sep	Osoyoos Lake	SMB		6.5		Imm	NVD	NVD		
6149	04-Sep	Osoyoos Lake	SMB		8.0		Imm	NVD	NVD		
6150	18-Sep	Deep Creek	KO	600	37.5	sp	F	NVD	NVD	Neg	
6151	18-Sep	Deep Creek	KO	850	42.0	sp	M	NVD	NVD	Neg	
6152	18-Sep	Deep Creek	KO	600	39.0	sp	F	NVD	NVD	Neg	missing number
6153	18-Sep	Deep Creek	KO	450	34.5	sp	F	NVD	NVD	Neg	
6154	18-Sep	Deep Creek	KO	900	42.5	sp	M	NVD	NVD	Neg	
6155	18-Sep	Deep Creek	KO	300	28.2	sp	F	NVD	NVD	Neg	
6156	18-Sep	Deep Creek	KO	800	39.0	sp	M	NVD	NVD	Neg	
6157	18-Sep	Deep Creek	KO	400	30.5	sp	M	NVD	NVD	Neg	
6158	18-Sep	Deep Creek	KO	1900	54.0	sp	M	NVD	NVD	Neg	
6159	18-Sep	Deep Creek	KO	850	41.8	sp	M	NVD	NVD	Neg	numbered twice
6160	18-Sep	Deep Creek	KO	650	38.5	sp	M	NVD	NVD	Neg	
6161	18-Sep	Deep Creek	KO	800	41.2	sp	M	NVD	NVD	Neg	
6162	18-Sep	Deep Creek	KO	1400	48.8	sp	M	NVD	NVD	Neg	
6163	18-Sep	Deep Creek	KO	550	36.3	sp	F	NVD	NVD	Neg	
6164	18-Sep	Deep Creek	KO	600	39.3	sp	F	NVD	NVD	Neg	
6165	18-Sep	Deep Creek	KO	750	40.2	sp	F	NVD	NVD	Neg	
6166	18-Sep	Deep Creek	KO	800	46.0	sp	F	NVD	NVD	Neg	
6167	18-Sep	Deep Creek	KO	950	43.3	sp	M	NVD	NVD	Neg	
6168	18-Sep	Deep Creek	KO	700	38.3	sp	F	NVD	NVD	Neg	
6169	18-Sep	Deep Creek	KO	500	34.0	sp	M	NVD	NVD	Neg	

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
6170	18-Sep	Deep Creek	KO	600	35.0	sp	M	NVD	NVD	Neg	
6171	18-Sep	Deep Creek	KO	450	35.0	sp	F	NVD	NVD	Neg	
6172	18-Sep	Deep Creek	KO	950	46.0	sp	F	NVD	NVD	Neg	
6173	18-Sep	Deep Creek	KO	1100	46.0	sp	M	NVD	NVD	Neg	
6174	18-Sep	Deep Creek	KO	1100	45.9	sp	M	NVD	NVD	Neg	missing number
6175	18-Sep	Deep Creek	KO	800	39.8	sp	M	NVD	NVD	Neg	numbered twice
6176	18-Sep	Deep Creek	KO	900	41.0	sp	F	NVD	NVD	Neg	
6177	18-Sep	Deep Creek	KO	650	35.5	sp	M	NVD	NVD	Neg	
6178	18-Sep	Deep Creek	KO	850	42.5	sp	F	NVD	NVD	Neg	
6179	18-Sep	Deep Creek	KO	1600	51.8	sp	M	NVD	NVD	Neg	
6180	18-Sep	Deep Creek	KO	400	31.0	sp	F	NVD	NVD	Neg	
6181	18-Sep	Deep Creek	KO	700	37.5	sp	F	NVD	NVD	Neg	
6182	18-Sep	Deep Creek	KO	700	39.5	sp	M	NVD	NVD	Neg	
6183	18-Sep	Deep Creek	KO	450	32.5	sp	F	Pos	NVD	Neg	
6184	18-Sep	Deep Creek	KO	700	39.5	sp	F	Pos	NVD	Neg	
6185	18-Sep	Deep Creek	KO	500	34.0	sp	F	NVD	NVD	Neg	
6186	18-Sep	Deep Creek	KO	600	39.5	sp	F	Pos	NVD	Neg	
6187	18-Sep	Deep Creek	KO	500	34.0	sp	F	NVD	NVD	Neg	
6188	18-Sep	Deep Creek	KO	1600	50.0	sp	M	NVD	NVD	Neg	
6189	18-Sep	Deep Creek	KO	900	42.0	sp	M	NVD	NVD	Neg	
6190	18-Sep	Deep Creek	KO	1400	51.0	sp	F	NVD	NVD	Neg	
6191	18-Sep	Deep Creek	KO	600	37.5	sp	F	NVD	NVD	Neg	
6192	18-Sep	Deep Creek	KO	700	40.5	sp	F	NVD	NVD	Neg	
6193	18-Sep	Deep Creek	KO	1150	46.0	sp	F	NVD	NVD	Neg	
6194	18-Sep	Deep Creek	KO	650	37.5	sp	M	NVD	NVD	Neg	
6195	18-Sep	Deep Creek	KO	700	41.0	sp	F	NVD	NVD	Neg	
6196	18-Sep	Deep Creek	KO	1600	49.5	sp	M	NVD	NVD	Neg	
6197	18-Sep	Deep Creek	KO	1000	44.0	sp	F	NVD	NVD	Neg	
6198	18-Sep	Deep Creek	KO	600	36.0	sp	M	NVD	NVD	Neg	
6199	18-Sep	Deep Creek	KO	600	38.5	sp	F	NVD	NVD	Neg	
6200	18-Sep	Deep Creek	KO	350	29.5	sp	M	NVD	NVD	Neg	
6201	18-Sep	Deep Creek	KO	350	25.5	sp	M	NVD	NVD	Neg	lump on side
6202	18-Sep	Deep Creek	KO	1150	44.5	sp	M	NVD	NVD	Neg	
6203	18-Sep	Deep Creek	KO	600	37.5	sp	F	NVD	NVD	Neg	
6204	18-Sep	Deep Creek	KO	1350	39.5	sp	M	NVD	NVD	Neg	
6205	18-Sep	Deep Creek	KO	700	37.8	sp	M	NVD	NVD	Neg	
6206	18-Sep	Deep Creek	KO	500	34.0	sp	F	NVD	NVD	Neg	
6207	18-Sep	Deep Creek	KO	700	40.5	sp	F	NVD	NVD	Neg	
6208	18-Sep	Deep Creek	KO	1500	49.5	sp	M	NVD	NVD	Neg	
6209	18-Sep	Deep Creek	KO	1400	50.5	sp	M	NVD	NVD	Neg	
6210	18-Sep	Deep Creek	KO	1200	48.0	sp	M	NVD	NVD	Neg	
6211	18-Sep	Deep Creek	KO	650	37.5	sp	M	NVD	NVD	Neg	
6212	18-Sep	Deep Creek	KO	550	35.5	sp	F	NVD	NVD	Neg	
6213	18-Sep	Deep Creek	KO	1150	44.0	sp	M	NVD	NVD	Neg	
6214	18-Sep	Deep Creek	KO	600	37.0	sp	F	NVD	NVD	Neg	
6215	18-Sep	Deep Creek	KO	1300	48.0	sp	F	NVD	NVD	Neg	
6216	18-Sep	Deep Creek	KO	500	35.5	sp	F	NVD	NVD	Neg	
6217	18-Sep	Deep Creek	KO	550	36.5	sp	F	NVD	NVD	Neg	
6218	18-Sep	Deep Creek	KO	850	43.5	sp	F	NVD	NVD	Neg	
6219	18-Sep	Deep Creek	KO	850	41.5	sp	F	NVD	NVD	Neg	
6220	18-Sep	Deep Creek	KO	900	39.4	sp	M	NVD	NVD	Neg	
6221	18-Sep	Deep Creek	KO	600	38.0	sp	F	NVD	NVD	Neg	
6222	18-Sep	Deep Creek	KO	1900	56.0	sp	M	NVD	NVD	Neg	
6223	18-Sep	Deep Creek	KO	500	33.4	sp	F	NVD	NVD	Neg	
6224	18-Sep	Deep Creek	KO	500	33.2	sp	M	NVD	NVD	Neg	
6225	18-Sep	Deep Creek	KO	800	40.5	sp	F	NVD	NVD	Neg	
6226	23-Sep	Mission Creek	KO	295	31.5	sp	F	NVD	NVD	Neg	
6227	23-Sep	Mission Creek	KO	565	36.2	sp	M	NVD	NVD	Neg	
6228	23-Sep	Mission Creek	KO	825	41.8	sp	M	NVD	NVD	Neg	
6229	23-Sep	Mission Creek	KO	195	27.2	sp	M	NVD	NVD	Neg	
6230	23-Sep	Mission Creek	KO	160	26.5	sp	F	NVD	NVD	Neg	
6231	23-Sep	Mission Creek	KO	170	26.5	sp	F	NVD	NVD	Neg	
6232	23-Sep	Mission Creek	KO	170	26.8	sp	F	NVD	NVD	Neg	
6233	23-Sep	Mission Creek	KO	200	28.1	sp	M	NVD	NVD	Neg	
6234	23-Sep	Mission Creek	KO	255	31.0	sp	M	NVD	NVD	Neg	
6235	23-Sep	Mission Creek	KO	205	29.2	sp	F	NVD	NVD	Neg	
6236	23-Sep	Mission Creek	KO	115	24.0	sp	F	NVD	NVD	Neg	
6237	23-Sep	Mission Creek	KO	190	28.3	sp	M	NVD	NVD	Neg	
6238	23-Sep	Mission Creek	KO	200	28.0	sp	F	NVD	NVD	Neg	
6239	23-Sep	Mission Creek	KO	200	28.0	sp	M	NVD	NVD	Neg	

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
6240	23-Sep	Mission Creek	KO	140	25.4	sp	F	NVD	NVD	Neg	
6241	23-Sep	Mission Creek	KO	205	28.0	sp	M	NVD	NVD	Neg	
6242	23-Sep	Mission Creek	KO	130	24.0	sp	M	NVD	NVD	Neg	
6243	23-Sep	Mission Creek	KO	120	23.5	sp	F	NVD	NVD	Neg	
6244	23-Sep	Mission Creek	KO	185	26.0	sp	M	NVD	NVD	Neg	
6245	23-Sep	Mission Creek	KO	225	28.5	sp	M	NVD	NVD	Neg	
6246	23-Sep	Mission Creek	KO	180	27.5	sp	M	NVD	NVD	Neg	
6247	23-Sep	Mission Creek	KO	155	26.5	sp	M	NVD	NVD	Neg	
6248	23-Sep	Mission Creek	KO	165	25.5	sp	M	NVD	NVD	Neg	
6249	23-Sep	Mission Creek	KO	190	29.0	sp	M	NVD	NVD	Neg	
6250	23-Sep	Mission Creek	KO	190	27.5	sp	M	Pos	NVD	Neg	
6251	23-Sep	Mission Creek	KO	185	28.0	sp	M	Pos	NVD	Neg	
6252	23-Sep	Mission Creek	KO	145	25.0	sp	M	Pos	NVD	Neg	
6253	23-Sep	Mission Creek	KO	155	26.0	sp	M	NVD	NVD	Neg	
6254	23-Sep	Mission Creek	KO	220	29.0	sp	M	NVD	NVD	Neg	
6255	23-Sep	Mission Creek	KO	170	27.0	sp	F	NVD	NVD	Neg	
6256	23-Sep	Mission Creek	KO	220	28.5	sp	M	NVD	NVD	Neg	
6257	23-Sep	Mission Creek	KO	215	28.0	sp	M	Pos	NVD	Neg	
6258	23-Sep	Mission Creek	KO	190	27.0	sp	M	NVD	NVD	Neg	
6259	23-Sep	Mission Creek	KO	200	29.0	sp	M	Pos	NVD	Neg	
6260	23-Sep	Mission Creek	KO	190	28.0	sp	M	Pos	NVD	Neg	
6261	23-Sep	Mission Creek	KO	1015	45.5	sp	M	Pos	NVD	Neg	
6262	23-Sep	Mission Creek	KO	1090	47.5	sp	M	Pos	NVD	Neg	
6263	23-Sep	Mission Creek	KO	1235	49.5	sp	M	Pos	NVD	Neg	
6264	23-Sep	Mission Creek	KO	565	40.5	sp	F	NVD	NVD	Neg	duplicate?
6265	23-Sep	Mission Creek	KO	765	43.5	sp	F	Pos	NVD	Neg	
6266	23-Sep	Mission Creek	KO	670	40.5	sp	F	Pos	NVD	Neg	
6267	23-Sep	Mission Creek	KO	200	27.5	sp	M	Pos	NVD	Neg	hole on belly
6268	23-Sep	Mission Creek	KO	620	39.5	sp	F	Pos	NVD	Neg	
6269	23-Sep	Mission Creek	KO	670	40.0	sp	M	Pos	NVD	Neg	
6270	23-Sep	Mission Creek	KO	205	28.5	sp	M	Pos	NVD	Neg	
6271	23-Sep	Mission Creek	KO	710	41.5	sp	F	Pos	NVD	Neg	
6272	23-Sep	Mission Creek	KO	375	33.0	sp	F	Pos	NVD	Neg	
6273	23-Sep	Mission Creek	KO	195	28.0	sp	F	Pos	NVD	Neg	
6274	23-Sep	Mission Creek	KO	190	26.5	sp	F	Pos	NVD	Neg	
6275	23-Sep	Mission Creek	KO	215	28.5	sp	M	Pos	NVD	Neg	
6276	23-Sep	Mission Creek	KO	155	26.2	sp	F	Pos	NVD	Neg	
6277	23-Sep	Mission Creek	KO	210	28.0	sp	F	Pos	NVD	Neg	
6278	23-Sep	Mission Creek	KO	590	41.5	sp	F	Pos	NVD	Neg	
6279	23-Sep	Mission Creek	KO	330	33.0	sp	F	Pos	NVD	Neg	
6280	23-Sep	Mission Creek	KO	270	31.0	sp	F	Pos	NVD	Neg	
6281	23-Sep	Mission Creek	KO	105	23.2	sp	F	Pos	NVD	Neg	
6282	23-Sep	Mission Creek	KO	160	26.8	sp	F	Pos	NVD	Neg	
6283	23-Sep	Mission Creek	KO	205	27.5	sp	F	Pos	NVD	Neg	
6284	23-Sep	Mission Creek	KO	1095	45.8	sp	F	Pos	NVD	Neg	
6285	23-Sep	Mission Creek	KO	330	31.8	sp	M	Pos	NVD	Neg	
6286	23-Sep	Mission Creek	KO	440	35.4	sp	F	Pos	NVD	Neg	
6287	23-Sep	Mission Creek	KO	215	29.5	sp	M	Pos	NVD	Neg	
6288	23-Sep	Mission Creek	KO	165	26.5	sp	M	Pos	NVD	Neg	
6289	23-Sep	Mission Creek	KO	470	36.5	sp	M	Pos	NVD	Neg	
6290	23-Sep	Mission Creek	KO	210	28.0	sp	M	Pos	NVD	Neg	
6291	23-Sep	Mission Creek	KO	290	30.0	sp	M	Pos	NVD	Neg	
6292	23-Sep	Mission Creek	KO	915	45.5	sp	F	Pos	NVD	Neg	
6293	23-Sep	Mission Creek	KO	1435	50.8	sp	M	NVD	NVD	Neg	
6294	23-Sep	Mission Creek	KO	370	31.0	sp	M	Pos	NVD	Neg	
6295	23-Sep	Mission Creek	KO	390	36.0	sp	F	Pos	NVD	Neg	
6296	23-Sep	Mission Creek	KO	210	27.4	sp	M	NVD	NVD	Neg	
6297	23-Sep	Mission Creek	KO	290	29.5	sp	M	Pos	NVD	Neg	
6298	23-Sep	Mission Creek	KO	340	33.5	sp	F	NVD	NVD	Neg	
6299	23-Sep	Mission Creek	KO	2900	62.0	sp	M	Pos	NVD	Neg	
6300	23-Sep	Mission Creek	KO	325	33.0	sp	M	Pos	NVD	Neg	
6301	28-Oct	Okanagan Lake	WF		13.2		Juv	NVD	NVD	Neg	
6302	28-Oct	Okanagan Lake	WF		12.0		Juv	NVD	NVD	Neg	
6303	28-Oct	Okanagan Lake	WF		11.5		Juv	NVD	NVD	Neg	
6304	28-Oct	Okanagan Lake	WF		12.5		Juv	NVD	NVD	Neg	
6305	28-Oct	Okanagan Lake	WF		12.1		Juv	NVD	NVD	Neg	
6306	28-Oct	Okanagan Lake	WF		14.0		Juv	NVD	NVD	Neg	
6307	28-Oct	Okanagan Lake	WF		22.4		Imm M	NVD	NVD	Neg	
6308	28-Oct	Okanagan Lake	WF		21.5		M	NVD	NVD	Neg	
6309	28-Oct	Okanagan Lake	WF		21.2		M	NVD	NVD	Neg	

Table 3. Data on pathogens in kokanee, whitefish, and non-salmonids collected from above and below McIntyre Dam in Year 2002

Fish Number	Date 2002	Lake	Species	Weight (g)	Length (cm)	Age	Sex	IHNV Positive Fish	IPNV Positive Fish	*C. shasta* Positive Fish	Comments
6310	28-Oct	Okanagan Lake	WF		19.8		Mat M	NVD	NVD	Neg	
6311	28-Oct	Okanagan Lake	WF		13.5		Juv	NVD	NVD	Neg	
6312	28-Oct	Okanagan Lake	WF		23.6		Juv	NVD	NVD	Neg	
6313	28-Oct	Okanagan Lake	WF		24.0		F	NVD	NVD	Neg	
6314	28-Oct	Okanagan Lake	WF		24.1		M	NVD	NVD	Neg	
6315	29-Oct	Skaha Lake	WF		30.5		Mat M	NVD	NVD	Neg	
6316	29-Oct	Skaha Lake	WF		32.5		Mat F	NVD	NVD	Neg	
6317	29-Oct	Skaha Lake	KO		21.5	Spawner		NVD	NVD	Neg	
6318	29-Oct	Skaha Lake	WF		29.0		Mat M	NVD	NVD	Neg	
6319	29-Oct	Skaha Lake	WF		26.0		Mat M	NVD	NVD	Neg	
6320	29-Oct	Skaha Lake	KO		22.5	Spawner	Mat F	NVD	NVD	Neg	
6321	29-Oct	Skaha Lake	KO		24.0	Spawner	Mat F	NVD	NVD	Neg	
6322	29-Oct	Skaha Lake	WF		30.5		Mat M	NVD	NVD	Neg	
6323	29-Oct	Skaha Lake	WF		27.0		Mat F	NVD	NVD	Neg	
6324	29-Oct	Skaha Lake	KO		24.5	Spawner	Mat F	NVD	NVD	Neg	
6325	29-Oct	Skaha Lake	WF		31.0		Mat F	NVD	NVD	Neg	
6326	29-Oct	Skaha Lake	WF		22.0		Imm F	NVD	NVD	Neg	
6327	29-Oct	Skaha Lake	WF		32.0		Mat F	NVD	NVD	Neg	
6328	29-Oct	Skaha Lake	KO		23.5	Spawner	Mat M	NVD	NVD	Neg	
6329	29-Oct	Skaha Lake	WF		20.5		Imm M	NVD	NVD	Neg	
6330	29-Oct	Skaha Lake	KO		25.5	Spawner	Mat F	NVD	NVD	Neg	
6331	29-Oct	Skaha Lake	WF		25.0		Imm F	NVD	NVD	Neg	
6332	29-Oct	Skaha Lake	WF		25.0		Mat F	NVD	NVD	Neg	
6333	29-Oct	Skaha Lake	KO		24.5	Spawner	Mat F	NVD	NVD	Neg	
6334	29-Oct	Skaha Lake	KO		26.0	Spawner	Mat F	NVD	NVD	Neg	
6335	29-Oct	Skaha Lake	KO		24.0	Spawner	Mat M	NVD	NVD	Neg	
6336	29-Oct	Skaha Lake	KO		22.5	Spawner	Mat F	NVD	NVD	Neg	
6337	29-Oct	Skaha Lake	WF		22.0		F	NVD	NVD	Neg	
6338	29-Oct	Skaha Lake	WF		18.5		Imm	NVD	NVD	Neg	
6339	29-Oct	Skaha Lake	WF		25.5		Mat M	NVD	NVD	Neg	
6340	29-Oct	Skaha Lake	WF		20.5		Imm	NVD	NVD	Neg	
6341	29-Oct	Skaha Lake	WF		20.5		Imm	NVD	NVD	Neg	

APPENDIX E

Findings from Year 2002 pathogen survey and summary data tables for years 2000, 2001, and 2002

Table 1. Pathogen surveys 2002 – salmonids and non-salmonids below dam*

Below McIntyre Dam

	No. Collected	IHNV	IPNV	MC	CS
Salmonids					
Sockeye (juveniles incl. 40 eggs)	**600**	**0/600**	**0/600**	**NT**	**NT**
Kokanee (spawners)	**8**	**0/8**	**0/8**	**0/8**	**0/8**
Sockeye (spawners)	**180**	**16/180**	**0/180**	**0/180**	**0/180**
Whitefish (various ages)	**77**	**0/77**	**0/77**	**NT**	**0/77**
Total salmonids	**865**				
Non-salmonids					
Ten species/groups	**349**	**0/349**	**0/349**	**NT**	**NT**
Total non-salmonids	**349**				

*IHNV = infectious haematopoietic necrosis virus; IPNV = infectious pancreatic necrosis virus; MC = *Myxobolus cerebralis*; CS = *Ceratomyxa shasta*; NT = not tested (test not required); fractions = no. fish positive for indicated pathogen/no. fish tested; IHNV was likely IHNV, type 1.

Table 2. Pathogen surveys 2002 – details of non-salmonids below dam*

Below McIntyre Dam

	No. Collected	IHNV	IPNV	MC	CS
Non-salmonids					
Black crappie	**40**	**0/40**	**0/40**	**NT**	**NT**
Bluegill	**29**	**0/29**	**0/29**	**NT**	**NT**
Largemouth bass	**34**	**0/34**	**0/34**	**NT**	**NT**
Northern pike minnow	**20**	**0/20**	**0/20**	**NT**	**NT**
Peamouth chub	**4**	**0/4**	**0/4**	**NT**	**NT**
Pumpkinseed	**6**	**0/6**	**0/6**	**NT**	**NT**
Prickly sculpin	**22**	**0/22**	**0/22**	**NT**	**NT**
Smallmouth bass	**43**	**0/43**	**0/43**	**NT**	**NT**
Sucker(s)	**62**	**0/62**	**0/62**	**NT**	**NT**
Yellow perch	**89**	**0/89**	**0/89**	**NT**	**NT**
Total non-salmonids	**349**				

*IHNV = infectious haematopoietic necrosis virus; IPNV = infectious pancreatic necrosis virus; MC = *Myxobolus cerebralis*; CS = *Ceratomyxa shasta*; NT = not tested (test not required); fractions = no. fish positive for indicated pathogen/no. fish tested.

Table 3. Pathogen surveys 2002 – salmonids and non-salmonids above dam*

Above McIntyre Dam

	No. collected	IHNV	IPNV	MC	CS
Salmonids					
Kokanee (juveniles)	**150**	**0/150**	**0/150**	**NT**	**0/150**
Kokanee (spawners)	**161**	**36/141**	**0/161**	**NT**	**0/161**
Whitefish (various ages)	**50**	**0/50**	**0/50**	**NT**	**0/50**
Total salmonids	**361**				
Non-salmonids					
Eight species or groups	**364**	**0/364**	**0/364**	**NT**	**NT**
Total non-salmonids	**364**				

* See footnotes to Table 1

Table 4. Pathogen surveys 2002 – details of non-salmonids above dam*

Above McIntyre Dam

	No. collected	IHNV	IPNV	MC	CS
Non-salmonids					
Northern pike minnow	**72**	**0/72**	**0/72**	**NT**	**NT**
Peamouth chub	**35**	**0/35**	**0/35**	**NT**	**NT**
Pumpkinseed	**27**	**0/27**	**0/27**	**NT**	**NT**
Prickly sculpin	**18**	**0/18**	**0/18**	**NT**	**NT**
Redside shiner	**38**	**0/38**	**0/38**	**NT**	**NT**
Smallmouth bass	**78**	**0/78**	**0/78**	**NT**	**NT**
Sucker(s)	**67**	**0/67**	**0/67**	**NT**	**NT**
Yellow perch	**29**	**0/29**	**0/29**	**NT**	**NT**
Total non-salmonids	**364**				

* See footnotes to Table 2

Table 5. Total salmonids collected and processed for pathogens above and below McIntyre Dam during sampling years 2000, 2001 and 2002

Species/Group	Years 00, 01& 02 Above Dam	Years 00, 01& 02 Below Dam
Sockeye (juveniles)	**0**	**1569**
Sockeye (adults)	**0**	**571**
Kokanee (juveniles)	**480**	**0**
Kokanee (adults)	**526**	**8**
Whitefish (various ages)	**161**	**148**
Total species/groups	2	3
Total salmonids collected	1167	2295
Number needed	1080	1080

Table 6. Total non-salmonids collected and processed for pathogens above McIntyre Dam during 2000, 2001, and 2002 samplings

Species/Group	2000	2001	2002	Total/sp. or group
Black bullhead (catfish)	**2**	**0**	**0**	**2**
Burbot	**1**	**0**	**0**	**1**
Carp	**1**	**0**	**0**	**1**
Chiselmouth	**0**	**1**	**0**	**1**
Chub(s)	**0**	**6**	**0**	**6**
Lake chub	**1**	**0**	**0**	**1**
Northern pike minnow	**68**	**53**	**72**	**193**
Peamouth chub	**71**	**55**	**35**	**161**
Pumpkinseed	**12**	**21**	**27**	**60**
Prickly sculpin	**0**	**32**	**18**	**50**
Sculpin(s)	**40**	**0**	**0**	**40**
Redside shiner	**28**	**54**	**38**	**120**
Smallmouth bass	**89**	**82**	**78**	**249**
Sucker(s)	**72**	**78**	**67**	**217**
Yellow perch	**6**	**5**	**29**	**40**
Totals collected	**391**	**387**	**364**	**1142**
Totals needed	**360**	**360**	**360**	**1080**

Table 7. Total non-salmonids collected and processed for pathogens below McIntyre Dam during 2000, 2001, and 2002 samplings

Species/ Group	2000	2001	2002	Total/sp. or group
Black bullhead (catfish)	**1**	**0**	**0**	**1**
Black crappie	**1**	**20**	**40**	**61**
Bluegill	**0**	**0**	**29**	**29**
Carp	**4**	**0**	**0**	**4**
Chiselmouth*	**0**	**3**	**0**	**3**
Largemouth bass	**52**	**51**	**34**	**137**
Northern pike minnow*	**8**	**27**	**20**	**55**
Peamouth chub*	**0**	**0**	**4**	**4**
Pumpkinseed	**24**	**37**	**6**	**67**
Prickly sculpin*	**0**	**0**	**22**	**22**
Sculpin(s)*	**22**	**0**	**0**	**22**
Smallmouth bass*	**39**	**37**	**43**	**119**
Sucker(s)*	**39**	**81**	**62**	**182**
Yellow perch*	**99**	**115**	**89**	**303**
Totals	**289**	**371**	**349**	**1009**
Needed	**360**	**360**	**360**	**1080**

*** Migratory species based on reported ability to live in streams or to migrate into streams to spawn (Scott and Crossman 1973)**

Table 8. Year 2000 and Year 2001 data on *Ceratomyxa shasta* in kokanee and whitefish above and below McIntyre Dam

	Above Dam	Below Dam
Year 2000		
Kokanee adults	5*/160	0/0
Kokanee juveniles	0/181	0/0
Whitefish (various ages)	0/38	0/7
Year 2001		
Kokanee adults	0/87**	0/0
Kokanee juveniles	0/150	0/0
Whitefish (various ages)	0/61	0/39

* Positives were from Mission Creek
** 150 fish were collected but intestinal samples for *C. shasta* testing were, by oversight, not collected from 63 of them

FINAL

OBJECTIVE 2
Exotic Fish Risk Assessment

Contribution No. *2* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Authors: Fabian Alexis
Herb Alex
Shayla Lawrence, BSc

Reviewed by: Chris Bull, R.P. Bio

Edited by: Howard Smith

EXECUTIVE SUMMARY

This report arising from Objective 2 of the three-year study "Evaluation of an experimental re-introduction of sockeye salmon into Skaha Lake" is to explore the possibility of certain undesirable exotic fish, termed "exotic species of concern" gaining access to upstream areas, and eventually colonizing them to the detriment of native species. While a number of exotic species are already quite widely established in the drainage, some exist only below McIntyre Dam. These might extend their range upstream and colonize Vaseux as well as Skaha Lake if the dam were modified or removed in the reintroduction process.

To confirm the ranges of exotic fishes as indicated from a literature review and in a report and recommendations from YEAR 1 and Year 2 sampling, the Okanagan Nation Fisheries Commission (ONFC) used a variety of fish sampling techniques to capture specimens over a range of habitats within the study area from April 15 to November 28, 2002.

Field sampling was by angling, beach seining, boat based electrofishing, backpack electrofishing, gillnetting, minnow trapping, trap netting and from a weed harvester. There were thought to be only five species of exotic fishes of concern, i.e. black bullhead, black crappie, largemouth bass, tench and walleye, until 2001 when a 6th species – bluegill sunfish, was captured by electrofishing in Osoyoos Lake.

Currently, black bullheads are in Skaha Lake and largemouth bass are in Vaseux Lake; but black crappie have not been found above Osoyoos Lake and walleye are in the Okanagan River drainage but not further upriver of Mallot, Washington.

Range extensions would be heavily influenced by availability of suitable food and habitat. Black crappie range widely in open water and feed on a variety of very small fishes and plankton. Largemouth bass are predatory feeders in littoral areas and because smallmouth bass are widely distributed in the Okanagan basin and share some food preferences and behavioral similarities with largemouth they may reflect some of the hazards that the former could constitute for salmonids. Both bass species are piscivorous, but while smallmouth are known to feed on sockeye fry as they coexist in littoral areas during migrations to and from the lakes pelagic zone, largemouth wait at the edge of the littoral zone as territorial ambush predators thus limiting their predation on pelagic salmonids. Tench are carp-like fish with likely some of the same impact on indigenous non-salmonids fish species that carp have – notably competition for food, and turbidity when they spawn. Tench spawn early in summer (May/June) but dependent on water temperatures as is for most fish. Walleye are predators known to travel long distances.

The risks associated with range extension of exotic species of concern into Skaha Lake and other upstream waters were assembled in years 1, 2 and 3 and are summarized in Table 3.

ACKNOWLEDGMENTS

The Okanagan Nation Fisheries Commission would like to acknowledge valuable contributions made by a number of people to Objective 2: Exotic Fish Species Risk Assessment (YEAR 3).

Steve Logan, Owner of Newport Beach R.V Park located on Westside road near Vernon B.C. for the use of their boat launch and parking lot to do bio-sampling. Mr. Logan was very supportive to ONFC and the study undertaken.

We would like to pay special thanks again to Monte Miller and the Colville Confederated Tribes (CCT) for the use of their electrofishing boat. Thanks for completing the electrofishing segment of the study and for sharing some “exotic fish “ photos.

The gillnets and beach seines were loaned by Steve Matthews of the Ministry of Water, Land and Air Protection (Penticton) while Don Ignace and Darby Hewitt of the Skeetcheson Band lent us two of their trap nets and Kanji Tsamura of BC Fisheries also lent us a trap net.

Thank you, Lynnea Wiens, Natasha Audy of Katim Enterprises and Bob Swite, summer student who provided fieldwork and data entry support.

Thanks to our quality control advisor Chris Bull, and to Howard Smith who edited this report.

The YEAR 3 report could not have been completed without the contributions of these resources and experts. Thanks again to everyone involved.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
ACKNOWLEDGMENTS ii
TABLE OF CONTENTS iii
LIST OF FIGURES iv
LIST OF TABLES iv
LIST OF PHOTOGRAPHS iv

1.0 INTRODUCTION 1
1.1 Project Background 1
1.2 Objective 2 Scope 1
1.3 Project Study Area 1

2.0 INVENTORY OF EXOTIC FISH SPECIES 3
2.1 Exotic fish inventory methods and results 3
2.1.1 Angling 4
2.1.2 Beach seining 4
2.1.3 Electrofishing 5
2.1.4 Backpack Electrofishing 5
2.1.5 Gillnetting 6
2.1.6 Minnow trapping 6
2.1.7 Trap netting 6
2.1.8 Weed Harvester 7
2.2 Inventory summary 7

3.0 AVAILABILITY OF SUITABLE HABITAT FOR EXOTIC SPECIES OF CONCERN. 16

4.0 ASSESSMENT OF THE RISK OF EXOTIC SPECIES INTRODUCTION TO SKAHA LAKE 17

5.0 REFERENCES 20

APPENDIX A Required Permits
APPENDIX B Angling Data
APPENDIX C Beach Seining Data
APPENDIX D Electrofishing boat Data
APPENDIX E Backpack Electrofishing Data
APPENDIX F Gill Netting Data
APPENDIX G Minnow Trapping Data
APPENDIX H Trap Netting Data
APPENDIX I Weed Harvester Data
APPENDIX J Species Codes

LIST OF FIGURES

Figure 1. Overview map of the study area 2
Figure 2. Map of Okanagan Lake 9
Figure 3. Sampling sites on South Okanagan Lake 10
Figure 4. Sampling Sites on Penticton Channel 11
Figure 5 Sampling sites on Skaha Lake 12
Figure 6. Sampling sites on Vaseux Lake 13
Figure 7. Sampling sites on Okanagan River Channel 14
Figure 8. Sampling sites on Osoyoos Lake 15
Figure 9. Bathymetric map of Skaha Lake 16
Figure 10. Bathymetric map of Osoyoos Lake 16

LIST OF TABLES

Table 1. Methods and locations for sampling exotic fishes of concern 4
Table 2. Summary of 2001 catch by fishing location 8
Table 3. Summary of Exotic fish risk assessment 19

LIST OF PHOTOGRAPHS

Photo 1. Beach Seining on South Okanagan Lake (BS 4) 5
Photo 2. Electrofishing in Osoyoos Lake (EF-b 10) 5
Photo 3. Minnow trapping in the Penticton Oxbows (MT 7a) 6
Photo 4. Minnow trap set in Vaseux Lake (MT17) 6
Photo 5. Vaseux Lake Tench (TN 2) 7
Photo 6. Trap net in North Arm Okanagan Lake (TN 4) 7

1.0 INTRODUCTION

1.1 Project Background

This report summarizes the third year of the three-year study "Evaluation of an experimental re-introduction of sockeye salmon into Skaha Lake". The Okanagan sockeye salmon is one of the last two significant populations in the Columbia River system, the other being the Wenatchee River stock in Washington State. Abundance of this stock has declined and fluctuated dramatically in the last fifty years (Hyatt & Rankin 1999). Anadromous sockeye probably populated many upstream waters at one time and the Okanagan Nation and tribes in the U.S. have proposed re-introducing the species into Skaha and possibly Okanagan Lake, both of which have larger rearing capacities than Osoyoos Lake where juvenile sockeye now spend their first year (see Figure 1). McIntyre Dam is largely impassible for sockeye which is currently the furthest point upstream that they can reach.

The Bonneville Power Authority (BPA) along with the Colville Confederated Tribes (CCT) and the Okanagan Nation Fisheries Commission (ONFC) are evaluating the proposal for a re-introduction of sockeye salmon into Skaha Lake. The ONFC was retained for project management and implementation of the data field collection for this report, which covers YEAR 3 of Objective 2, the 'Exotic Species Risk Assessment'.

1.2 Objective 2 Scope

The concern implicit in Objective 2 is the possibility of undesirable exotic fish passage to, and colonization of upstream areas. A number of exotic fish not indigenous to the Okanagan have become widely established in the Okanagan system. Some of these are found only below McIntyre Dam, which is generally a barrier to fish migration, but with removal or changes in the dam structure; they could extend their range upstream and colonize waters such as Vaseux, Skaha and Okanagan Lakes. These populations are referred to as the 'exotic fishes of concern'.

Objective 2 calls for an evaluation of the potential risks through the following tasks:

- Task A: continue to review available fish inventory information from the Okanagan River system.
- Task B: repeat the inventory of presence or absence of exotic fish species and habitat use above and below McIntyre Dam.
- Task C: complete a literature review of habitat requirements of additional exotic species of concern. No new species were found during the 2002 sampling.

1.3 Project Study Area

At the year two BPA review meeting it was decide to expand the study area to include the north arm of Okanagan Lake because this region has likely Exotic Species habitat. The rest of the study area remains the same i.e. below McIntyre Dam encompassing the north and central basin of Osoyoos Lake and the Okanagan River channel; and above McIntyre Dam including Okanagan River, Vaseux Lake, Skaha Lake and the southern portion of Okanagan Lake (see Figure 1). Barriers to fish migration at dams located at the outlets of Skaha and Okanagan Lakes have provisions for fish passage but are not in operation.

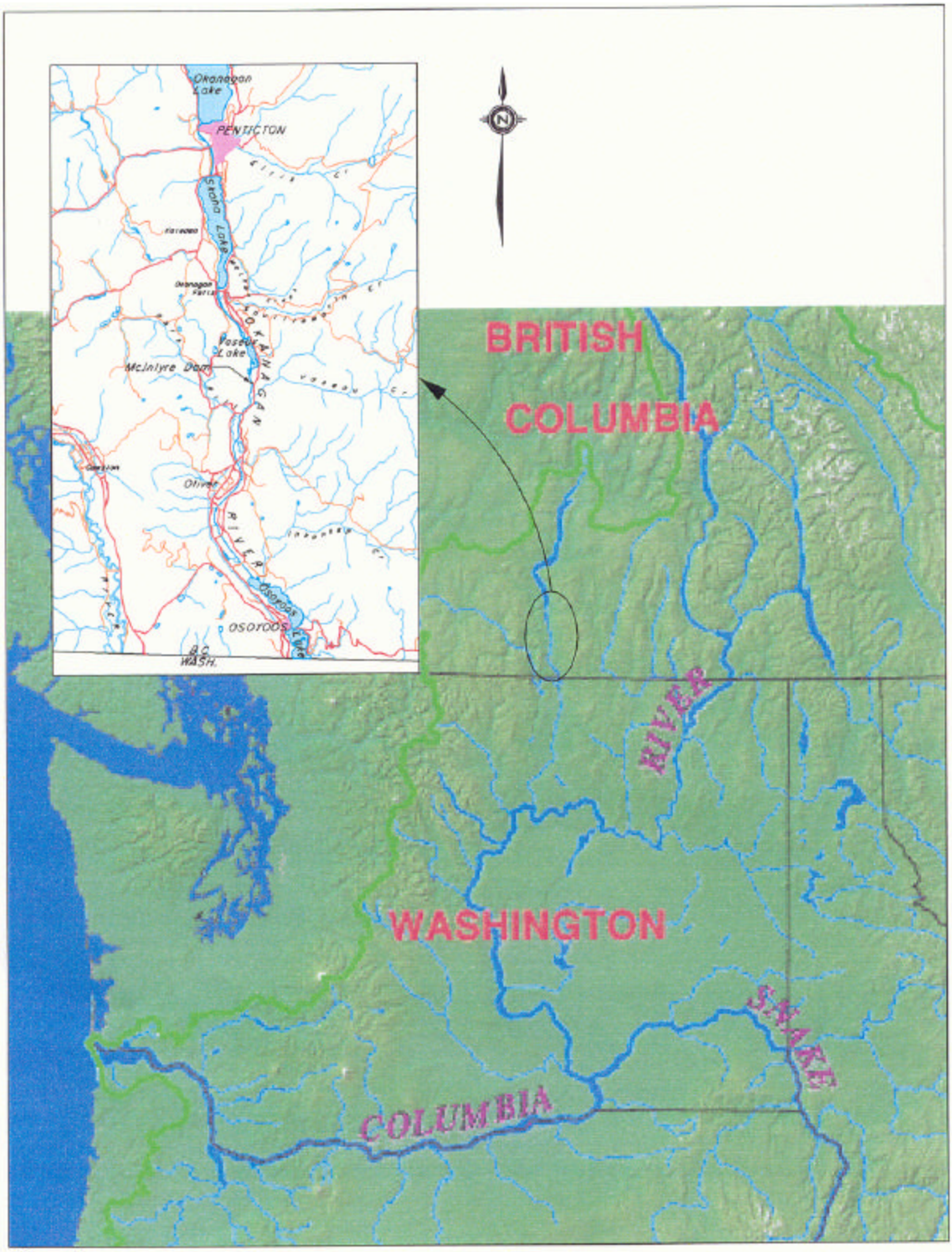


Figure 1. Overview map of the study area

2.0 INVENTORY OF EXOTIC FISH SPECIES

To confirm the extent of exotic fish range and distribution as indicated by the literature review and after one year of sampling, the ONFC used a wide variety of capture techniques and sampled a wide range of habitats within the study areas. The sampling plan was based on the YEAR 2 report and recommendations. ONFC was responsible for field data collections and project management. Glenfir Resources was retained to provide quality control for the program.

The sampling in YEAR 3 targeted the exotic species of concern and areas of their likely habitat as determined in YEAR 1 and 2. These include,

1. Minnow trap, beach seine, electro fish and trap net in the north arm of Okanagan Lake because of its exotic species habitat possibilities.
2. Minnow trap in areas not sampled in 2001, 2002.
3. Beach seine the south end of Okanagan Lake.
4. Sample by angling and trap netting in and above Vaseux Lake to determine how far up the basin largemouth bass and black crappie have migrated,
5. Fish for black bullheads in South Okanagan Lake to measure the rate of colonization.

2.1 Exotic fish inventory methods and results

ONFC conducted the exotic fish inventory in accordance with all required permits from the Ministry of Water, Land and Air Protection (MOWLAP) and Fisheries and Oceans Canada (DFO) as noted in Appendix A.

Sampling was conducted from April 15 to November 28, 2002 with at least one method per week, to cover migrations of fish species utilizing different habitat types during different times of the year. Sampling sites were established in YEAR 1. After Year 2 when several pertinent recommendations were received it was decided to expand the sampling area to include the north arm of Okanagan Lake and to focus on the exotic species of concern by targeting their habitat types, and to double efforts in Skaha Lake. Table 1 outlines the sampling methods used during the four sampling seasons and selected locations. Details of each sampling method and fish caught are outlined in Sections 2.1.1 to 2.1.8. Refer to Fig. 2 through 8 for sites and methods used.

Table 1. Methods and locations for sampling exotic fishes of concern

Method	Months	Locations	Species targeted
Angling	May, September & November	Vaseux lake, Okanagan River, Penticton Oxbows	Black Crappie, Largemouth Bass
Beach seining	May, June, September & November	South Okanagan and Osoyoos Lake, North Okanagan	13 littoral fish species
Electrofishing-boat	April, June, August & November	South Okanagan, Skaha, Osoyoos Lake, North Okanagan Lake	18 littoral fish species
Electrofishing-backpack	July	Okanagan River	Small river fishes (RBT, CH)
Gill netting	August	Osoyoos Lake	Walleye & pelagic species
Minnow trapping	April, May, July, & November	General	Small individuals
Floating trap net	July and September	Vaseux Lake, North Okanagan	Black Crappie and Largemouth bass
Weed Harvester	August	Osoyoos Lake	Sockeye fry

The Catch Efficiency of each kind of sampling gear was recorded. A summary of species caught by each kind of fishing gear is presented in Table 2, and detailed summaries are in Appendices C-H.

2.1.1 Angling

After several attempts at angling without success, it was decided to discontinue this method of sampling. See Appendix B for dates and areas sampled.

2.1.2 Beach seining

Fourteen new beach seine sites were added this year in the north arm of Okanagan Lake. (See Fig. 2). These were in addition to last year's sites in southern part of Okanagan Lake (Photo 1). A large seine net 30 m long, 3 m deep and with mesh sizes (stretch measure) of 3 mm in the bunt end and 10 and 25 mm panels in each wing was used. As anticipated, seines employed from shore over smooth substrate caught species which frequent the littoral zone. In addition to 14 identified species some unidentifiable juvenile fish were caught (see Appendix C for details).

Species caught:	black crappie	black bullhead	peamouth chub
prickly sculpin	common carp	redside shiner	largemouth bass
sockeye fry	northern pike minnow	smallmouth bass	sucker spp.
yellow perch	whitefish spp.	bluegill	

Photo 1. Beach seining on South Okanagan Lake (BS 4)

2.1.3 Electrofishing

Night surveys with the boat-mounted electrofisher (Photo 3) were conducted in April, June, August and November (Appendix D). See figures 2, 3, 5,and 8 for sites. The boat, equipped with a Smith-root model 7.5 GPP electrofisher, sampled transects parallel to the shoreline, in water depths of less than 3.5 meters. Voltage was kept constant at 500 volts (DC) with the duty cycles varying between 20% and 55%. The majority of electrofishing was undertaken at outputs between 3.8-6.5 Amps. Species caught from the study area are listed below.

Species caught:

black crappie	black bullhead	common carp	rainbow trout
redside shiner	burbot	prickly sculpin	sockeye
whitefish spp.	yellow perch	bluegill	kokanee
northern pike minnow	largemouth bass	peamouth chub	smallmouth bass
pumpkinseed	sucker spp		

Photo 2. Electrofishing in Osoyoos Lake (EF-b 10)

2.1.4 Backpack Electrofishing

As per the recommendations from Year 2, one day of backpack electrofishing was conducted on the natural section of the Okanagan River, near Oliver, BC. Target species were small river fishes and no new species were found (refer to species caught in Appendix E).

2.1.5 Gillnetting

Gillnets were used to target walleye in Osoyoos Lake (GN 1, 2, and 3) in 3 areas identified in the YEAR 1 recommendations.

Gillnetting was also completed at two sites in Skaha Lake. Gangs were made up of 5-6 nets; gill nets used at all sites ranged from 1" to 5.5" in mesh size (see Appendix F for complete details)

Species caught:

common carp	northern pike minnow	sucker spp.	adult sockeye
whitefish spp.	kokanee	rainbow trout	peamouth chub

2.1.6 Minnow trapping

Minnow traps were distributed throughout much of the study area in April, May, June, August, September and November and fished for 24-hour periods. Several extra sites were included in Year 3 in the north arm of Okanagan Lake as per the recommendations in Year 2. (see Figure 2). The trap mesh was 6 mm and the circular entrance was 2 cm in diameter. The traps were baited with canned sardines or salmon roe. Usually, 3 to 4 minnow traps were set at each site. (Photos 3 and 4).

Species caught:

black bullhead	prickly sculpin	common carp	kokanee
largemouth bass	pumpkin seed	rainbow trout	redside shiner
smallmouth bass	sucker spp.	bluegill	yellow perch
northern pike minnow			

Photo 3. Minnow trapping in the Penticton Oxbows (MT 7a)

Photo 4. Minnow trap set in Vaseux Lake (MT17)

2.1.7 Trap netting

Three floating traps were fished for 48hr periods in Vaseaux Lake specifically targeting black crappie. No black crappie was caught but a tench was (Photo 5). There was also 1 site in Osoyoos Lake and 3 sites in Okanagan Lake (Photo 6). Furthermore, trap netting was conducted in the north arm of Okanagan Lake. The net was set in water 1 to 3 m deep, 5 m offshore (see Appendix H for data and Catch Efficiency)

Species caught:

black bullhead	largemouth bass	yellow perch	sucker spp
pumpkinseed	northern pike minnow	tench	

Photo 5. Vaseux Lake Tench (TN 2)

Photo 6. Trap net in the North Arm of Okanagan Lake (TN 4)

2.1.8 Weed Harvester

In August a weed harvester conducted a clean up of Eurasian milfoil near the northern basin, and Haines Provincial Park of Osoyoos Lake. Permission to board the harvester was granted by the North Okanagan Regional District (NORD) to observe any by-catch of sockeye fry. No sockeye fry were observed, but some smallmouth bass were caught up in the grids. (see Appendix I for more details).

2.2 Inventory summary

No new species were discovered this year within the study area, which ranged from the north arm of Okanagan Lake all the way south to Osoyoos Lake. Therefore, to date, the species of concern remain black bullhead, brown bullhead, black crappie, bluegill, largemouth bass, tench and walleye. Of these species black bullhead are found as far as Skaha Lake; and largemouth bass as far upstream as Vaseux Lake. In Year 3 two tench were collected on two separate occasions in Vaseux Lake, -- the first time in this study they have been caught. Black crappie and bluegill have been found only in Osoyoos Lake, and brown bullhead and walleye have not yet been caught in the study area. Table 2 summarizes the fish species caught during 2002 sampling. The catch data and Catch Efficiency are found in Appendices B through I, and the species codes are in Appendix J. Figures 2 through 8 show sampling sites located on composite air photos.

Table 2. Summary of 2002 catch by fishing location

		Above McIntyre Dam					Below McIntyre Dam	
Species found during 2002 sampling	**Okanagan Lake North**	**Okanagan Lake South**	**Skaha Lake**	**Vaseux Lake**	**Okanagan River channel & oxbow**		**Okanagan River channel**	**Osoyoos Lake**
Burbot		EF-b,TN						GN
Black crappie								BS, EF-b
Black bullhead			EF-b, MT	MT, TN	MT		MT	BS
Brown bullhead								
Bluegill sunfish								BS,EF-b
Prickly sculpin	MT	BS, EF-b, MT	EF-b, MT	MT	MT		B-EF, MT	BS, EF-b, MT
Chinook salmon								
Chiselmouth							B-EF	
Common carp	BS, EF-b	EF-b	EF-b	MT				, BS, EF-b, GN
Eastern brook trout								
Longnose dace							B-EF	
Goldfish								
Kokanee			EF-b, GN		MT			GN
Largemouth bass				MT, TN				BS, EF-b, GN
Lake chub								
Northern pike minnow	BS, TN,MT, EF-B	BS, EF-b, MT	EF-b MT,GN	MT	MT		B-EF,	EF-b, GN
Peamouth chub	BS, MT, EF-b	BS, EF-b	EF-b GN		MT			BS, EF-b, GN
Pumpkinseed	BS,	MT	EF-b	MT, TN			B-EF	BS, EF-b
Rainbow trout	EF-b		EF-b, GN				B-EF, MT	EF-b,
Redside shiner	BS, EF-b	BS, EF-b, MT			MT		B-EF	
Sockeye salmon								BS, EF-b, GN
Smallmouth bass		MT	EF-b	MT	MT		B-EF MT	BS, EF-b
Sucker spp.	TN, EF-b	BS, EF-b	EF-b, GN		MT		B-EF	EF-b, GN
Tench				MT				
Whitefish spp.	EF-b	BS, EF-b	EF-b					GN, BS, EF-b
Walleye								
Yellow perch	TN,MT,EF-b		EF-b, MT	MT, TN	MT		MT	BS, EF-b, MT

Fish capture methods and gear codes	EF-b	electrofishing boat
	MT	minnow trapping
	GN	Gillnetting
	AG	Angling
	BS	beach seining
	TN	trap netting
	B-EF	Backpack electrofish

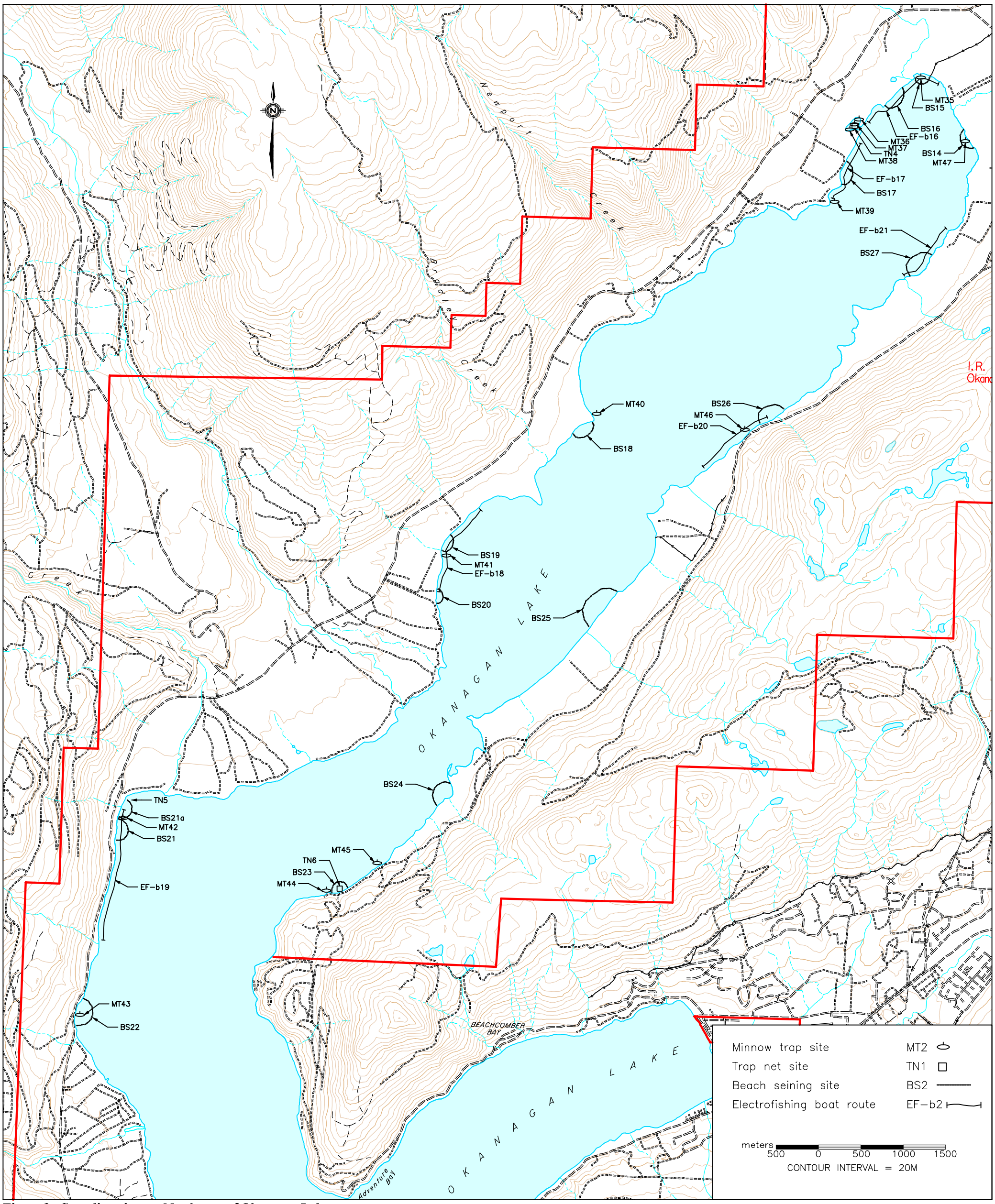


Figure 2. Sampling sites on North arm of Okanagan Lake

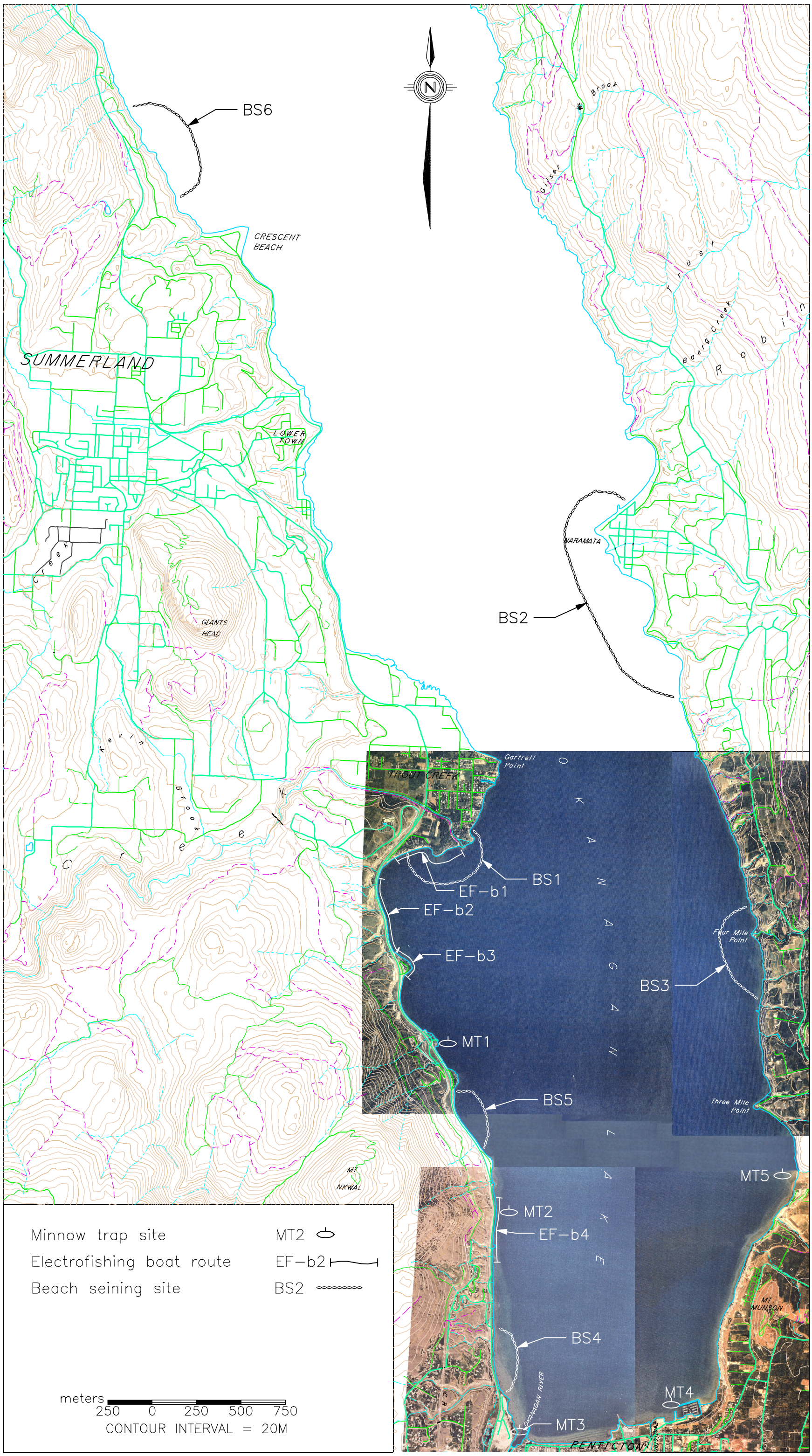


Figure 3. Sampling sites on South Okanagan Lake

Figure 4. Sampling sites on Penticton Channel

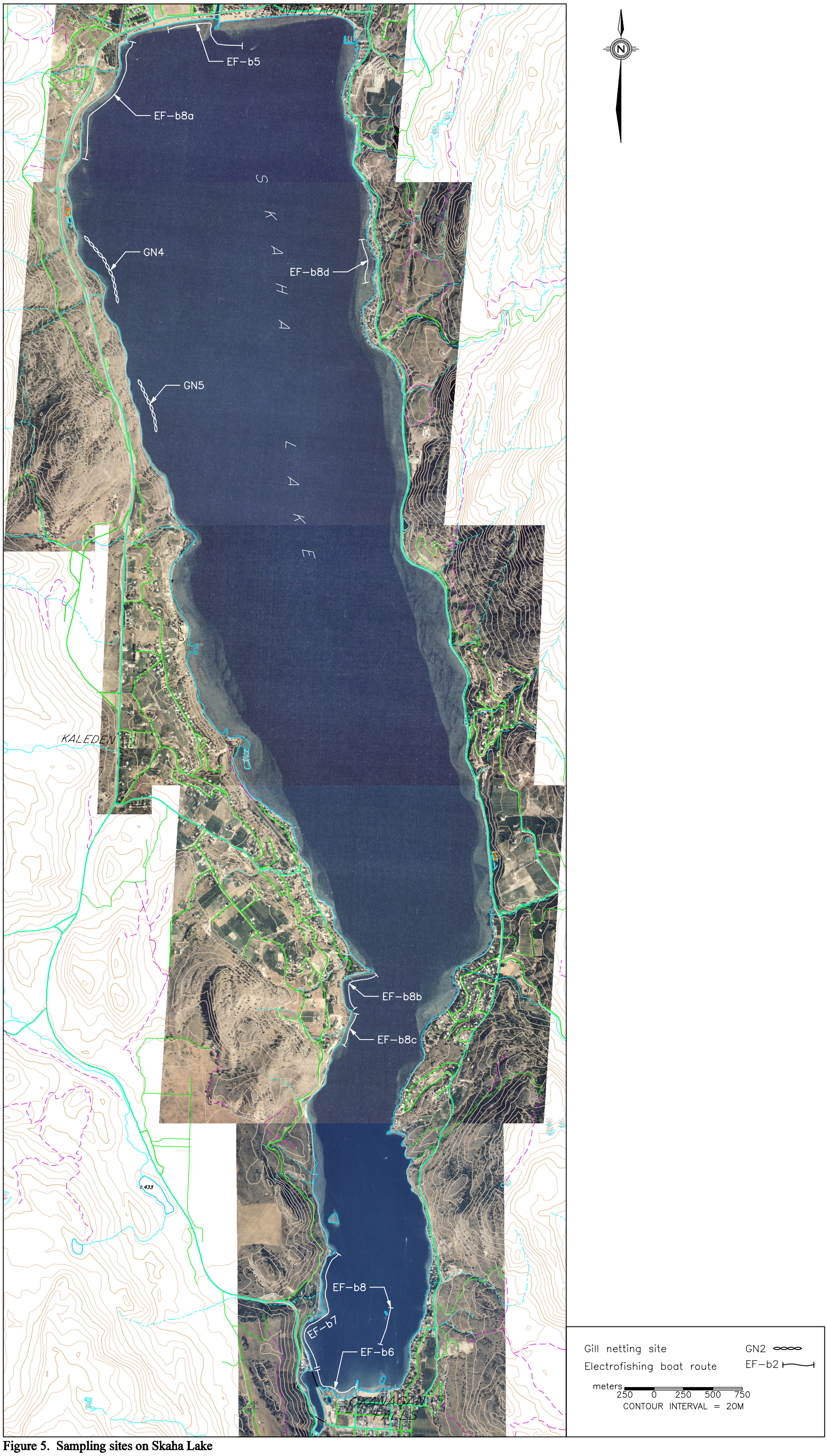


Figure 5. Sampling sites on Skaha Lake

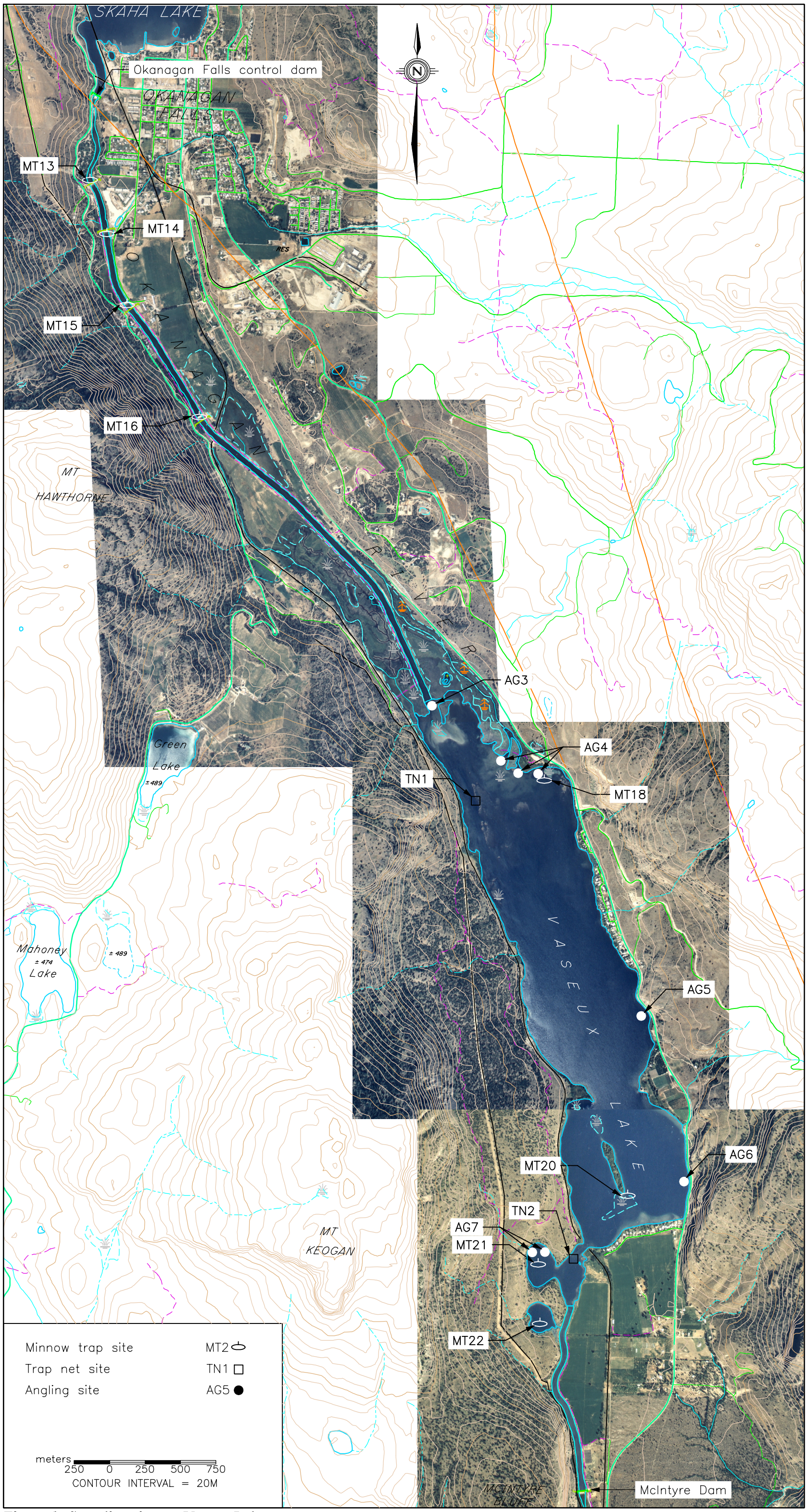


Figure 6. Sampling sites on Vaseux Lake

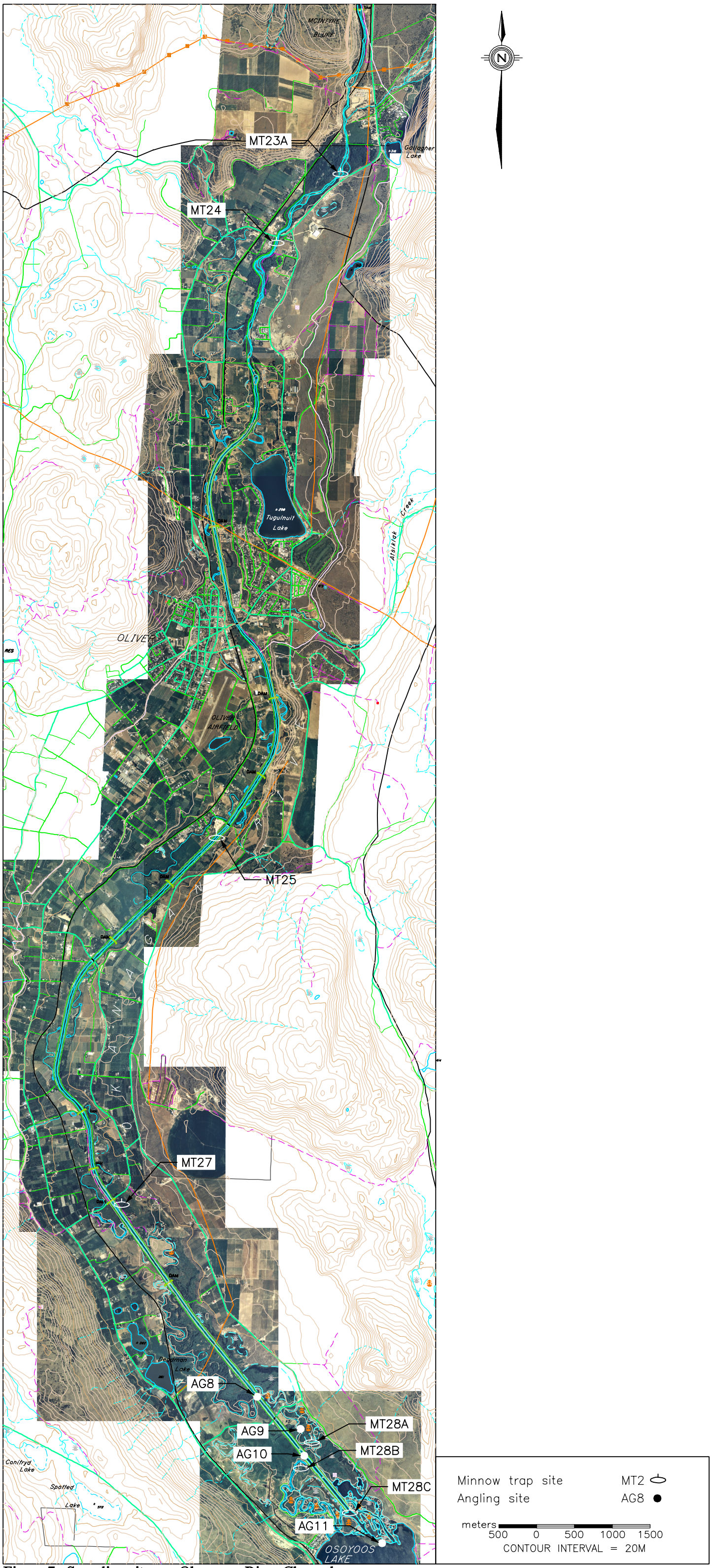


Figure 7. Sampling sites on Okanagan River Channel

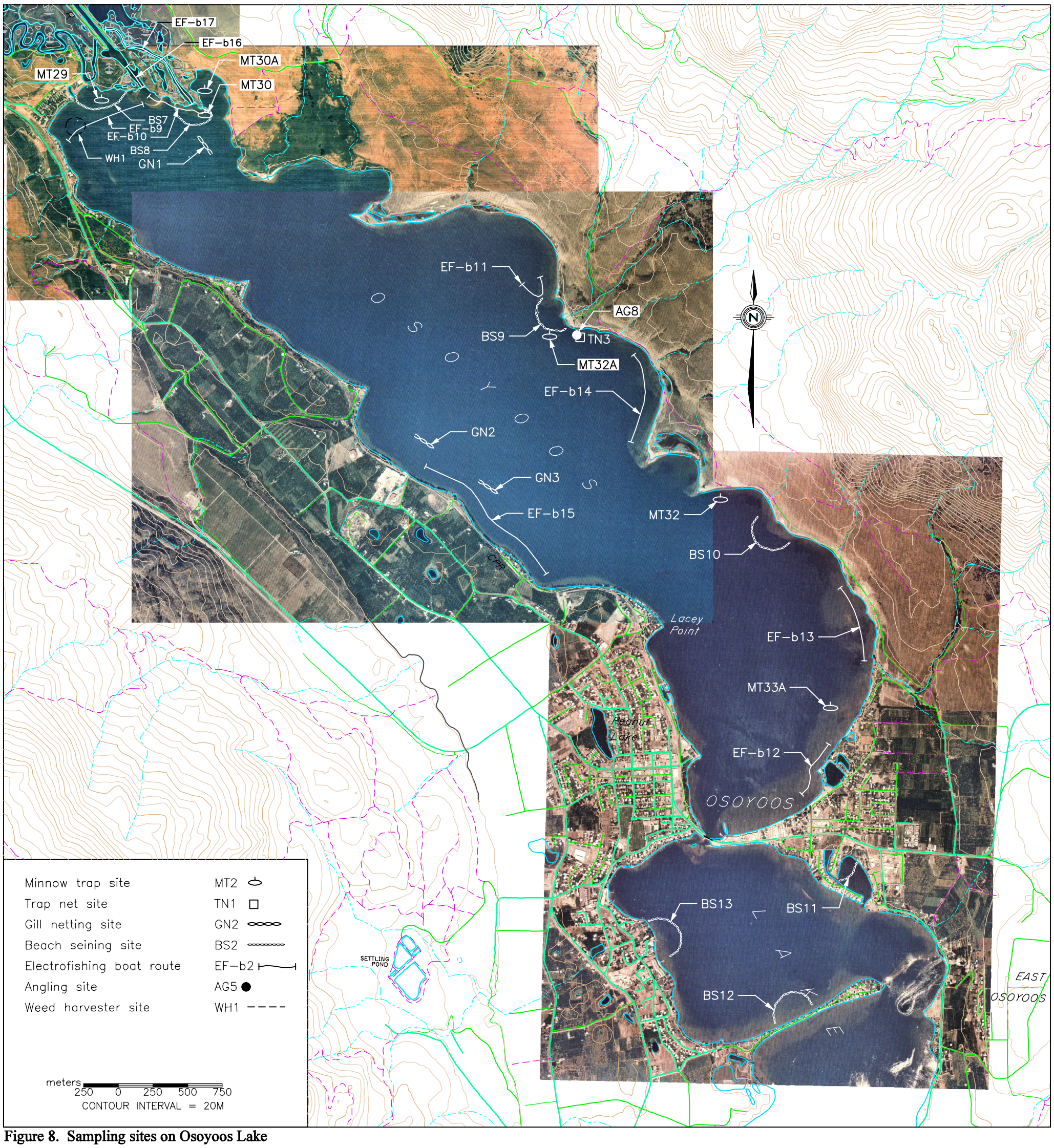


Figure 8. Sampling sites on Osoyoos Lake

3.0 AVAILABILITY OF SUITABLE HABITAT FOR EXOTIC SPECIES OF CONCERN

The possibility of undesirable exotic fish moving to areas upstream of McIntyre Dam such as Skaha and/or Okanagan Lakes is a concern because if such habitats prove suitable to exotic species they may adapt for long-term colonization. The Skaha Lake littoral zone (Figure 9) has rooted aquatic vegetation along the shallow eastern and western shorelines thus providing habitat for fish that prefer such areas. Given access these exotic species, black crappie, bluegill, largemouth bass and tench could survive in Skaha Lake but not necessarily flourish as well as they do in Osoyoos Lake with its shallow mean depth and extensive littoral area.

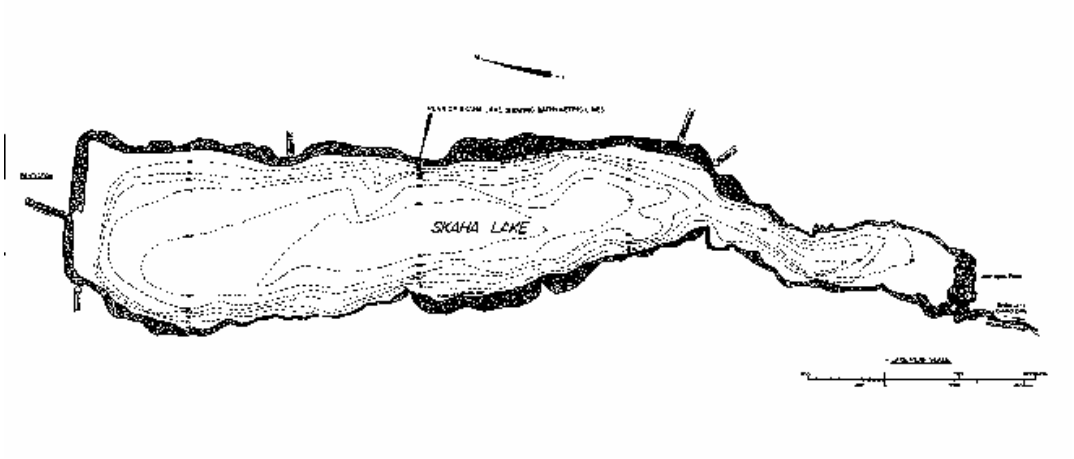


Figure 9. Bathymetric Map of Skaha Lake

Along its large littoral area, Osoyoos Lake (Figure 10) supports many fish species, and is an important nursery ground for young sockeye salmon (Anon, 1972). There is a high density of fish in all habitats of Osoyoos Lake including a large percentage of non-salmonids. Bluegill, found during sampling in YEAR 2, inhabit shallow, weedy, littoral areas as juveniles. but when they reach >50-75mm they move into open-water within the limnetic zone. Black bullheads already exist in Skaha Lake. Black crappie, largemouth bass and tench typically inhabit littoral areas like those found in Osoyoos Lake and could inhabit Skaha Lake. Walleye are found in both the pelagic and littoral areas of lakes; they are also piscivorous and prey heavily on juvenile sockeye when present.

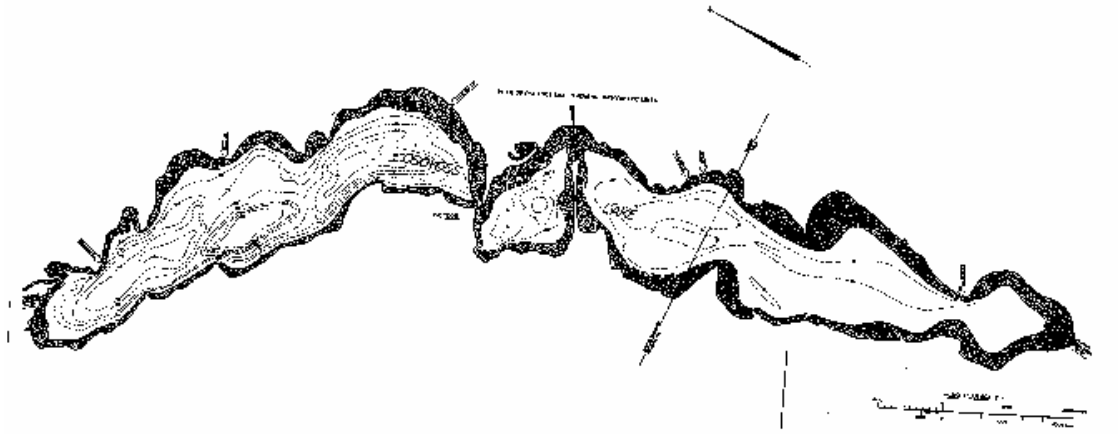


Figure 10. Bathymetric map of Osoyoos Lake

4.0 ASSESSMENT OF THE RISK OF EXOTIC SPECIES INTRODUCTION TO SKAHA LAKE

After a complete review of YEARS 1, 2, and 3, there arise two risks from the possible introduction of exotic species into Skaha Lake:

1. Predation on young salmonids by carnivorous fish species
2. Strong competition for habitat and/or food.

From the three year literature review and sampling it was concluded that there were six exotic species of concern i.e. black crappie, black bullhead, largemouth bass, tench, bluegill and walleye.

Largemouth bass (already found in Vaseux Lake above McIntyre Dam) are a predatory fish that feed in the littoral areas. By studying smallmouth bass (established throughout the Okanagan Basin) it was hoped to extrapolate findings and apply them to the somewhat similar habitats and feeding preferences of largemouth bass (a fish of the same genus). The literature search concluded that the two species use different areas with smallmouth bass using cooler deeper areas (Scott and Crossman 1973; Coble 1975) whereas largemouth bass thrive best in warm, shallow, weedy areas of lakes or river backwaters (Newbury and Gaboury 1993; Scott and Crossman 1973). Both largemouth and smallmouth bass are piscivorous but largemouth bass are described as territorial ambush predators, which behavior would seem likely to make them comparatively less threatening to pelagic salmonids (Naito 2000). Smallmouth feed on sockeye fry primarily in the littoral zone where the young fish are abundant after emergence and on sockeye smolts during their out-migration.

Juvenile bluegills are typically found in littoral zones, but on reaching about 50-75mm they move into open water within the limnetic zone where they feed predominantly on limnetic zooplankton. Fish are rarely eaten so bluegill is of little consequence for deep pelagic species like kokanee, sockeye and rainbow trout.

Walleye are found in the Okanagan River south of the International Border and there is no apparent physical barrier to their movement north. These fish would have an impact on juvenile sockeye and kokanee but this would occur primarily in Osoyoos Lake if they were to extend their range to include it. Walleye are sensitive to light and it appears this photosensitivity maybe what keeps them from colonizing the upper areas of the Okanagan system (Vedan 2003).

There are a number of barriers to fish migration up the Okanagan River. For instance, the control dam at the outlet of Okanagan Lake is a barrier to black bullheads that exist in Skaha Lake and the control dam at the outlet of Skaha Lake is a barrier to largemouth bass that are well established in Vaseux Lake above McIntyre Dam. Since black bullheads have been identified during this study in both Skaha and Osoyoos lakes they are no longer considered an exotic species of concern.

Tench are a carp-like fish that would most likely have the same role in the ecosystem that carp have, such as competition for food with native species. The risks associated

with the upstream migration and colonization of exotic species into Skaha and South Okanagan Lakes from Years 1, 2, and 3 are summarized in Table 3.

In the Okanagan drainage the design of fish passages should be based on the jumping capabilities of the salmonids. There is little information on the jumping capabilities of exotic species, but it is known, that they do not jump very high. With this in mind, the recommendation of this report is that there are some minimum height requirements for the fish passage sections of dams. For instance sockeye salmon can probably ascend drops of 1.5 m or more and depending a great deal on where they are leaping from (Vedan 2003).

Osoyoos and Skaha Lake habitats differ primarily in the amount of littoral area. Skaha Lake contains rooted aquatic vegetation along only the eastern and western shorelines whereas, Osoyoos Lake provides considerable and widely distributed littoral habitat suitable for species such as largemouth bass, black crappie, bullhead, bluegill sunfish and tench. If access was provided to Skaha Lake, exotic species could probably survive there but perhaps not as successfully as they do in Osoyoos Lake.

Studies were conducted on the north arm of Okanagan Lake in Year Three, due to the fact that there is acceptable exotic species habitat in this area. However no species of concern were noted in this area during inspection of catches after the sampling season.

The risks associated with the introduction of all these species are minimal. Sockeye either live in a different zone or pass by them too quickly for carnivorous fish to have a significant impact.

Table 3. Summary of results from YEARS 1, 2 and 3 and perceived risks

Exotic species of concern	Geographical Range of species within South Okanagan Basin	Habitat preferences and species interactions	Skaha Lake areas thought likely to be colonized	Exotic Fish Risk Assessment
Black crappie	Caught in Osoyoos Lake oxbows; not above McIntyre Dam	Lake littoral zone. Adults feed on very small fish.	Littoral	Little interaction with salmonids
Largemouth bass	Vaseux and Osoyoos Lake where they have coexisted with salmonids for 70 years	Warm, shallow, weedy areas. Piscivorous but predation would be minimized on pelagic species except during emergence and smolts.	Littoral	Would feed on salmonids passing through the littoral zones
Tench	Caught in Osoyoos and Vaseux in 2002	Littoral areas of lakes, or swamps, particularly where organic material is substantial	Littoral and backwater oxbows	Rare in Osoyoos Lake & most likely have little interaction with salmonids.
Walleye	Not in Osoyoos, Skaha or South Okanagan lakes; established population in the Columbia mainstem	Littoral and pelagic areas of lakes seasonally inhabit the same areas, and are known to prey on juvenile salmonids.	There is suitable habitat in Skaha & Osoyoos Lake	Would have an impact on resident salmonids if they established themselves in the Okanagan Basin.
Bluegill	In Osoyoos Lake.	Littoral zone; adults move into limnetic open-water; feed predominantly on limnetic zooplankton and rarely eat fish.	Littoral as juveniles and limnetic open water as adults.	Occupy different habitat and feed on zooplankton, which makes them of little consequence to deep pelagic species like kokanee, sockeye and rainbow trout.

5.0 REFERENCES[1]

Anonymous. 1972. Limnology of the Mainstem Okanagan lakes. Bulletin No. 3. Study Committee, Canada-British Columbia- Okanagan Basin Agreement, Penticton, B.C., 4pp.

Bull, C.J. 2002. Glenfir Resources. April 30, 2002. Personal Communication.

Coble, D.W. 1975. Smallmouth bass. Pages 21-22 in H. Clepper, ed. Black bass biology and management. Sport Fish. Inst., Washington, DC.

Hyatt, K.D. and D.P. Rankin. 1999. An Evaluation of Okanagan Sockeye Salmon Escapement Objectives. Pacific Stock Assessment Review committee, working paper S99-18.

Long. K. 2002. Exotic Species at Risk Assessment. Evaluation of an Experimental Re-Introduction of Sockeye Salmon into Skaha Lake, Year 2 of 3. Okanagan Nation Fisheries Commission, Westbank, BC.

Naito, G. 2000. Presence and distribution of exotic fish species in the Okanagan watershed. Prepared for the Okanagan Nation Fisheries Commission.

Newbury, R.W. and M.N. Gaboury. 1993. Stream analysis and fish habitat design – A field Manual. Newbury Hydraulics Ltd. and the Manitoba Habitat Heritage Corporation.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada.

Vedan, Addie. 2003. Objective 2 A; Leaping and Swimming Abilities of Exotic Species of Concern. Evaluation of an Experimental Re-Introduction of Sockeye Salmon into Skaha Lake, Year 3 of 3. Okanagan Nation Fisheries Commission, Westbank, B.C..

[1] Reference used to produce literature reviews listed within the appendisized literature reviews

APPENDIX A

Required Permits

OKANAGAN NATION ALLIANCE

3255 C Shannon Lake Road, Westbank, BC V4T 1V4
Phone (250) 707-0095 Fax (250) 707-0166 www.syilx.org

June 3rd, 2002

Steve Matthews
Senior Fish Biologist
Environmental Stewardship Division
Okanagan Region
Ministry of Water, Land and Air Protection
Suite 201-3547 Skaha Lake Road
Penticton, BC V2A 7K2

COPY

Dear Steve,

Re: Scientific Collection Permit (File: 34770-20)

Thank you for the Scientific Collection Permit File: 34770-20, for our Skaha Lake sampling project to collect fish for scientific purposes. In past permits the Ministry has written in a clause stating "this permit is issued without prejudice to the title and rights of the Okanagan Nation or any member Band of the Okanagan Nation".

The ONFC recognizes the good working relationship that has developed with regional MoWLAP in Penticton and have in the past accepted the permits issued as a courtesy of goodwill amongst government agencies. However, the Okanagan Nation Fisheries Commission (ONFC), care of the Okanagan Nation Alliance (ONA) can not recognize the issued permit without the clause.

Therefore, please accept this letter as notification of our scientific works in Okanagan territory for your records.

Thank you

Deana Machin
Program Manager

COPY

BRITISH COLUMBIA

File: 34770-20

Phone: (250) 707-0095

SCIENTIFIC COLLECTION PERMIT

Permittee:
Okanagan Nation Fisheries Commission
3255 C Shannon Lake Road
Westbank BC V4T 1V4

is hereby authorized under Section 19(1) of the Wildlife Act, RSBC 1996, and as provided in Section 2(c)(i) Permit Regulation (B.C. Reg. 235/2000), to collect fish for scientific purposes from nontidal waters subject to the conditions set forth herein:

Permitted Waters: Okanagan Lake, Skaha Lake, Vaseux Lake, Osoyoos Lake and Okanagan River (including oxbows)

Permitted Areas: & Times:

No lake sampling (with the exception of minnow traps) within .5 kilometers of any streams utilized by rainbow trout (with the exception of Okanagan River using electroshocker only) during the period March 15 to June 15 and within .5 kilometers of any streams utilized by kokanee during the period September 1 to October 31.

No sampling (with the exception of minnow traps) in any streams utilized by rainbow trout during the periods April 1 to July 15 and November 1 to March 31, and no sampling in any streams utilized by kokanee during the period September 1 to April 30.

No lake sampling (with the exception of minnow traps) within 0.5 kilometers of known kokanee shore spawning areas during the period October 1 to April 30.

No seining in littoral zones of Skaha Lake, Vaseux Lake, Vaseux Lake oxbows and Osoyoos Lake during the period March 15 to June 30.

Gillnetting is permitted on a trial basis on Skaha Lake only (see Permitted Gear Section for more details).

RECEIVED
APR 22 2002
Okanagan Nation Alliance

Permitted Species: All non native fish species to specified limits indicated on Sampling Plan.

Moribund or dead kokanee samples collected as part of any ongoing Fisheries Program research projects (kokanee trawling or *Mysis relicta* Test Fishery) can be utilized for disease analysis provided they are surplus to the project requirements.

Additional fish species may be added to this Permit upon receipt of a detailed list of target species and the sample size

requirements for each fish species.

Permitted Gear:

(a) Equipment
Angling, gillnetting, electroshockers (backpack and boat mounted), minnow traps, seine nets, dip nets as per the Sampling Plan submitted by permittee.

(b) Operational Strategy
The collection operation must be designed to avoid the bycatch of non-target organisms. Ideally, all non-target organisms that are captured will be released alive in health condition. If there is a bycatch of non-target species, particularly salmonid species, collection methods must be modified prior to resuming sampling operations.
Gillnets are permitted on a trial basis only. Capture methodologies (mesh size, net location, fishing times and duration) must be designed to minimize capture of non-target species as indicated above. Gillnets must be checked a minimum of once per hour to assess bycatch.

Monitoring of Operation: The Permittee will allow Ministry of Water, Land and Air Protection observers to inspect the collection procedure at any time without advance notice being given.

Permitted Personnel: Howie Wright, Shayla Lawrence, Herb Alex, Fabian Alexis, Alfred Snow, Keith Lewis, Kari Long and any additional qualified personnel as authorized by the ONFC. Qualified fish sampling personnel must be present during all sampling activities.

Permit Period: April 15, 2002 to March 31, 2003.

Expiry Date: April 1, 2003.

See reverse side of General Conditions

Approved by:

Tom Ethier

Tom Ethier
Acting Section Head

Date: April 15, 2002

Cc: Rick Hildebrand, Conservation Officer Service, Kamloops
Steve Matthews, Fisheries Program, Penticton

Any contravention or failure to comply with the terms and conditions of this permit is an offence under the Wildlife Act, RSBC 1996 and B.C. Reg. 253/2000. Section 2(c)(i) Permit Regulation.

GENERAL CONDITIONS

This permit is issued without prejudice to the title and rights of the Okanagan Nation.

1. This collecting permit is not valid
   (a) in national parks,
   (b) in provincial parks unless approved in writing by regional staff of BC Parks,
   (c) for salmon other than kokanee, or
   (d) for collecting fish by angling unless the permittee and crew members possess a valid angling licence.

2. This permit is valid only for the activities approved on the application form and in accordance with any restrictions set out therein.

3. The Permittee must notify the district conservation officer(s) of the permittee's schedule for collection activities in their areas prior to the commencement of those activities.

4. This permit must be carried by the permittee while engaged in fish collecting and produced for inspection upon request of a conservation officer, fishery officer or constable.

5. This permit is valid only for trained, qualified staff named in the Application. The permittee will comply with all Worker's Compensation Board requirements and other regulatory requirements.

6. Any specimens surplus to scientific requirements and any species not authorized for collection shall be immediately and carefully released alive at the point of capture.

7. Fish collected under authority of this permit shall not be used for food or any purpose other than the objectives set out in the approved application for a scientific collection permit. The permittee shall not sell, barter, trade, or give away, or offer to sell, barter, trade or give away fish collected under authority of this permit. Dead fish shall be disposed of in a manner that will not constitute a health hazard, nuisance or a threat to wildlife.

8. No fish collected under authority of this permit shall be transported alive or transplanted to another body of water unless separately authorized by the Federal/Provincial Committee on live fish permits.

9. The permittee shall submit to the Regional Fisheries Section Head for the area under consideration the fish collection data within 90 days of completion of the collecting activity. Interim reports and/or sample data cards will be provided upon request to the requesting officer.

10. This collecting permit may be cancelled at any time and shall be surrendered to a Conservation Officer on demand or to the issuer immediately upon receipt of written notice of its cancellation.

11. Ensure staff are always working in water that is 5°C or greater if sampling for presence or absence of fish.

To:

- Conservation Officer Service – Ministry of Environment, Lands and Parks, Penticton FAX 492-1314
- Penticton RCMP Detachment – Atten. Watch Commander FAX 492-4851
- Osoyoos RCMP Detachment – Atten. Officer in Charge FAX 495-7416

April 17, 2001

Dear Sir or Madam:

The Okanagan Nation Fisheries Commission will be conducting fisheries research on Okanagan, Skaha and Osoyoos Lakes and the rivers between these lakes. Similar to last years sampling we will be fishing along shorelines at night from a large boat with many lights, setting nets etc. at various times. We wanted you to know about our operations in advance since persons observing these operations may report illegal fishing or criminal activity. Out tentative schedule is as follows,

- electrofishing from the boat in the evenings from April 22nd to 26th, 2001
- minnow trapping during the day April 17th to May 11th, 2001
- beach seining various sampling during the day between May 1st and 18th
- gill netting during the evenings between May 1st and 18th, 2001
- angling sampling during the day for the Month of May 2001.

All our activities are legitimate fisheries research and both Fisheries and Oceans Canada (a.k.a. Department of Fisheries and Oceans or DFO) and the Fisheries Section of the Ministry of Environment are fully informed.

Should you require further information please contact, Kari Long or Dawn Machin with the Okanagan Nation Fisheries Commission (250) 707 0095.

Yours truly,

Kari Long
Okanagan Nation Fisheries Commission
FAX 707 0166

APPENDIX B

Angling Data

BPA Angling - 2002

Date	Location description	Site	Species Caught					Fishing Effort				Bait & Tackle
			SMB	YP	NSC	CP	LMB	Start Time	Stop Time	Hours Fished	No. of fishers	
07-May-02	VDS # 1							7:15	9:00	1:45	3	Worms, spinners, jiggers
14-May-02	Vaseaux L - OK R. mouth	3						10:15	10:35	0.34	2	Spinners, Roe
14-May-02	Vaseaux L - wildlife viewing	4						11:00	11:20	0.34	2	Spinners, Roe
14-May-02	Vaseaux L - along Hwy	5						12:30	13:15	0.67	2	Spinners, Roe
14-May-02	Osoyoos L - Rattlesnake	8						14:45	15:30	0.67	3	Spinners, Roe
16-May-02	Vaseaux L - OK R. mouth	3						10:00	10:25	0.42	3	Spinners, Jiggers, Roe
16-May-02	Vaseaux L - along Hwy	5						11:35	12:10	0.58	2	Spinners, Jiggers, Worms
16-May-02	Osoyoos L - Rattlesnake	8						13:45	14:30	0.67	3	Spinners, Jiggers, Worms

APPENDIX C

Beach Seining Data

				Species Caught																	Fishing Effort				Comments
Date	Lake	Site	Location	BGB	BCB	BH	CAS	CP	RSC	LMB	NSC	PCC	PMB	RBT	SK	SMB	SU	YP	WF	UNK	No. of hauls	Net Depth (m)	Net Length (m)	Mesh size (mm)	
April 8, 2002	OSOYOOS	1	N. Basin, W of river mouth				10								25				3		1	3 m	35 m	3, 10, 25 mm	
April 8, 2002	OSOYOOS	2	River mouth												7			1			1	3 m	35 m	3, 10, 25 mm	
April 8, 2002	OSOYOOS	3	E. of river mouth												3						1	3 m	35 m	3, 10, 25 mm	
May 2, 2002	OK LK - NA	22	Old pole wharf				27												2		1	3 m	35 m	3, 10, 25 mm	
May 2, 2002	OK LK - NA	21	North of Mudhole				32												18		1	3 m	35 m	3, 10, 25 mm	
May 2, 2002	OK LK - NA	23	Eastside of lake				13												1		1	3 m	35 m	3, 10, 25 mm	
May 2, 2002	OK LK - NA	20	Komasket park (S. of wharf)				6										4		1		1	3 m	35 m	3, 10, 25 mm	
May 2, 2002	OK LK - NA	19	Komasket park (below daycare)				6											1			1	3 m	35 m	3, 10, 25 mm	Substrate consists of fine mud - poor site to work
May 2, 2002	OK LK - NA	18	Below S. Joe property																		0	3 m	35 m	3, 10, 25 mm	Possible electrofishing site
May 2, 2002	OK LK - NA	16	Louie Property																		0	3 m	35 m	3, 10, 25 mm	Possible electrofishing site
May 2, 2002	OK LK - NA	17	C Louis Property				5												6		1	3 m	35 m	3, 10, 25 mm	
May 3, 2002	OSOYOOS	7	Ok River mouth				6								3			1	1		1	3 m	35 m	3, 10, 25 mm	
May 3, 2002	OSOYOOS	8	Eastside of river mouth				2								25			1	10		1	3 m	35 m	3, 10, 25 mm	
May 3, 2002	OSOYOOS	10	Whitesands												8						1	3 m	35 m	3, 10, 25 mm	
May 3, 2002	OSOYOOS	11	Inlet @ Central Basin				2	3				2	1				3	12			1	3 m	35 m	3, 10, 25 mm	
May 3, 2002	OSOYOOS	12	Haynes point Campground				4								3						1	3 m	35 m	3, 10, 25 mm	
May 17, 2002	OSOYOOS	11	Inlet @ Central Basin		16	13	2	1									6	1			1	3 m	35 m	3, 10, 25 mm	
May 17, 2002	OSOYOOS	13	Westside of Central basin					1													1	3 m	35 m	3, 10, 25 mm	
May 17, 2002	OSOYOOS	12	Haynes point Campground				7								34						1	3 m	35 m	3, 10, 25 mm	
May 17, 2002	OSOYOOS	7	Ok River mouth				20								21						1	3 m	35 m	3, 10, 25 mm	
May 17, 2002	OSOYOOS	10	Whitesands				1								16				14		1	3 m	35 m	3, 10, 25 mm	
June 3, 2002	OSOYOOS	11	Inlet @ Central Basin		1	4							6			1	6	15			1	3 m	35 m	3, 10, 25 mm	
June 3, 2002	OSOYOOS	12	Haynes point Campground					2													1	3 m	35 m	3, 10, 25 mm	
June 3, 2002	OSOYOOS	10	Whitesands												1						1	3 m	35 m	3, 10, 25 mm	
June 3, 2002	OSOYOOS	8	Eastside of river mouth																		1	3 m	35 m	3, 10, 25 mm	
June 3, 2002	OSOYOOS	1	N. Basin, W of river mouth				4							3	17				2		1	3 m	35 m	3, 10, 25 mm	
June 13, 2002	OK LK - NA	17	C.Louis Property				1				9	1									1	3 m	35 m	3, 10, 25 mm	Sunny, clear, calm waters
June 13, 2002	OK LK - NA	16	Louie Property				29												1		1	3 m	35 m	3, 10, 25 mm	
June 13, 2002	OK LK - NA	15	Irish Creek				2		4		21	115						3			1	3 m	35 m	3, 10, 25 mm	Six CMC
June 13, 2002	OK LK - NA	14	Deep Creek				3		1									1		34	1	3 m	35 m	3, 10, 25 mm	One snail
June 13, 2002	OK LK - NA	27	Gregoire Property [barn]								13	12									1	3 m	35 m	3, 10, 25 mm	
June 13, 2002	OK LK - NA	26	Spider Ranch				4				2	99					3				1	3 m	35 m	3, 10, 25 mm	
June 13, 2002	OK LK - NA	25	South of Spider Ranch					1	29		25	10									1	3 m	35 m	3, 10, 25 mm	
June 13, 2002	OK LK - NA	24	Bonneau Property				1		98		15	326	5				22	6			1	3 m	35 m	3, 10, 25 mm	
June 13, 2002	OK LK - NA	22	Old pole wharf						25%		15%	55%						5%			1	3 m	35 m	3, 10, 25 mm	Mostly PCC, then RSC, NSC, YP
June 13, 2002	OK LK - NA	21	North of Mudhole						20%		15%	60%	5%								1	3 m	35 m	3, 10, 25 mm	Mostly PCC, then RSC; PMB - approx. 3480 in total
June 13, 2002	OK LK - NA	21 A	Alexis Beach								1										1	3 m	35 m	3, 10, 25 mm	
June 13, 2002	OK LK - NA	20	Komasket park(S. of wharf)						9		2	4					1				1	3 m	35 m	3, 10, 25 mm	
June 13, 2002	OK LK - NA	19	Komasket park (below daycare)																		1	3 m	35 m	3, 10, 25 mm	No longer a site(omit)
June 13, 2002	OK LK - NA	18	Below S. Joe property						35%		15%	50%									1	3 m	35 m	3, 10, 25 mm	Mostly PCC, then RSC, NSC - approx. 2960 in total

June 14, 2002	Osoyoos	7	Ok River mouth															yes			1	3 m	35 m	3, 10, 25 mm	YP juveniles present
June 14, 2002	Osoyoos	10	Whitesands																		1	3 m	35 m	3, 10, 25 mm	No fish
June 14, 2002	Osoyoos	8	Eastside of river mouth																		1	3 m	35 m	3, 10, 25 mm	
June 14, 2002	Osoyoos	9	Rattlesnake				5														1	3 m	35 m	3, 10, 25 mm	
June 14, 2002	Osoyoos	10	Whitesands																		1	3 m	35 m	3, 10, 25 mm	No fish
June 14, 2002	Osoyoos	11	Inlet @ Central Basin					2			3	6						7			1	3 m	35 m	3, 10, 25 mm	Lots of green algae & slime\ Lots of mud & silt (21 BNH present)
June 14, 2002	Osoyoos	12	Haynes point Campground				1							1							1	3 m	35 m	3, 10, 25 mm	
July 4, 2002	OK LK - NA	22	Old pole wharf				1		1		17							1	1		1	3 m	35 m	3, 10, 25 mm	
July 4, 2002	OK LK - NA	21	North of Mudhole				7		68		29	3	1			35		2		10	1	3 m	35 m	3, 10, 25 mm	One painted turtle
July 4, 2002	OK LK - NA	21 A	Alexis Beach				17													100	1	3 m	35 m	3, 10, 25 mm	
July 4, 2002	OK LK - NA	24	Bonneau Property				12		630		42	10	40			22		69			1	3 m	35 m	3, 10, 25 mm	
July 4, 2002	OK LK - NA	20	Komasket park (S. of wharf)				2		4		30	27									1	3 m	35 m	3, 10, 25 mm	
July 4, 2002	OK LK - NA	18	Below S. Joe property						75%		15%	5%				5%					1	3 m	35 m	3, 10, 25 mm	Mostly RSC, then NSC, SU,and PCC
July 4, 2002	OK LK - NA	11	South of Spider Ranch						50%		15%	5%				5%					1	3 m	35 m	3, 10, 25 mm	Mostly RSC, then NSC, SU,and PCC
July 4, 2002	OK LK - NA	10	Spider Ranch				4		28		2	2				11		22			1	3 m	35 m	3, 10, 25 mm	
July 4, 2002	OK LK - NA	16	Louie Property				27		2		28	47						1			1	3 m	35 m	3, 10, 25 mm	
July 4, 2002	OK LK - NA	17	C Louis Property								1										1	3 m	35 m	3, 10, 25 mm	
July 4, 2002	OK LK - NA	7	Head of the lake				1				40	1						11			1	3 m	35 m	3, 10, 25 mm	
July 4, 2002	OK LK - NA	8	Deep creek								10	1				1					1	3 m	35 m	3, 10, 25 mm	One CP
July 4, 2002	OK LK - NA	23	Eastside of lake				3		21		4							6		25	1	3 m	35 m	3, 10, 25 mm	
July 5, 2002	Osoyoos	11	Inlet @ Central Basin							500		1	4					2			1	3 m	35 m	3, 10, 25 mm	One BCB, no adult fish, construction, noise pollution 10m from shore
July 5, 2002	Osoyoos	13	Westside of Central basin				5			3		1				2					1	3 m	35 m	3, 10, 25 mm	
July 5, 2002	Osoyoos	7	N. Basin, W of river mouth				1			2						1		5			1	3 m	35 m	3, 10, 25 mm	
July 5, 2002	Osoyoos	8	East of river mouth				1					1									1	3 m	35 m	3, 10, 25 mm	
July 5, 2002	Osoyoos	10	Whitesands									1								1	1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	Osoyoos	11	Lagoon	3	16					12						1		1			1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	Osoyoos	12	Haines Point													3					1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	Osoyoos	3	WS river mouth				6			1			10			2					1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	17	C Louis Property				23						23				1				1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	16	Louie Property				8						2								1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	15	Irish Cr. - HOL Site																		0	3 m	35 m	3, 10, 25 mm	Water levels to low
September 16, 2002	OK LK - NA	14	Deep Cr.				25		1				1					3			1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	27	Gregoire Property [barn]				2					1	1					1			1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	26	Spider Ranch				7				1	1					1				1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	25	South of Spyder Ranch																		0	3 m	36 m	3, 10, 25 mm	Water levels to low
September 16, 2002	OK LK - NA	22	Old pole wharf				17														1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	21	Mud Hole				6														1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	23	near OKIB boundary						172		16		1				1				1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	20	Komasket - south of wharf				4						2								1	3 m	35 m	3, 10, 25 mm	
September 16, 2002	OK LK - NA	18	Below S. Joe Property				3		3		6										1	3 m	35 m	3, 10, 25 mm	

APPENDIX D

Electrofishing boat Data

			Species Caught																		Fishing Effort					
Date	Lake	Site	BCB	BGB	BKH	BB	CP	KO	LMB	NSC	PCC	PMB	RB	RSC	CAS	SMB	SU	SK	WF	YP	SEC.	Volts	Amps	Duty Cycle	Temp.	Comments
April 15/02	Skaha	EF-b 8a					6			2	1				2		2		2		1612	500 60pps	3.3	35%	5.6-5.9	
April 15/02	Skaha	EF-b 8b					1			3	1			1			2		1		1016	500 60pps	330%	33%	5.0	
April 15/02	Skaha	EF-b 8c									1						1		1		750	500 60pps	3.3	33-35%	5.2	
15-Apr-02	Skaha	EF-b 7						2					1				9				1025	500 60pps	4.0	30%	5.8-6.0	
15-Apr-02	Skaha	EF-b 6					1	14								1	5				1025	500 60pps	3.1	20%	6.0	
15-Apr-02	Skaha	EF-b 8			2					1		7			1	##	2				>600	500 60pps	3.1	20%	5.6	
15-Apr-02	Skaha	EF-b 8d																			610	500 60pps	3.1	20%	5.9	No fish caught
15-Apr-02	Skaha	EF-b 5								1							9		1		850	500 60pps	3.1	30%	5.2	
17-Apr-02	Osoyoos	EF-b 9						2		3	1						3		6	##	1530	500 60pps	2.7-3.0	15-20%	9.1	Water is turbd
17-Apr-02	Osoyoos	EF-b 10					19			2					1	2	5		5	52	1720	500 60pps	3.1	20%	8.6	
17-Apr-02	Osoyoos	EF-b 11								1								3	3	12	1050	500 60pps	2.7	15-18%	7.3	
17-Apr-02	Osoyoos	EF-b 12																50			18	500 60pps	2.6	10-20%	8.9	
17-Apr-02	Osoyoos	EF-b 9-ef-b 10								11							10		25	30	5040	500 60pps	3	20%	8.1-8.5	Observed carp and emergent sockeye fry in littoral zone
16-Jun-02	Okanagan - North Arm	EF-b-17					2			3	2						11			7	814	500 60pps	3-4.0	40%	19.5	Shallow water
16-Jun-02	Okanagan - North Arm	EF-b-16					10			6	2						6			2	661	500 60pps	4	40%	19.5	Tules
16-Jun-02	Okanagan - North Arm	EF-b-21								1										1	224	500 60pps	4	40%	21.2	
16-Jun-02	Okanagan - North Arm	EF-b-20					30			1	1						38			1	1866	500 60pps	4	40%	21.3	Clay Bottom
16-Jun-02	Okanagan - North Arm	EF-b-19				1	1			6	8	1		1			21			2	2106	500 60pps	4	40	15.7	Sporadic Reeds
17-Jun-02	Skaha	Site 6			1					4	2	1			1	16	5			4	1117	500 60pps	4.5	40%	19	
17-Jun-02	Skaha	Site 7			2		1					4			1	39	9				1510	500 60pps	4	40%	18.9	
17-Jun-02	Skaha	Site 8									1	1				29	16				1060	500 60pps	4	40%	19.4	
17-Jun-02	Skaha	Site 5					2			1							50				900	500 60pps	4.5	40	16.9	Heavy Curent into lake
19-Jun-02	Osoyoos	Site 9			2		14			4	2		2			3	15	7	12	##	1805	500 60pps	4	40%	19.8	
19-Jun-02	Osoyoos	Site10	1		1		27			1		1	1		1	3	4	1	9	##	2262	500 60pps	4	40%	20	
19-Jun-02	Osoyoos	Site11					1										3			35	730	500 60pps	4	40%	18.6	
19-Jun-02	Osoyoos	Site 12														1				8	930	500 60pps	4	40%	19.3	
19-Jun-02	Osoyoos	Site13					5										2			35	900	500 60pps	4	40%	19.9	
20-Jun-02	Osoyoos	Site 9					6			3						5	11		10	##	1788	500 60pps	4	40%	20.6	
20-Jun-02	Osoyoos	Site10			1		39	1		2					2	5	6		9	##	2160	500 60pps	4	40%	22.1	
20-Jun-02	Osoyoos	Site11					3									1	1			34	630	500 60pps	4	40%	22.1	
20-Jun-02	Osoyoos	Site 12					1						1		1					21	725	500 60pps	4	40%	21.1	
24-Jun-02	Osoyoos	Site 5					1			8	10	2		11			38			22	2400	500 60pps	4.2	40%	19.2	
24-Jun-02	Osoyoos	Site 6					10			11	60	13		8			16		1	27	1500	500 60pps	4.2	35%	21.4	
26-Aug-02	Okan. Lk. - South	Site A Trout Creek					1			1	2						3				1500	500 60pps	3.9	30%	22.6	
26-Aug-02	Okan. Lk. - South	Site B West of Trout Creek					1			4	33			3	2		3			2	482	500 60pps	40	30%	22.6-22.9	
26-Aug-02	Okan. Lk. - South	SiteT1					1			3	2			13			9			1	1660	500 60pps	4	30%	23.1	Made two EF passes of this site
26-Aug-02	Skaha	Site T1								30	24			8			1		15	1	810	500 60pps	4	30%	22.8	
26-Aug-02	Skaha	Site 5					13			1	3	1	1		13	25	10				750	500 60pps	4.3	30%	22.3	
26-Aug-02	Skaha	Site 8a					1								1	2	15				966	500 60pps	4.3	30%	22	
27-Aug-02	Skaha	Site 8d					4				2						8				1320	500 60pps	4.4	40%	21.2	
27-Aug-02	Skaha	Site 6					2				3					4	8				998	500 60pps	4.3	40%	21.8	
27-Aug-02	Skaha	Site 7					22			2						8	6				950	500 60pps	4.3	40%	22	
27-Aug-02	Osoyoos	Ef Site b9	11	10			20		10	1	1	6			1	36	4			##	1635	500 60pps	3.5	30%	24.4	
27-Aug-02	Osoyoos	Site Ef b-10	5				10		6	4						25	6		4	13	1200	500 60pps	3.9	30%	24.6	
27-Aug-02	Osoyoos	Site Ef-B-10a	11	4			23		37						3	69				##	1260	500 60pps	4	30%	24.9	
28-Aug-02	Osoyoos	Site Ef-b11 Rattlesnake		5	1		10		12						2	9				51	900	500 60pps	4.1	40%	24.8	
28-Aug-02	Osoyoos	SiteEf-b12		1			2		5							14	1			26	860	500 60pps	4.1	30%	24.4	
04-Sep-02	Osoyoos	Site Ef B-9	15	12					##	1		2			2	35	2			96	1700	500 60pps	2.2-4.0	30-35	20.9	
04-Sep-02	Osoyoos	Site 9	2	3	1		2		36	1					1	37	3			48	1320	500 60pps	3	35%	20.7	
28-Oct-02	Okanagan - North Arm	EF-b-19								3	##		1	1					12	8	2400	500 60pps	3.6	30%	11.1	
28-Oct-02	Okanagan - North Arm	EF-b-18						18		6	13						13		2	13	1570	500 60pps	3.6	30%	10.1	
29-Oct-02	Skaha	Site 5			3		2	50		11				1	1	1	19			49	1500	500 60pps	3.4	35%	10.1	Nsc 520 mm Ate ko. 220mm
29-Oct-02	Skaha	Site 8a					2	11		1	3					6	17		12		2530	500 60pps	3.3	35%	10.8-10.4	
29-Oct-02	Skaha	Site 8			2		1			1		17				##	5			1	1080	500 60pps	3.2	40%	11.2	
29-Oct-02	Skaha	Site 6			2		1	1				3				6	5				880	500 60pps	3.4	30%	10.7	
29-Oct-02	Skaha	Site 7					1	22		3						3	22				840	500 60pps	3.5	30%	10.8	
29-Oct-02	Skaha	Site 8D			2		3	8		8	9		1		2		14		4	1	2345	500 60pps	4	35%	10.8	
31-Oct-02	Osoyoos	Site 9	2				1	1	2						2	1	1		2	65	880	500 60pps	3.2	25%	10.3	
31-Oct-02	Osoyoos	Site 10	23	1				5		1					1	1	8			16	960	500 60pps	4.5/3.2	25/30%	10.(10.3-10.4)	
31-Oct-02	Osoyoos	Site11													1			10	2	14	900	500 60pps	3.2	30%	10.6	
31-Oct-02	Osoyoos	Site 12							1							1		6			660	500 60pps	3.8	40%	9.7	

APPENDIX E

Backpack Electrofishing Data

Date	Location	Site #	Cond.	Temp.	Sec.	Setting	Voltage	Species caught	Numbers of fish	Crew	Weather	Comments
July11/02	Okanagan River											
July11/02	Deer park	1	224	22	206	L4	200	pumpkinseed	3	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Deer park	1						smallmouth bass	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Deer park	1						prickley sculpin	2	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Vaseux Creek	2			204	J5	400	longnose dase	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Vaseux Creek	2						salmonid fry	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02		3			337	J5	400	rainbow trout	6	Hwright/Halex/Klong	Sunny/Clear	
July11/02		3						smallmouth bass	2	Hwright/Halex/Klong	Sunny/Clear	
July11/02		3						longnose dase	6	Hwright/Halex/Klong	Sunny/Clear	kept 1 longnose dace
July11/02		3						sucker	3	Hwright/Halex/Klong	Sunny/Clear	kept 1 SU
July11/02	SC at first island	3a			209	J5	200	sucker	2	Hwright/Halex/Klong	Sunny/Clear	
July11/02	SC opposite Transect # 1	4			62	J5	200	none	0	Hwright/Halex/Klong	Sunny/Clear	
July11/02		5			175	J5	200	prickley sculpin	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02		5						smallmouth bass	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Transect # 3	6			269	J5	200	rainbow trout	1	Hwright/Halex/Klong	Sunny/Clear	kept possible other
July11/02	The island	7			227	L4	600	red side shiner	2	Hwright/Halex/Klong	Sunny/Clear	
July11/02	The island	7						longnose dase	4	Hwright/Halex/Klong	Sunny/Clear	UNK-possible PMB
July11/02	Pool below island	8				D3	600	none	0	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Around isle upstream of Oasis gas station	9				L4	100	none	0	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Side-channel near Oasis gas station	10			621	L5	200	longnose dase	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Side-channel near Oasis gas bar	10						rainbow trout	5	Hwright/Halex/Klong	Sunny/Clear	kept RB
July11/02	Gravel bar below Hwy bridge	11			411	L5	200	red side shiner	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Gravel bar below Hwy bridge	11						smallmouth bass	4	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Gravel bar below Hwy bridge	11						chiselmouth chub	4	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Gravel bar below Hwy bridge	11						northern pike minnow	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Gravel bar below Hwy bridge	11						rainbow trout	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Gravel bar below Hwy bridge	11						sucker	2	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Oxbow RL below Hwy bridge	12			240	L5		pumpkinseed	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Oxbow RL below Hwy bridge	12						smallmouth bass	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	SC near Transect # 4	13		24	431		200	longnose dase	1	Hwright/Halex/Klong	Sunny/Clear	
July11/02	SC near Transect # 4	13						sucker	4	Hwright/Halex/Klong	Sunny/Clear	
July11/02	Island below Transect # 5	14			174	I5	200	northern pike minnow	1	Hwright/Halex/Klong	Sunny/Clear	

APPENDIX F

Gill Netting Data

BPA Gill Netting - 2002

				Species Caught									Fishing Effort				
Date	Lake	Site	Mesh size (cm)	CP	NSC	SK Adult	RBT	KO	PCC	MWF	WF	SU	Depth of Lake at set	Depth of GN	Time Set	Time Picked	Area Description
23-Apr-02	Skaha	one	2.0, 2.5, 3.5, 4.0, 4.5		3			1	13	2		1	30 metre	20m		21:50	10 m from shoreline 30 feet to 90 feet
23-Apr-02	Skaha	two	2.0, 2.5, 3.0, 4.5, 5.5											20m		23:08	200 m from shoreline and 50 m north of transect
25-Jun-02	Osoyoos	one	2.0, 2.5, 3.0, 3.5, 4.5,								5		North 50FT South 100	20m	18:10	4:37	South End Osoyoos. East of river mouth
25-Jun-02	Osoyoos	Two	2.5, 3.5, 4.5								22	5	South 20ft North 60	20m	18:45	6:20	South of Acoustic transect site
27-Jun-02	Osoyoos	One	2.0, 2.5, 3.5, 4.5, 5..5,					1					20m	20m	1:15		200m north of transect
27-Jun-02	Osoyoos	Two	2.0, 2.5, 3.0, 3.5, 4.0, 4.5					1			1		20m.	20m	21:15	5:15	500m South of transect
15-Jul-02	Osoyoos	one	2.0, 2.5, 3.0, 3.5, 4.0, 5.5			3					12		100ft	20m	7:34	5:50	North end of Osoyoos Lk.
17-Jul-02	Osoyoos	one	2.0, 2.5, 3.0, 3.5, 4.5, 5.5					1	9			1	65ft South 90 North	20m	6:30	5:30	Set 50m South of transect
17-Jul-02	Osoyoos	Two	2.0, 2.5, 3.5, 3.5, 5.0								1	1	100ft	20m	9:00	5:45	50m North of transect
25-Nov-02	Osoyoos	One	1.0, 1.5, 2.0, 3.0, 3.5, 4.0, 5.0, 5.5	1							1		30m	20m	17:15	7:45	North of Acoustic transect
28-Nov-02	Skaha	One	1.5, 3.0, 3.5, 4.0, 5.0				1	1				1	30m	20m	2.15	7:47	Below saddle of Howies transect
28-Nov-02	Skaha	Two	2.0, 3.0, 3.5, 4.0, 4.5, 5.0,					1					30m	20m	2.55	7:47	Below saddle of Howies transect

APPENDIX G

Minnow Trapping Data

		Species Caught														Fishing Effort					
Location	MT site #	SU	SMB	CAS	NSC	PMB	RSC	RBT	YP	BB	LMB	CP	PCC	BKH	TC	Date set	Time set	No of traps	Date picked	Time picked	Comments
Inlet of Penticton channel	6			4					2							04-Apr-02	9:50	3	05-Apr-02	9:57	
Bridge of Penticton channel	7			3	1											04-Apr-02	10:05	3	05-Apr-02	9:40	
Penticton Oxbow 1	7a															04-Apr-02	10:30	3	05-Apr-02	10:15	one salamander
Penticton Oxbow 2	7b				12					1						04-Apr-02	10:40	3	05-Apr-02	10:25	
Outlet of Penticton channel	8			3			1									04-Apr-02	10:50	3	05-Apr-02	10:36	
VDS 17	13			2												04-Apr-02	11:15	3	05-Apr-02	11:00	
VDS 16	14															04-Apr-02	11:20	3	05-Apr-02	11:04	
VDS 15	15			3												04-Apr-02	11:25	3	05-Apr-02	11:08	
VDS 14	16			4												04-Apr-02	11:30	3	05-Apr-02	11:15	
Vaseux Lake Wildlife Park	18															04-Apr-02	11:55	3	05-Apr-02		
Okanagan River - Vincor sign	23a															04-Apr-02	12:05	3	05-Apr-02	11:37	
Okanagan River	24															04-Apr-02	13:10	3	05-Apr-02	11:54	
Okanagan River	25															04-Apr-02	13:45	3	05-Apr-02	13:11	
Okanagan River	27															04-Apr-02	14:00	3	05-Apr-02	13:20	
Okanagan River	28a															04-Apr-02	14:40	3	05-Apr-02	13:33	
Okanagan River	28b															04-Apr-02	14:50	3	05-Apr-02	13:44	
Okanagan River -VDS 1 & Oxbows	28c															04-Apr-02	14:55	3	05-Apr-02		
Osoyoos Lake	29															30-Apr-02	10:15	3	01-May-02	10:00	
Osoyoos Lake	30								8							30-Apr-02	10:20	3	01-May-02	10:11	
Osoyoos Lake	30a								70							30-Apr-02	10:25	3	01-May-02	10:16	
Osoyoos Lake	32a															30-Apr-02	10:40	3	01-May-02	10:32	
Osoyoos Lake	32								6							30-Apr-02	11:00	3	01-May-02	10:40	
Okanagan Lake - South	1			9												30-Apr-02	4:40	3	01-May-02	4:22	
Okanagan Lake - South	2															30-Apr-02	5:18	3	01-May-02	4:36	
Okanagan Lake - South	3															30-Apr-02			01-May-02		Note: There were not enough trap snaps to complete site areas.
Okanagan Lake - South	4			4												30-Apr-02	5:03	5	01-May-02	4:50	Put five traps instead of three because not enough traps snaps for other sites
Okanagan Lake - South	5			5												30-Apr-02	4:54	3	01-May-02	4:58	
Vaseux Lake	20				5											30-Apr-02	13:25	3	01-May-02	12:35	
Vaseux Lake	21			1		1										30-Apr-02	13:35	3	01-May-02	12:45	
Vaseux Lake	22			3												30-Apr-02	13:40	3	01-May-02	13:00	
Skaha Lake	9			1												30-Apr-02	15:15	3	01-May-02	15:00	
Skaha Lake	10			2												30-Apr-02	15:20	3	01-May-02	15:10	
Skaha Lake	11															30-Apr-02	15:30	3	01-May-02	15:17	
Skaha Lake	12			9												30-Apr-02	15:40	3	01-May-02	15:30	
Okanagan Lake																30-Apr-02	16:40	3	01-May-02	16:22	
Okanagan Lake																30-Apr-02	17:18	3	01-May-02	16:36	
Okanagan Lake				4												30-Apr-02	17:03	5	01-May-02	16:50	
Okanagan Lake				5												30-Apr-02	16:54	3	01-May-02	16:58	
Okanagan Lake																30-Apr-02	9:42	3	01-May-02	9:15	
Okanagan Lake																30-Apr-02	9:55	3	01-May-02	9:25	1 trap opened / photo 1 lagoon
Okanagan Lake																30-Apr-02	10:03	3	01-May-02	9:30	
Okanagan Lake																30-Apr-02	10:09	3	01-May-02	9:35	lilly pad
Okanagan Lake																30-Apr-02	10:24	3	01-May-02		traps not found / traps found @ later date
Okanagan Lake																30-Apr-02	10:32	3	01-May-02	10:30	
Okanagan Lake																30-Apr-02	11:00	3	01-May-02	10:55	
Okanagan Lake																30-Apr-02	11:17	3	01-May-02	11:10	photo site 2
Okanagan Lake																30-Apr-02	11:50	3	01-May-02	11:35	
Okanagan Lake																30-Apr-02	12:00	3	01-May-02	11:45	28 unk. #10 jar / flagged site
Okanagan Lake																30-Apr-02	12:25	3	01-May-02	13:05	3 unk.
Okanagan Lake																30-Apr-02	12:45	3	01-May-02	13:20	
Okanagan Lake																30-Apr-02	13:13	3	01-May-02	13:45	photo 3-4 site 13
Okanagan Lake																30-Apr-02	13:35	3	01-May-02	14:00	lg willow Joe property
Inlet of Penticton Channel	6			1	1		6									04-Jun-02	9:43	3	05-Jun-02	9:47	positive ID @ office
Bridge of Penticton channel	7			2												04-Jun-02	9:58	3	05-Jun-02	10:00	
Penticton oxbow 1	7a															04-Jun-02	10:05	3	05-Jun-02	10:15	1 garter snake
Penticton oxbow 2	7b				2	17										04-Jun-02	10:17	3	05-Jun-02	10:25	

		Species Caught														Fishing Effort					
Location	MT site #	SU	SMB	CAS	NSC	PMB	RSC	RBT	YP	BB	LMB	CP	PCC	BKH	TC	Date set	Time set	No of traps	Date picked	Time picked	Comments
Outlet of Penticton channel	8		8	10												04-Jun-02	10:28	3	05-Jun-02	10:38	
VDS 17	13															04-Jun-02	10:43	3	05-Jun-02	11:13	
VDS 16	14						1									04-Jun-02	11:03	3	05-Jun-02	11:17	
VDS 15	15			5		3		1								04-Jun-02	11:12	3	05-Jun-02	11:23	
VDS 14	16			1												04-Jun-02	11:17	3	05-Jun-02	11:28	
Vaseux Lake Wildlife Park	18			2		18										04-Jun-02	11:41	6	05-Jun-02	11:50	
Okanagan River - Vincor sign	23a	2	1	1				1								04-Jun-02	11:58	3	05-Jun-02	12:05	
Okanagan River	24															04-Jun-02	13:00	3	05-Jun-02	12:27	
Okanagan River	25															04-Jun-02	13:35	3	05-Jun-02	13:16	
Okanagan River	26	3					1									04-Jun-02	13:46	3	05-Jun-02	13:23	
Okanagan River	27															04-Jun-02	14:00	3	05-Jun-02	13:30	
Okanagan River	28a															04-Jun-02	14:25	3	05-Jun-02	14:00	
Okanagan River	28b			4												04-Jun-02	14:30	3	05-Jun-02	13:55	
Okanagan River	28c															04-Jun-02	14:34	3	05-Jun-02	13:51	
Osoyoos Lake- North weedbed	29															11-Jun-02	15:00	3	12-Jun-02	13:09	
Osoyoos Lake - West River Mouth	30															11-Jun-02	15:05	3	12-Jun-02	13:15	
Osoyoos Lake - Rattlesnake Point	31			3												11-Jun-02	15:15	3	12-Jun-02	13:28	
Osoyoos Lake - Whitesands	32															11-Jun-02	15:19	3	12-Jun-02	13:34	
Skaha Lake	9			1												11-Jun-02	10:00	4	12-Jun-02		photo 11-12
Skaha Lake	10															11-Jun-02	10:10	4	12-Jun-02		photo 10
Skaha Lake	11			1												11-Jun-02	10:30	4	12-Jun-02		photo 7 & 9
Skaha Lake	11a		5	2												11-Jun-02	10:36	4	12-Jun-02		
Skaha Lake	12		1	1												11-Jun-02	11:20	3	12-Jun-02		
Inlet of Penticton Channel	6		7													12-Aug-02	10:15	3	13-Aug-02	9:40	
Bridge of Penticton Channel	7			3												12-Aug-02	10:45	4	13-Aug-02	10:02	one trap missing
Penticton Oxbow 1	7a															12-Aug-02	10:50	4	13-Aug-02	10:10	
Penticton Oxbow 2	7b															12-Aug-02	10:56	4	13-Aug-02	10:21	
Outlet of Penticton Channel	8		2	12												12-Aug-02	11:05	4	13-Aug-02	10:39	
VDS 17	13															12-Aug-02	11:25	3	13-Aug-02	11:00	
VDS 16	14		1	2												12-Aug-02	11:40	3	13-Aug-02	11:06	
VDS 15	15															12-Aug-02	11:45	3	13-Aug-02	11:15	
VDS 14	16		1	2												12-Aug-02	11:50	3	13-Aug-02	11:22	
Vaseux Lake Wildlife Park	18			3		16					7	1			1	12-Aug-02	12:15	6	13-Aug-02	11:47	
Okanagan River - Vincor sign	23a															12-Aug-02	12:32	3	13-Aug-02	12:09	
Okanagan River	24							1								12-Aug-02	13:32	3	13-Aug-02	12:45	stuck in mouth of trap
Okanagan River	25		2													12-Aug-02	14:00	3	13-Aug-02	13:40	
Okanagan River	26				1											12-Aug-02	14:10	3	13-Aug-02	13:49	
Okanagan River	27															12-Aug-02	14:18	3	13-Aug-02	14:00	
Okanagan River	28a															12-Aug-02	14:35	3	13-Aug-02	14:20	
Osoyoos Lake - North weedbed	29															09-Sep-02	10:23	3	10-Sep-02	12:40	
Osoyoos Lake River - West River Mouth	30															09-Sep-02	10:28	3	10-Sep-02	12:45	
Osoyoos Lake - Rattlesnake Point	31															09-Sep-02	10:46	3	10-Sep-02	13:06	
Osoyoos Lake - Whitesands	32															09-Sep-02	11:00	3	10-Sep-02	13:36	
Skaha Lake	9			3												09-Sep-02	12:55	3	10-Sep-02	15:54	
Skaha Lake	10				1					1						09-Sep-02	13:05	3	10-Sep-02	16:09	
Skaha Lake	11		2													09-Sep-02	13:13	3	10-Sep-02	16:15	
Skaha Lake	11a		1													09-Sep-02	13:20	3	10-Sep-02	16:40	
Skaha Lake	12		2													09-Sep-02	13:34	3	10-Sep-02	16:34	
Okanagan Lake - South	s1			3	7											09-Sep-02	14:25	3	12-Sep-02	12:13	boat trouble caused 3day delay in pu of traps
Okanagan Lake - South	s5															09-Sep-02	14:54	3	12-Sep-02	12:20	1 trap opened
Okanagan Lake - South	s4			7	5	1	2									09-Sep-02	15:07	4	12-Sep-02	12:30	
Okanagan Lake - South	s2			1	4											09-Sep-02	15:15	3	12-Sep-02	11:15	
Okanagan Lake - South	3			9	4											09-Sep-02	15:23	3	12-Sep-02	12:05	
Okanagan Lake - NA - (Westside) Old Pole Wharf	43			1									1			06-Nov-02	9:26	3	07-Nov-02	9:05	
Okanagan Lake - NA - (Westside) OKIB Rec. Area	42			1	1											06-Nov-02	9:36	3	07-Nov-02	9:17	
Okanagan Lake - NA - (Eastside) near Band boundary line	44			2												06-Nov-02	9:52	3	07-Nov-02	9:33	
Okanagan Lake - NA - (Eastside)				7												06-Nov-02	10:07	3	07-Nov-02	9:44	
Okanagan Lake - NA - (Westside) Komasket Rec. Park																06-Nov-02	13:36	3	07-Nov-02	10:00	

		Species Caught														Fishing Effort					
Location	**MT site #**	SU	SMB	CAS	NSC	PMB	RSC	RBT	YP	BB	LMB	CP	PCC	BKH	TC	**Date set**	**Time set**	**No of traps**	**Date picked**	**Time picked**	**Comments**
Okanagan Lake - NA - (Westside) Joe Property				3												06-Nov-02	10:54	3	07-Nov-02	10:13	
Okanagan Lake - NA - (Eastside) Spyder ranch																06-Nov-02	11:07	3	07-Nov-02	10:38	
Okanagan Lake - NA - (Eastside) Gregoire property																06-Nov-02	11:40	3	07-Nov-02	10:58	
Okanagan Lake - NA - (Head of the Lake) Rose Louis property																06-Nov-02	11:50	3	07-Nov-02	11:15	
Okanagan Lake - NA - (Head of the Lake) Lewis property				1	1											06-Nov-02	12:30	3	07-Nov-02	11:30	
Okanagan Lake - NA - (Head of the Lake) Irish Creek				1	4				2							06-Nov-02	12:42	3	07-Nov-02	11:45	
Okanagan Lake - NA - Lagoon				2												06-Nov-02	13:10	3	07-Nov-02	12:15	
Okanagan Lake - NA - Lawrence property				2												06-Nov-02	13:25	3	07-Nov-02	12:25	
Okanagan Lake - NA - Cecil Louis property																06-Nov-02	13:38	3	07-Nov-02	12:35	
Skaha Lake	9			1												21-Nov-02	10:40	3	22-Nov-02	10:13	
Skaha Lake	10			1										3		21-Nov-02	10:51	3	22-Nov-02	10:24	
Skaha Lake	11			3												21-Nov-02	11:04	3	22-Nov-02	10:36	
Skaha Lake	11a			1												21-Nov-02	11:14	3	22-Nov-02	10:46	
Skaha Lake	12			1												21-Nov-02	11:23	3	22-Nov-02	10:55	
Osoyoos Lake - North weedbed	29															21-Nov-02	12:43	3	22-Nov-02	12:36	
Osoyoos Lake - West River Mouth	30			7												21-Nov-02	12:56	3	22-Nov-02	12:42	
Osoyoos Lake - East of River Mouth (north)	30a															21-Nov-02	13:01	3	22-Nov-02	12:47	
Osoyoos Lake - Rattlesnake Point	32a			7												21-Nov-02	13:08	3	22-Nov-02	12:56	
Osoyoos Lake - Whitesands	32															21-Nov-02	13:16	3	22-Nov-02	13:07	
Osoyoos Lake - South	33 A															21-Nov-02	13:22	3	22-Nov-02	13:14	

APPENDIX H

Trap Netting Data

BPA Trap Netting - 2002

			Species Caught													Fishing Effort	
Date Net Set	Lake	Site #	BNH	CAS	LMB	SU	PMB	YP	SMB	LMB	NSC	SK	BH	CP	Other	Date Net Checked	Depth Set
May 14/02 10:30	Vaseaux	TN 1	1	2	1			3								May 16/02 @ 10:15 am	two metre
May 14/02 12:30	Vaseaux	TN 2					1	1							1 tench	May 16/02 @ 11:39 am	two metre
May 14/02 15:00	Osoyoos	TN 3		1				3							1 SK smolt	May 16/02 @ 13:15 pm	two metre
July 10, 2002 @ 11:45 am	Okanagan - North Arm	TN 5				4	1				2			1	4 Aquarium Turtles	July 12, 2002 @ 9:16 am	two metre
July 10, 2002 @ 2:05 pm	Okanagan - North Arm	TN 4	0	0	0	0	0	0			0			0	0	July 12, 2002 @ 10:20 am	1.5 metre
July 10, 2002 @ 3:35 pm	Okanagan - North Arm	TN 6					1	1			3				1 Garter Snake	July 12, 2002 @ 12:02 pm	two metre
July 29, 2002 @ 11:05 am	Vaseaux	TN 1		1					2							July 31, 2002 @ 2:00 pm	two metre
July 29, 2002 @ 11:05 am	Vaseaux	TN 2		1			4	3	2					4		July 31, 2002 @ 12:40 pm	two metre
July 29, 2002 @ 11:05 am	Osoyoos	TN 3				1			4				1			July 31, 2002 @ 10:35 am	two metre
August 13, 2002 @ 9:57 am	Okanagan - North Arm	TN 5						2			9					August 15, 2002 @ 9:30 am	two metre
August 13, 2002 @ 1:49 pm	Okanagan - North Arm	TN 4				1	4	9			13				5 aquarium turtles	August 15, 2002 @ 11:11 am	1.5 metre
August 13, 2002 @ 10:57 am	Okanagan - North Arm	TN 6	0	0	0	0	0	0	0		0		0	0		August 15, 2002 @ 10:09 am	two metre
November 18, 2002 @ 3:14 pm	Vaseaux	TN 1	0	0	0	0	0	0	0	0	0	0	0	0	0	November 20, 2002 @ 11:08 am	two metre
Windy weather	Vaseaux	TN 2	Not done due to very windy weather														
November 18, 2002 @ 12:10 pm	Osoyoos	TN 3							1	1		2				November 20, 2002 @ 1:04 pm	two metre

APPENDIX I

Weed Harvester Data

BPA Weed Harvester - 2002

			Species Caught						Fishing Effort			
Date	**Lake**	**Site**	**PMB**	**SMB**	**YP**	**NSC**	**CP**	**LMB**	**Start Time**	**Stop Time**	**Crew**	**Comments**
07-Aug-02	Osoyoos Lake	Willow Beach		49					7:20 AM	7:55 AM	F. Alexis B. Swite	see note below
07-Aug-02	Osoyoos Lake	Willow Beach		53					8:11 AM	8:46 AM	F. Alexis B. Swite	see note below
07-Aug-02	Osoyoos Lake	Willow Beach		31					10:01 AM	10:31 AM	F. Alexis B. Swite	Fish samples and photos taken
07-Aug-02	Osoyoos Lake	Willow Beach	1	43	1				10:47 AM	11:16 AM	F. Alexis B. Swite	
14-Aug-02	Osoyoos Lake	Willow Beach (Weed Piles)	0	0	0	0	0	0	9:45 AM	11:00 AM	F.Alexis S. Lawrence	Weather was too windy for weed harvester to operate and therefore, crew shifted through the weed piles.
14-Aug-02	Osoyoos Lake	Haines Prov. Park (Weed Piles)	0	0	0	0	0	0	12:00 PM	1:00 PM		Sifted through Eurasia milfoil piles and found no evidence of juvenile fish. Also for the milfoil piles at time of search it was very hot and decomposing rapidly. Observed three small schools of juvenile black bull head along beach shore.

Note: While on the harvester it was observed that although fish did get caught up in the weeds, most fish did escape through the grids. More importantly, no sockeye fry observed in weeds.

APPENDIX J

Species codes

APPENDIX J - List of Species Codes

The following species codes were used in the tables listing the species inventoried in the Okanagan Basin. The codes are based on Fisheries Information Summary System (FISS) BC fish species codes (18).

Species Code	Common name	Scientific name
BB	burbot	*Lota lota*
BCB	black crappie	*Pomoxis nigromaculatus*
BH	bullhead, catfish; general	*Ameiurus* spp.
BKH	black bullhead	*Ameiurus melas (*formerly *Ictalurus melas)*
BNH	brown bullhead	*Ameiurus nebulosus (formerly Ictalurus nebulosus)*
BS	bass, sunfish; general	*Micropterus* spp., *Lepomis* spp., *Pomoxis* spp.
BSU	bridgelip sucker	*Catostomus columbianus*
CAS	prickly sculpin	*Cottus asper*
CBC	chub; general	
CC	sculpin; general	primarily *Cottus* spp.
CCG	slimy sculpin	*Cottus cognatus*
CMC	chiselmouth	*Acrochelius alutaceus*
CP	carp	*Cyprinus carpio*
CSU	largescale sucker	*Catostomus macrocheilus*
DC	dace; general	*Rhinichthys* spp., *Phoxinus* spp.
EB	eastern brook trout	*Salvelinus fontinalis*
GC	goldfish	*Carassius auratus*
KO	kokanee	*Oncorhynchus nerka*
LDC	leopard dace	*Rhinichthys falcatus*
LMB	largemouth bass	*Micropterus salmoides*
LNC	longnose dace	*Rhinichthys cataractae*
LSU	longnose sucker	*Catostomus catostomus*
LT	lake trout	*Salvelinus namaycush*
LW	lake whitefish	*Coregonus clupeaformis*
MW	mountian whitefish	*Prosopium williansoni*
NSC	northern pike minnow (formerly squawfish)	*Ptycheilus oregonensis*
PCC	peamouth chub	*Mylocheilus caurinus*
PMB	pumpkinseed, sunfish	*Lepomis gibbosus*
PW	pygmy whitefish	*Prosopium coulteri*
RB	rainbow trout, (formerly Kamloops trout)	*Oncorhynchus mykiss* (formerly *Salmo gairdneri)*
RSC	redside shiner	*Richardsonius balteatus*
SK	sockeye salmon	*Oncorhynchus nerka*
SMB	smallmouth bass	*Micropteruus dolomieui*
SP	not identified	
ST	steelhead (summer run)	*Oncorhynchus mykiss*
SU	sucker; general	*Catostomus* spp.
TC	tench	*Tinca tinca*
WF	whitefish; general	*Prosopium* spp., *Coregonus* spp., *Stenodus* spp.
WP	walleye	*Stizostedion vitreum*
YP	yellow perch	*Perca flavescens*

FINAL

OBJECTIVE 2 Task B1
Results of sockeye fry predator sampling in Osoyoos Lake

Contribution No. *3* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Author: Karilyn Long, BSc.

Reviewed by: Chris Bull, R.P. Bio

Edited by: Howard Smith

1.0 Introduction

As part of the *"Evaluation of an experimental re-introduction of sockeye salmon into Skaha Lake*" (Bonneville Power Authority #20124), a life cycle model of sockeye is being produced. This model requires an estimate of fry survival from emergence to smolting and so it is important to know the extent of predation which occurs as newly emerged sockeye fry migrate from the river to lake rearing areas. To supply this information, the Okanagan Nation Fisheries Commission (ONFC) examined the stomach contents of specimens from the predator community during late May of 2002, when emergent sockeye fry were known to be holding in the littoral zones of Osoyoos Lake.

2.0 Study Area

Sampling was limited to Osoyoos Lake, the only rearing lake presently accessible to sockeye fry. Okanagan River empties into the north end of Osoyoos Lake which contains abundant littoral areas where sampling was done.

3.0 Methods

Fyke netting conducted 18 km upstream from the confluence of Okanagan River and Osoyoos Lake showed that sockeye fry emerged from their redds in April. Furthermore beach seining in Osoyoos Lake during April and June 2002 confirmed the presence of fry in the littoral zones (Long, 2002).

Fishing for predators was concentrated in the littoral zones since sockeye fry seem to spend several weeks in these areas after emerging from the river and before moving into the pelagic zones (Alexis, 2003).

ONFC electrofished the north end of Osoyoos Lake on April 17, 2002 (at the onset of emergent sockeye fry migration), however the boat was too large to access the shallows (<2 m) which were thought to be prime areas for predators. Many sockeye fry, but very few large predators were caught (mostly small spawning yellow perch).

Because the shallow bottomed electrofishing boat was often unavailable, angling for predator fish was carried out at Vertical Drop Structure 1, about 1km above the mouth of Okanagan River. Angling occurred May 7th, May 14th and May 16th, (to coincide with the peak out-migration of sockeye fry), but no predators were captured.

On May 21st, 2002 the Colville Confederated Tribes (CCT) shallow-bottomed electrofishing boat became available and was used to sample the north end of Osoyoos Lake, the mouth of Okanagan River and Rattlesnake Point (located approximately 3 km south of the river mouth on the east side of Osoyoos Lake). Two hours of electrofishing was conducted at the river mouth using 30volts, and 4 Amps setting. An additional 30 minutes was spent fishing the lake at Rattlesnake Point using the same settings and fishing at depths of 0.5 to 2 metres.

4.0 Results

Fyke netting in the Okanagan River showed that sockeye fry began to emerge as early as April 4th, peaked about April 22 and were fully emerged by May 14th, 2002 (Long, 2002).

Following emergence Okanagan sockeye fry tend to hold in the littoral zone of Osoyoos Lake prior to migrating into pelagic areas (Alexis, 2003). As early as April 8th, sockeye fry were caught by beach seining but the highest numbers were captured on May 17th and fry were still being caught in seines on June 3rd.

Electrofishing (May 21st) was timed to coincide with the period when both fry and predators were using the littoral zone, however no fry were caught or observed. During the 2.5 hours of electrofishing, 24 fish were caught including: largemouth bass (2), smallmouth bass (4), suckers (5), whitefish (7), and one each of; black crappie, northern pike minnow, chub and yellow perch (Table 1).

Table 1. List of species and stomach contents of fish caught on May 21st, 2002

Fish number	Species	Length (cm)	Weight (g)	Location	Stomach contents
1	Largemouth bass	32.5	750	Osoyoos Lake river mouth	1 sculpin and 1 Unidentifiable fish
2	Sucker	47.0	1200	Osoyoos Lake river mouth	all digested, mostly plant material
3	Whitefish	17.5	100	Osoyoos Lake river mouth	undiscernibly, digested material
4	Largemouth bass	40.5	1300	Osoyoos Lake river mouth	4 sculpin
5	Smallmouth bass	32.5	650	Osoyoos Lake river mouth	1 sculpin
6	Black crappie	34.1	850	Osoyoos Lake river mouth	2 unknown & 1 sculpin
7	Smallmouth bass	26.9	350	Osoyoos Lake river mouth	1 unidentifiable fish
8	Smallmouth bass	39.5	1100	Osoyoos Lake river mouth	1 unidentifiable fish
9	Northern pike minnow	34.1	650	Osoyoos Lake river mouth	empty – tapeworm
10	Tench	35.5	700	Osoyoos Lake river mouth	digested vegetation
11	Sucker	43.5	1050	Osoyoos Lake river mouth	empty – tapeworm
12	Sucker	36.5	650	Osoyoos Lake river mouth	Vegetation
13	Smallmouth bass	20.3	150	Osoyoos Lake river mouth	empty
14	Chub	29.5	400	Osoyoos Lake river mouth	empty – digested
15	Sucker	36.5	700	Osoyoos Lake river mouth	Vegetation, digested
16	Whitefish	24.6	250	Osoyoos Lake river mouth	Earthworm and vegetation
17	Whitefish	27.1	300	Osoyoos Lake river mouth	Vegetation
18	Whitefish	27.0	350	Osoyoos Lake river mouth	Vegetation and chironomids
19	Whitefish	24.4	250	Osoyoos Lake river mouth	Bugs
20	Whitefish	24.0	250	Osoyoos Lake river mouth	Vegetation
21	Whitefish	20.0	200	Osoyoos Lake river mouth	Empty
22	Yellow perch	17.1	100	Osoyoos Lake river mouth	Oligochaetes & chironomids
23	Sucker	43.5	850	Rattlesnake point	Vegetation
24	Whitefish	35.3	500	Rattlesnake point	chironomids & vegetation

Six of the 24 fish caught were found to have fish in their stomachs. The six piscivorous fish included largemouth bass (photo 1), smallmouth bass and black crappie. The fish which had been eaten were prickly sculpins plus several unidentifiable fish.

ONFC caught neither prickly sculpin nor sockeye fry by electrofishing. This is believed to be due to turbidity caused by the high flows in Okanagan River which made it difficult to see and capture the smaller fish. It is therefore difficult to determine if the predators were not eating sockeye fry because few fry were present or because fry were not encountered by the predators.

Photo 1. Largemouth bass with 4 prickly sculpin removed from its stomach.

5.0 Discussion

Although piscivorous fish such as black crappie, and large and smallmouth bass were found to prey upon sculpins, the sampling was not adequate to determine the extent of predation on emerging sockeye fry. Increased sampling of potential sockeye predators is recommended for the future. Electrofishing should be conducted at the river mouth during fry migration and beach seining should also be conducted in the littoral zones along the north side of the lake.

6.0 References

Alexis, F. 2003. Exotic Fish Assessment. As part of the Year 3, Evaluation of an experimental re-introduction of sockeye salmon into Skaha Lake. Submitted by the Okanagan Nation Fisheries Commission.

Long, K. 2002. Okanagan River sockeye egg & alevin development summary. Submitted by Okanagan Nation Fisheries Commission: Westbank, BC. Submitted to Douglas County Public Utility District: East Wenachee, Washington.

FINAL

OBJECTIVE 2 Task B1
Results of sockeye smolt predator sampling in the forebay and tailrace of Zosel Dam 2002

Contribution No. *4* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Author: Chris Fisher

Reviewed by: Chris Bull, R.P. Bio

Edited by: Howard Smith

1.0 INTRODUCTION

The second year of field sampling was a part of the study to evaluate an experimental re-introduction of sockeye salmon (*Oncorhynchus nerka*) into Skaha Lake (Bonneville Power Administration #20124). To provide a better estimate of smolt survival, predator sampling occurred during suspected peak outmigration, May 2002. Fish collection was targeted towards known or potential predators of sockeye smolts including, northern pike minnow (*Ptychocheilus oregonensis*), smallmouth bass (*Micropterus dolomieui*), largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), adult yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum*).

2.0 METHODS

Sampling was conducted in the tailrace area of Zosel Dam (from the base of the dam to 50 m downstream on May 20, beginning at approximately 9:00 p.m. PST. Electro-fishing gear was used for 30 minutes. Upon capture predatory fish were immediately subdued to reduce the possibility of regurgitation. Gut contents were examined via dissection on site once electro-fishing was completed.

3.0 RESULTS

A total of 50 predators were collected in the tailrace area (Table 1, Figure 1). The most abundant species collected were northern pike minnow (29), followed by smallmouth bass (17), and largemouth bass (3).

Table 1. Stomach contents of collected fish predators from electro-fishing sampling in tailrace of Zosel Dam during May 20th 2002.

SPECIES	LENGTH (MM)	SEX	STOMACH CONTENTS
Northern Pike Minnow	495	Female	Empty
Northern Pike Minnow	560	Female	Empty
Northern Pike Minnow	530	Female	Empty
Northern Pike Minnow	513	Female	Empty
Northern Pike Minnow	520	Female	Empty
Northern Pike Minnow	527	Female	Empty
Northern Pike Minnow	494	Female	Empty
Northern Pike Minnow	475	Female	Empty
Northern Pike Minnow	475	Female	Empty
Northern Pike Minnow	415	Male	Empty

Table 1. continued

SPECIES	LENGTH (MM)	SEX	STOMACH CONTENTS
Northern Pike Minnow	405	Female	Empty
Northern Pike Minnow	560	Female	Unidentified fish
Northern Pike Minnow	436	Female	Empty
Northern Pike Minnow	448	Female	Empty
Northern Pike Minnow	520	Female	Empty
Northern Pike Minnow	550	Female	Empty
Northern Pike Minnow	427	Male	Empty
Northern Pike Minnow	446	Female	Empty
Small mouth bass	439	Female	1 smolt 150mm
Small mouth bass	247	male	1 fish unidentified 90mm
Small mouth bass	340	Female	1 sculpin - 80mm
Small mouth bass	362	Male	Empty
Large mouth bass	300	Male	Empty
Large mouth bass	218	Female	1 unidentified fish
Northern Pike Minnow	560	Female	1 Yellow perch - 106mm
Northern Pike Minnow	416	Male	Empty
Northern Pike Minnow	533	Female	1 Yellow perch - 106mm
Northern Pike Minnow	395	Male	1 smolt - 104mm
Northern Pike Minnow	412	Female	Empty
Northern Pike Minnow	510	Female	Empty
Northern Pike Minnow	542	Female	1 unidentified fish 175 mm (spiny ray)
Northern Pike Minnow	471	Female	Empty
Northern Pike Minnow	465	Female	Empty
Northern Pike Minnow	462	Female	1 Yellow perch -70mm
Northern Pike Minnow	426	Male	1 unidentified fish
Small mouth bass	323	Male	Empty
Small mouth bass	317	Male	Empty
Small mouth bass	319	Male	1 Yellow perch 110mm
Small mouth bass	318	Female	Empty
Small mouth bass	276	Male	1 unidentified fish
Small mouth bass	345	Female	Empty
Small mouth bass	328	Male	1 sculpin
Small mouth bass	319	Male	Empty
Small mouth bass	286	Female	2 unidentified fish (non-smolt)
Small mouth bass	302	Female	Empty
Small mouth bass	280	Female	1 unidentified fish (non-smolt)
Small mouth bass	395	Male	Empty
Small mouth bass	329	Male	Empty
Large mouth bass	249	Male	Empty

Twenty-four percent or 7 of the twenty-nine northern pike minnow collected contained fish. Of the 7 northern pike minnow containing fish, one was positively identified as a sockeye salmon smolt. The gut contents of three other northern pike minnow containing fish were too decomposed to positively identify, however, one of the fish was determined to be a “spiny-ray” fish i.e. a non-salmonid. The gut contents of the remaining three northern pike minnows included yellow perch.

Figure 1. Collection basin on electro-fishing boat during predation sampling in the tailrace area of Zosel Dam, May 2002.

Eight of the 17 smallmouth bass collected contained fish in their stomachs. One of the eight smallmouth bass stomachs contained a positively identified sockeye smolt (Figure 2). Five smallmouth bass had unidentifiable fish in their stomachs, of which two were determined not to be salmonids. Two sculpins and one yellow perch were found in the stomachs of the three remaining smallmouth bass.

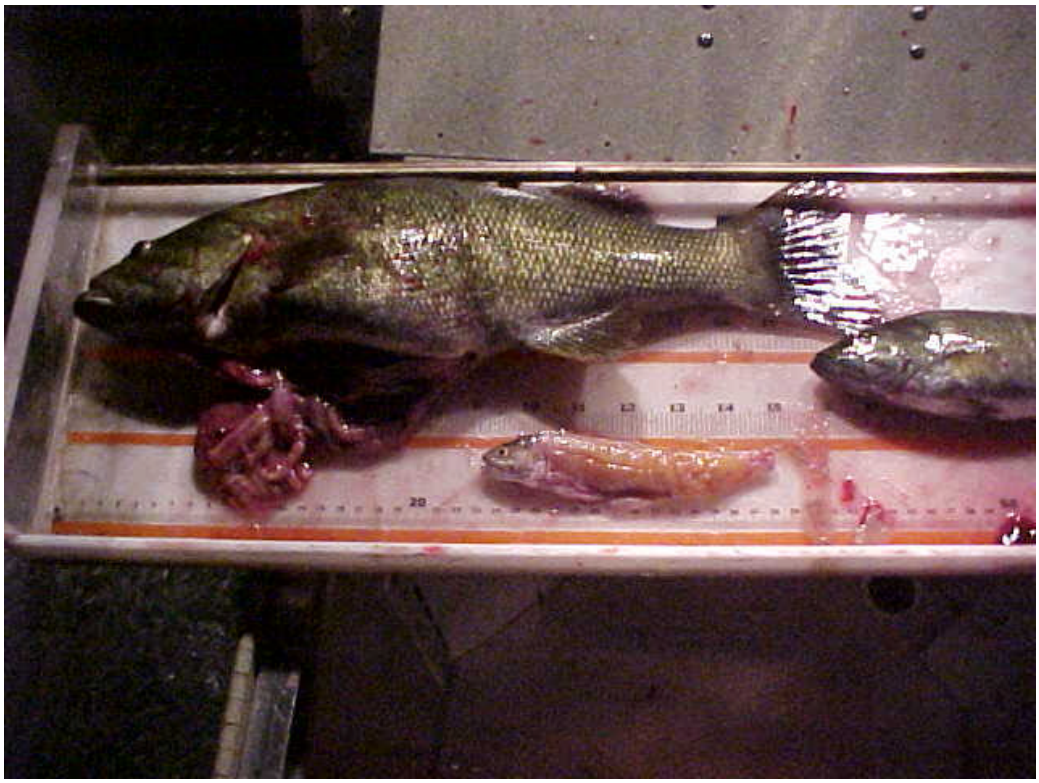


Figure 2. Smallmouth bass collected by electro-fishing in the tailrace of Zosel Dam during May 2002. One sockeye smolt was found in its stomach.

Three largemouth bass were collected, one of which contained unidentifiable fish in its stomach.

4.0 SUMMARY

A total of 50 piscivorous predators (29 northern pike minnow, 17 smallmouth bass and 3 largemouth bass) were collected and their stomachs were examined. Smallmouth bass had the greatest occurrence of fish in their diet (50%), with 1 (5.6%) of the smallmouth bass containing a positively identified sockeye smolt. Twenty-four percent of the northern pike minnow contained fish in the gut, with one (3%) northern pike minnow containing a positively identified sockeye smolt. Three of the northern pike minnow contained yellow perch. Three largemouth bass were sampled of which one contained an unidentified fish.

Electro-fishing occurred on May 20th. However, because few sockeye smolts were observed while electro-fishing, and conversations with Tom Scott, Oroville/Tonasket Irrigation District manager, indicated that he had observed large numbers of sockeye smolts moving through the dam the previous week, it is likely that most of the sockeye smolts had migrated from Osoyoos Lake before May 20th. Therefore, it is likely the frequency of sockeye smolts in the stomachs

of predators, particularly northern pike minnow and smallmouth bass, in the Zosel Dam tailrace area is greater than the 3% and 5.6%, respectively that were observed. Based on sampling conducted during 2002 and the results from 2001 (frequency of occurrence in smallmouth bass 7.1%; and in northern pike minnow 6%), it appears that fish are a more common component in the diet of smallmouth bass than they are in other fish predators and consequently may be the principal piscivorous predator on sockeye smolts in the tailrace area of Zosel Dam.

To quantify the predation rate on the sockeye population in the Okanogan River, particularly during smolt out-migration, a study which involves a known number of sockeye smolts released in Lake Osoyoos and recaptured downstream of Zosel Dam should be considered.

FINAL

OBJECTIVE 3 Task C
Okanagan River (Reach A and B)
Spawning Area Restoration Feasibility

Contribution No. *5* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Authors: Karilyn Long, BSc.
Robert Newbury, P.Eng.

Reviewed by: Chris Bull. R.P. Bio.

Edited by: Howard Smith

EXECUTIVE SUMMARY

The transboundary multi-agency workshop held in 1997, summarized the risks and benefits of re-introducing sockeye salmon (*Oncorhynchus nerka*) into Okanagan Lake (Peters et al. 1998). The discussions led to assessing an experimental re-introduction into Skaha Lake where previous surveys highlighted a lack of suitable spawning areas. Okanagan Lake drains into Skaha Lake by a short section of the Okanagan River. It is this stretch of water between the two lakes which has been identified as most promising for development of spawning areas. This report follows inventories done in year 1 and 2 by identifying restoration options to benefit spawning sockeye accessing Skaha Lake. This section of the Okanagan River was straightened and dyked in the mid 1950's and is essentially one long river glide; rip rapped for its entire length. The river has two distinct reaches; the upper most reach which runs 3 km from Okanagan Lake Outlet Dam to Green Mtn Road (hereafter referred to as Reach A) below which Reach B extends to Skaha Lake.

There is an opportunity in Reach A to use the existing slope to create spawning ramps having depths and velocities that mimic those found above Vertical Drop Structure 13 (located 1.3 km north of Oliver) where sockeye currently spawn. This can be accomplished by the construction of spawning ramps and is the highest priority for restoration, to produce spawning areas for both re-introduced sockeye and resident kokanee (*O. nerka*) and potentially rainbow trout (*O. mykiss*) and whitefish (*Coregonus* sp.).

The four spawning ramps could accommodate 4000 spawning pairs of sockeye and cost C$92,500. By placing suitably sized gravel on half of one ramp, 3750 pairs of kokanee could be accommodated at typical autumn flows. The ramps would be located in existing depressions and will not project above the existing low water profile thus maintaining the low water gradient and preserving existing flood capacity.

The creation of setback dykes, re-establishment of riparian vegetation and creation of off-channel areas in Reaches A and B, although not necessary for the effectiveness of spawning areas, would contribute to returning the river ecosystem to a more historically natural state. Construction of setback dykes and re-establishment of riparian vegetation along a 1000m section in Reach A and a 2250m length section in Reach B, both along the west bank of the river will provide shade and cover and increase the diversity and abundance of terrestrial and aquatic wildlife. The cost for setback dykes and vegetation in Reach A and B is C$538,000 and C$1,210,500 respectively.

Off-channel habitat creation in conjunction with setback dyking areas benefit rainbow trout under-yearlings which over-winter and rear in such areas particularly when summer droughts are a problem. This type of habitat was found in this section of river prior to channelization. Creation of off-channel habitat in Reaches A and B would cost C$130,000. Table 4 contains a summary of proposed works their benefits, risks and costs.

Considerable effort will be needed to ensure the necessary widespread support and funding.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
TABLE OF CONTENTS ii
LIST OF FIGURES AND TABLES ii
1.0 Introduction 1
2.0 Study Area 2
3.0 Restoration Options 3
3.1 Ramp spawning platforms 4
3.1.1 Conceptual design 4
3.1.2 Benefits and Risks 6
3.1.3 Costs 7
3.2 Setback dykes and riparian vegetation 7
3.2.1 Conceptual design 7
3.2.2 Benefits and Risks 9
3.2.3 Costs 9
3.3 Off channel creation 9
3.3.1 Conceptual design 9
3.3.2 Benefits and Risks 10
3.3.3 Costs 10
3.4 Summary of Recommended Works 11
4.0 Implementation plan 12
4.1 Prioritization of works 12
4.2 Agency approvals 12
4.3 Land negotiations 13
4.4 Community support and awareness 13
4.5 Pre and post-construction monitoring 13
5.0 Conclusion 13
6.0 References 14

LIST OF FIGURES AND TABLES

Figure 1. Okanagan River, 1930's Reach A. 1
Figure 2. Location of Reach A and B within the Okanagan Basin. 2
Figure 3. Location of restoration options 3
Figure 4. Profiles of the river bed, design grade and design flood water level 4
Figure 5. Locations of proposed spawning ramps 5
Figure 6. Map of setback dyking opportunities 8
Figure 7. Typical cross section of off-channel habitat 10

Table 1. Ramp dimensions 6
Table 2. Spawning areas potentially created for sockeye and kokanee 6
Table 3. Potential risks and their proposed mitigation 7
Table 4. Summary of proposed works, benefits and risks 11
Table 5. Approvals needed 12

1.0 INTRODUCTION

During Year 2 of the study concerned with re-introduction of sockeye salmon *(Oncorhyncus nerka*) into Skaha Lake, the Okanagan Nation Fisheries Commission (ONFC) conducted an inventory of the amount, location and quality of habitat which could be accessible to sockeye introduced into Skaha Lake. Subsequently ONFC staff along with several other experts identified opportunities for possible sockeye habitat enhancement and in Year 3, the amount of spawning/ incubation area which could be created by acting on these opportunities was determined. There is also an interest in restoring lost elements of the river ecosystem by exercising such options as setback dyking, off-channel creation in the form of side channels and pools created in the riparian area adjoining the channel and planting riparian vegetation. This paper presents the design, benefits, risks and costs of such initiatives, expanding upon work by Gaboury *et al*. (2000) on restoring natural segments of the south Okanagan River to include Reach A and B, and it recommends instream and riparian works to enhance and restore salmon, trout and possibly whitefish (*Coregonus* sp.) spawning and rearing areas.

From Okanagan Lake to McIntyre Dam (Fig. 2), less than 1% (63m^2) of the total spawning areas surveyed was considered to be high quality (ONFC, 2002) as detailed in the year 2 report. Since the sockeye that will be used in any re-introduction currently spawn in the Okanagan River upstream of Osoyoos Lake, utilizing the Okanagan River upstream of Skaha Lake, where emerging sockeye fry can tavel downstream and populate Skaha Lake may be the best option for introducing this stock into Skaha Lake. In this section of river, the reach from the Okanagan Lake Outlet Dam to the Green Mt. Road crossing was considered most promising for development of suitable spawning areas. This 3.07km section of the Okanagan River (referred to hereafter as Reach A) was straightened and dyked in the mid 1950's. It is essentially one long river glide; rip rapped for its entire length and having little established riparian vegetation.

The Figure 1 photo was taken in the 1930's prior to channelization (Vedan, 2003), when the Okanagan River that flowed through Penticton contained oxbows bordered by thick riparian cover.

Figure 1. Okanagan River, 1930's

2.0 STUDY AREA

Reach A runs from Okanagan Lake Outlet Dam to the Green Mt. Road Bridge crossing (Fig. 2). The river from the end of Reach A to Skaha Lake (Reach B) is in a backwater zone produced by Skaha Lake. At higher flows, it has a very low hydraulic gradient and consequently the substrate becomes clogged with fine sediments.

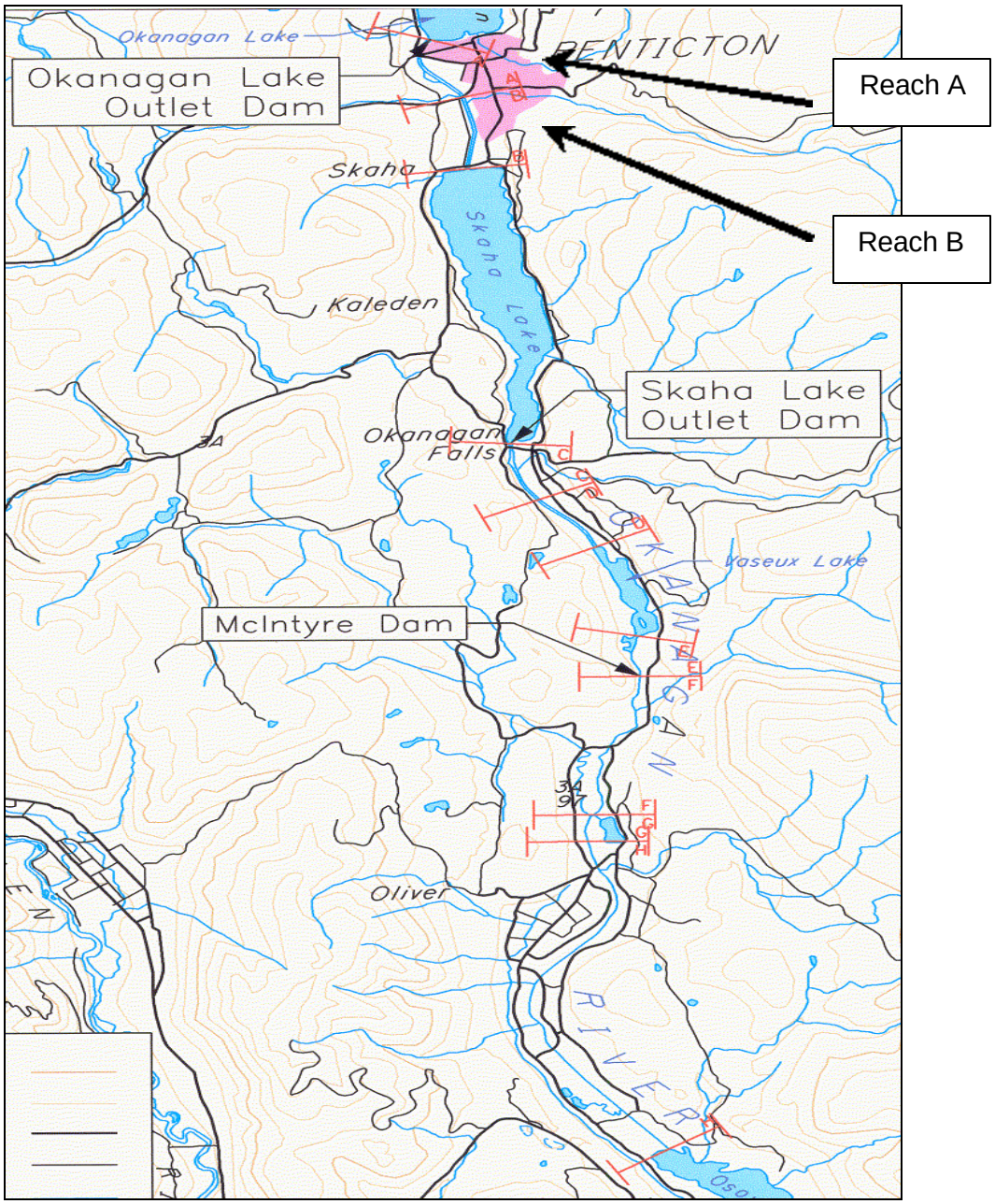


Figure 2. Location of Reach A and B within the southern Okanagan Basin.

3.0 RESTORATION OPTIONS

After reviewing restoration options that could restore salmonid spawning areas (Fig. 3) while protecting kokanee spawning areas and improving the overall health of the ecosystem, it is recommended that a series of coarse gravel with part of one finer-grained spawning ramps be built in Reach A to mimic both the areas where kokanee now spawn in the reach and where sockeye currently spawn above Vertical Drop Structure 13 (Newbury, 2002). Other restoration recommendations that could lead to improved long-term ecosystem health include;

- construct dykes set back from the ordinary high water mark of the river creating a strip of natural ground between the dike fill and the riverbank;
- re-establish riparian vegetation within the set back dyke and;
- create side channel pools or backwater areas also within the newly set back dykes; where such backwater areas off the main channel were present before channelization when the river supported salmonid spawners (Vedan, 2003).

Options such as meander re-establishment would be unlikely to be effective for creating spawning given the already low slope in Reach A and B (Newbury, 2002). The spawning ramps would not interfere with, or be harmed by this option if it were needed to expand spawning areas and/or facilitate fish passage in the future.

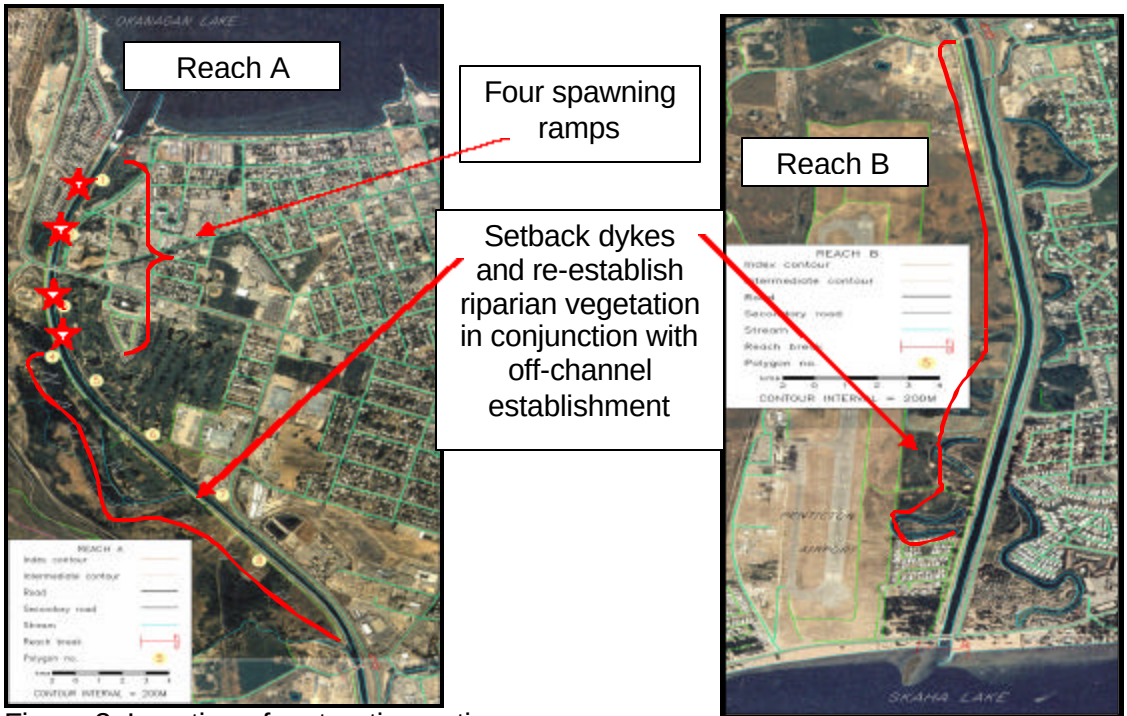


Figure 3. Location of restoration options

3.1 Ramp spawning platforms

3.1.1 Conceptual design

A 100m long gravel platform was constructed in Reach A for Skaha Lake kokanee spawners over 20 years ago (Bull, pers. comm. 2002). This flat gravel platform which supports the majority of local kokanee spawners has not changed visibly since installation. However no measure of egg survival has been made to determine its true effectiveness.

It has been suggested that Reach A could be modified to include productive spawning areas for sockeye, kokanee and small numbers of trout if suitable gravel was provided (ONFC, 2002). Unlike a gravel platform, a ramp type structure would allow the gradient to be modified while providing high stability, and mimicking conditions in other places where sockeye now spawn successfully

Four spawning ramps are proposed for the reach below the Okanagan Lake Outlet Dam (Fig. 4 and 5). The ramps should be located in existing depressions, and deep enough to ensure that they will not project above the surface at low water. The existing kokanee platform is located between planned sites of ramps 3 and 4. The ramp locations were chosen on the basis of the June 1980 profile and cross-section surveys undertaken in the Skaha – Okanagan Lakes reach (Shubert, 1983). However, final locations and gravel volumes should not be confirmed until further bed surveys are done.

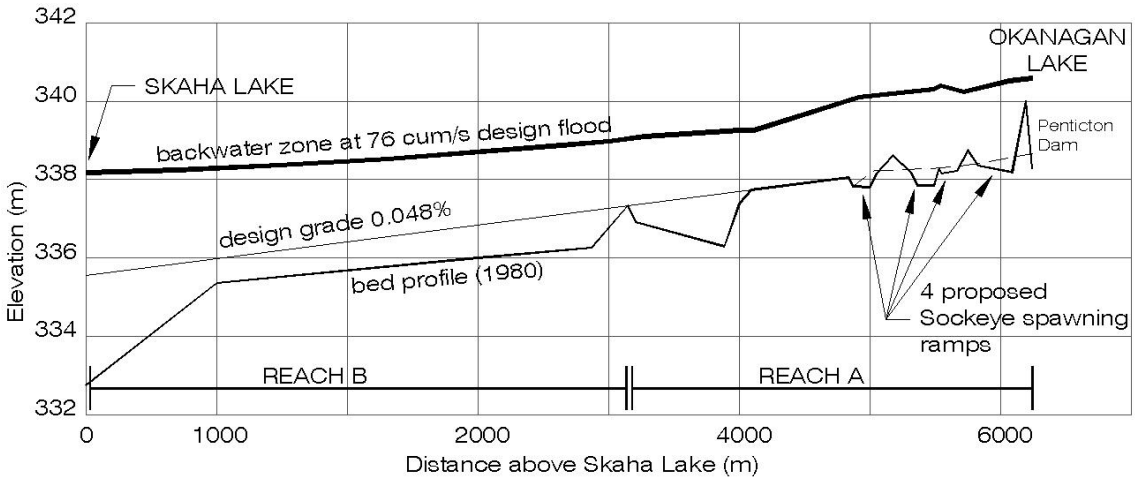


Figure 4. Profiles of the river bed, design grade and design flood water level

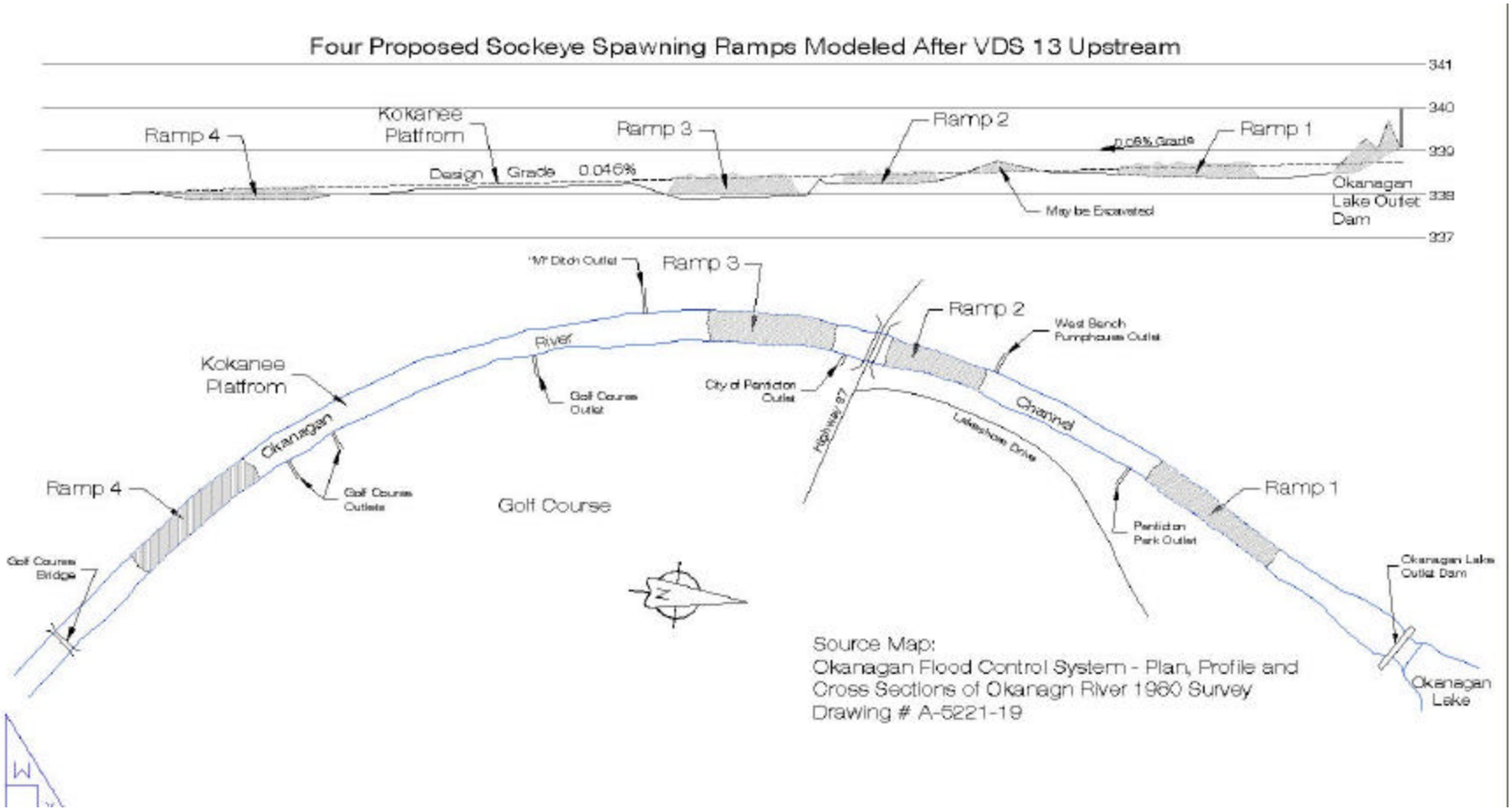


Figure 5. Profile and plan of proposed spawning ramps.

The depth of gravel on the ramps will vary between 22 and 50 cm to mimic conditions often found in natural spawning areas. All four ramps will be 24m wide with individual lengths varying between 100 and 150m (Table 1).

Table 1. Ramp dimensions

Ramp	***Length (m)***	***Width (m)***	***Area (m^2)***	**Gravel volume (m^3) required**
Ramp 1	150	20.8	3120	900
Ramp 2	100	25	2500	600
Ramp 3	125	25	3125	1200
Ramp 4	150	25	3750	1000
Total	***525 m***		***12,495 m^2***	***3,700 m^3***

The channel is designed so that the maximum gravel size relocated during very high water is less than 12 mm in diameter. The spawning gravel ramps will be built of stable 25 to 75 mm diameter gravel observed in successful sockeye redds. Sockeye are documented as utilising substrates of 13 to 102mm (Reiser & Bjornn, 1979) and in the channelized sections of the Okanagan River where gravel is found the median size in spawning beds is about 26mm (ONFC, 2002).

Ford et al. (1995) found kokanee to spawn in gravel at 15 to 100mm in diameter, and in the Okanagan River they are found to use gravel averaging about 30mm in diameter (ONFC, 2002). A portion of ramp 4 will receive additional gravels averaging about 30mm in diameter size to accommodate kokanee (ONFC, 2002) and trout spawners.

3.1.2 Benefits and Risks

The primary purpose of the ramps is to produce spawning areas for re-introduced sockeye and to increase areas for resident kokanee. Each spawning ramp should accommodate between 900 and 1300 spawning pairs of sockeye, based on an estimated need of 2.7m^2 per pair (Summit, 2000). The accumulated spawning area created for sockeye would be 10,625m^2, accommodating almost 4000 pairs (Table 2).

By placing gravel of a size suitable for kokanee in half of ramp 4, and given that kokanee require 0.5m^2 per pair (Bull, 2002) an additional 3750 pairs could be accommodated at this ramp. During 1992-2001, an average of 3500 spawner pairs/ year and in 2002, 47,250 spawner pairs were estimated to have utilized Reach A. (MoWLAP, 2002).

Table 2. Spawning areas potentially created for sockeye and kokanee

Spawning platform	**Spawning area (m^2) created**	**No. of Spawning pairs sockeye**	**No. of Spawning pairs kokanee**
ramp 1 (below dam)	3120	1157	
ramp 2 (above Hwy. 97)	2500	926	
ramp 3 (below Hwy. 97)	3125	1157	
ramp 4 (above golf course bridge) *	3750	694	3750
TOTAL:	**12,495 m^2**	**3934**	**3750**

* assuming half the area of ramp 4 is used by kokanee and half by sockeye

Because the proposed spawning ramps would be built so as not to interfere with the current kokanee ramp there should be no loss of the present kokanee spawning area. Potential risks associated with spawning ramps are considered manageable as shown in Table 3.

Table 3. Potential risks and their proposed management

Risks to ramps in Reach A	***Management plan***
Ramp blow-out and/or spawning gravel loss or displacement	The channel was designed so that the, maximum gravel size likely to be relocated is less than 12 mm diameter. The spawning gravel ramps will be stable and composed of 25 to 75 mm diameter gravels (i.e. of a size commonly found in successful redds).
Adverse effects on the dyke, particularly at flood levels	The ramps will be located in existing depressions and will not project above the existing low water profile thus maintaining the low water gradient and preserving existing flood capacity.
Issues for recreational rafters and tubers	Tubing or floating through Reach A will be unimpeded as the tops of the ramps have been designed to coincide with the water surface at lowest levels. Flat and rounded cobbles will be placed on the upstream face of the ramps to resist erosion and create smooth water at the entrance.

3.1.3 Costs

The ramps are simply constructed with sloping rounded cobble walls on the upstream and downstream faces. For preliminary estimates, the cost of purchasing and placing 3700m^3 of spawning gravels and cobble riprap is C$92,500 (at $25.^{00} per m^3). This cost includes all engineering, building and monitoring (see 4.5 below).

3.2 Setback dykes and riparian vegetation

3.2.1 Conceptual design

The setback dyke option is only feasible for the 1000m of Reach A along the west bank of the river north of Shingle Creek (Fig. 6) and downstream of the proposed spawning ramps. The river bank of Reach A has been developed except for a section owned by the Penticton Indian Band. If the Penticton Indian Band were agreeable this would be the only section along Reach A where setback dyking could occur without having to move homes, highways or businesses.

The dyke would be set back from the ordinary high water mark of the river creating a strip of natural ground between the dyke fill and the river bank. Another setback dyke could be developed along 2250m of the west bank of Reach B, where old meanders could be used as backwater or off channel habitat for several fish species.

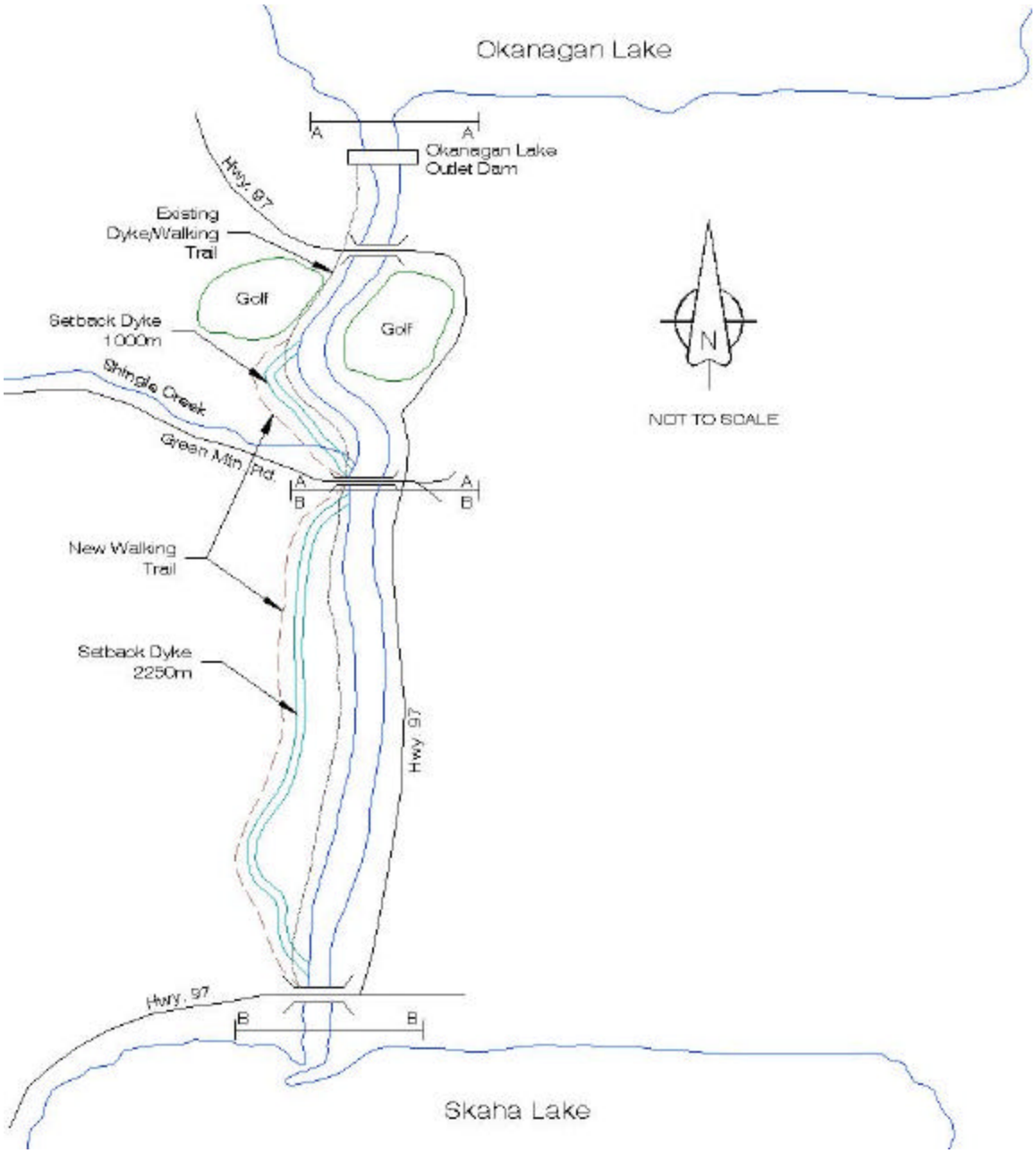


Figure 6. Map of setback dyking opportunities.

3.2.2 Benefits and Risks

There is less risk associated with a setback dyke then with the current dyke. The primary benefit for developing such a short section of setback dyking surrounded by an area with extensive development is for the establishment of riparian vegetation. The benefits associated with setback dyking include;

1. Lower water level at flood stage as a consequence of a wider flood plane;
2. Increased stability of the river bed during floods and therefore increase stability of the ramp structures;
3. Increased shading and cover with the development of riparian areas; and
4. Increased diversity and abundance of various terrestrial and aquatic wildlife species by the establishment of new riparian areas, floodplain wetlands and sloughs (Gaboury *et al*. 2000). There is also the benefit of increasing the endangered cottonwood forest ecosystem, one of the rarest plant communities of the province (SOSCP, 2000; MELP, 1997).

An attractive additional benefit from establishing setback dykes would be the opportunity to develop an interpretative trail along the newly re-designed dyke. The dyke-trail currently used would need to be moved to be made continuous with the set-back dyke. The elevations of the setback dykes would match these of the existing ones. There may be some intakes in this area that would need conduits through the new floodplain.

3.2.3 Costs

Setback dykes in the lower Okanagan River could cost anywhere from $144/m to $400/m depending on the level of development. The higher cost would apply in a developed area where landscaping and new trails are required (Gaboury *et al*. 2000). Assuming a cost of $400/m, the 1000m of setback dyke created in Reach A, would cost $400,000; in Reach B the 2250 m of setback dyke would cost C$900,000. Based on past work near the channel by the ONFC (Alexis, pers. comm. 2002) re-establishing riparian vegetation in Reach A would cost approximately C$138,000 for plant purchases and labour. The 2250m of vegetation is Reach B would cost CAN$310,500. Planting costs also cover follow-up maintenance.

3.3 Off channel establishment

3.3.1 Conceptual design

The area available for the creation of off channel rearing habitat is limited to the same 1000m of river in Reach A, and 2250m of Reach B where setback dykes are proposed. Again, consultation with the Penticton Indian Band would be needed before making any further plans for development.

Side channels and backwaters provide comparatively stable flows year-round, moderate temperature regimes and useful complexes of channel and pool habitats (Lister & Finnigan, 1997). Construction of such an area could be done in conjunction with the setback dyking (Fig. 7). As in the case of the restoration options discussed above, the infrastructure of the dyke, water withdrawal and channel integrity would need to be addressed.

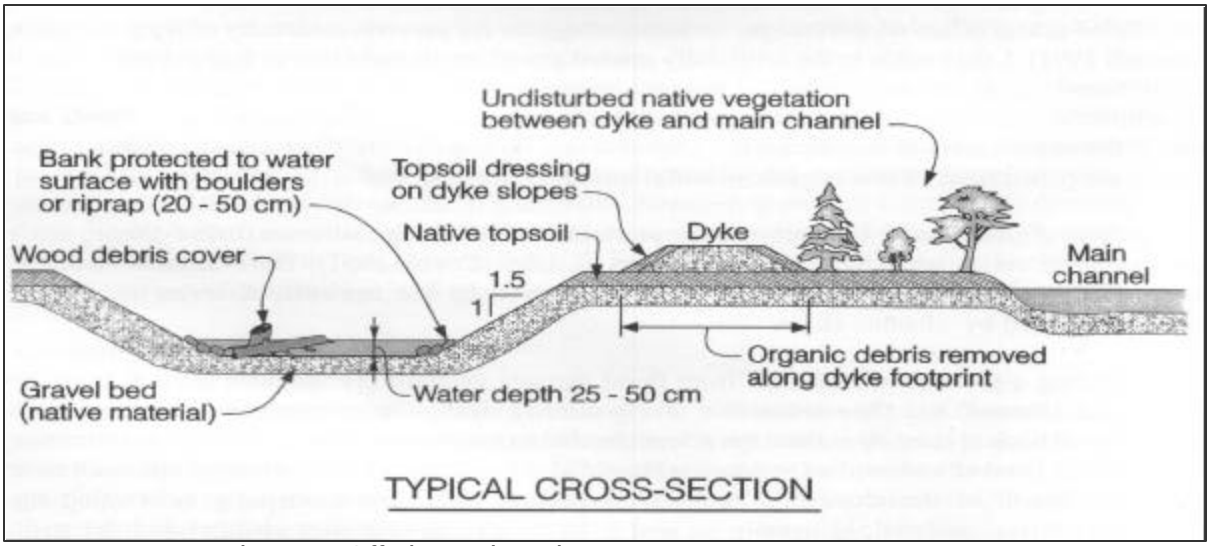


Figure 7. Off-channel rearing areas

3.3.2 Benefits and Risks

There are no risks to creating off-channel rearing areas but, such habitat would benefit rainbow trout under-yearlings which are known to grow and overwinter in these areas when available (Lister and Finnigan 1997; Adams & Whyte, 1990). Off-channel habitats contribute to salmonid production particularly where, as in the Okanagan, summer droughts accompanied by low flow can be a problem (Adams & Whyte, 1990). Because flows are more stable in the off-channel areas than in the main channel, the quality of habitat there is easier to maintain (Adams & Whyte, 1990).

3.3.3 Costs

Details of side channel and backwater design and construction will be site specific and require further surveys. Construction costs will vary with the complexity of the designs as well as with broader ecosystem provisions, (to include waterfowl habitats for example). As a preliminary cost-estimate, 10% of the setback dykes costs or C$130,000 may be anticipated as the cost of constructing pools and small access channels as the dykes are moved.

3.4 Summary of Recommended Works

Table 4. Summary of recommended works, benefits and risks

Recommended work	Location	Expected benefits	Expected Risks	Costs (C$)
Four sockeye and kokanee spawning ramps	In Reach A (360m to 1000m downstream of the dam) between the Okanagan Lake outlet dam and the golf course bridge. (see Fig. 4)	New spawning areas for approximately 4000 sockeye pairs and 3750 kokanee pairs. Built without impeding recreational tubing.	None: The increased slope of the ramps could be built without changing the slope of the overall reach and therefore preserve the capacity of the channel in the event of flooding.	$92,500 for 4 ramps
Setback dykes & Re-establish riparian vegetation	1000m in Reach A and 2250m in Reach B, both along the west bank of the river.	increase riparian induced shade and cover, increase diversity and abundance of terrestrial and aquatic wildlife species.	None: There is little risk of flood, and dyke integrity can be easily maintained.	Reach A Dyke $400,000 Veg: $138,000 Reach B Dyke: $900,000 Veg: $310,500
Off-channel habitat establishment	In setback dyking areas (see above)	Refuge for rainbow trout, during low summer flows and in winter.	None: There is little risk of flood and dyke integrity can be easily maintained.	Reach A & B $130,000

4.0 IMPLEMENTATION PLAN

4.1 Prioritization of works

The highest priority projects are the spawning ramps within the upper section of Reach A. Setback dyking, riparian vegetation re-establishment and off-channel habitat establishment are not necessary for effective spawning but would be a step toward a more natural stream bank like that which existed originally and which has been historically documented.

4.2 Agency approvals

Approvals will be required from the agencies listed in Table 5 based on Gaboury *et al.* (2000).

Table 5. Approvals needed

Agency	**Legislation/ Regulation**	**Description approvals**
Fisheries and Oceans Canada	Fisheries Act	Approval for activities that affect fish habitat
Ministry of Water, Land and Air Protection (Regional Operations)	Fisheries Act Fish protection Act	Approval for activities that affect fish habitat
Ministry of Water, Land and Air Protection (Regional Operations)	Provincial Wildlife Act	Permission to use lands within South Okanagan Wildlife Management Areas
Ministry of Water, Land and Air Protection (Regional Operations)	Water Act	Water license. Approval for alteration and work in and about a stream (Section 9)
Transport Canada	Navigable Waters Protection Act	Permit for activities around navigable waters.
British Columbia Ministry of Transportation & Highways		Access to travel along dyke to build ramps.
British Columbia Ministry of Health	Health Act	Approval of construction camp, sewage disposal and potable water supply
British Columbia Municipal Affairs, Recreation & Housing: Archaeology Branch	Heritage Conservation Act	Approval to excavate and alter sites of archaeological significance
Regional district of Okanagan /Similkameen	Municipal Act Regional Bylaws	Approval of zoning. Permits for construction
Okanagan Nation Fisheries Commission	Case law	Mandatory consultation
Penticton Indian Band	Contract and Agreement	Mandatory consultation
City of Penticton		Trail re-routing along the dyke
Special Interest Groups		e.g. Coyote Tours, SOSCP

4.3 Land negotiations

The river is accessible from the dykes along its entire length so private land would not be crossed when building ramps. However permission will be needed from the Penticton Indian Band and appropriate government agencies.

4.4 Community support and awareness

Community support is particularly important in the South Okanagan where numerous stewardship and restoration initiatives are on-going. A communications plan would need to be developed for this restoration project, as all work is along, or from the river dyke which functions as a public walkway frequented by residents and tourists. The river is also used by people floating down the channel on rafts and tubes during the summer months. It will be a benefit to the community and to continued stewardship of the Okanagan River, with its notable flora and fauna, to promote this area and describe species found within and along the river. The communication plan would need to include preparation of articles for local newspapers, radio and television as well as presentations to town council and other administrative bodies.

4.5 Pre and post-construction monitoring

As in all such developments, post construction monitoring will be needed to assess features such as water levels and sedimentation which could adversely affect fish populations – particularly sockeye, kokanee, rainbow trout and whitefish. An ecosystem based monitoring program would also include wildlife species that could be affected by the projects. The results of this monitoring will guide the implementation of any further restoration activities.

Sockeye and kokanee egg-fry survivals should be determined by counting spawners on the spawning ramps and assessing resulting fry densities. The effect of ramp construction over the full range of water levels can be determined by installing continuous recorders at strategic locations and periodic surveys of the channel and floodplain will show the transport and deposition of sediment and the relative stability of the streambed and adjacent channel.

5.0 CONCLUSION

The ramp spawning areas would provide benefits for sockeye and kokanee in the first spawning period after completion and likely for rainbow trout and whitefish as well. Widespread support and ample funding will be required as will access for sockeye through McIntyre and Skaha Lake dams. Multipurpose ponds and side channels proposed for the setback dyke zones will need detailed planning. Construction may only require a year, but planning, community dialogue and securing required agency approvals may be a more protracted process.

6.0 REFERENCES

Adams, M.A. and I.W. Whyte. 1990. Fish habitat enhancement: a manual for freshwater, estuarine and marine habitats. Department of Fisheries and Oceans Publication. DFO 4474. 330pp.

Alexis, F. Project supervisor, Okanagan Nation Fisheries Commission. (Personal communication: Sept 17th, 2002)

Bull, C. Glenfir Resources. (Personal communication: Sept 17, 2002)

Ford, B.S., P.S. Higgins, A.F. Lewis, K.L. Cooper, T.A. Watson, C.M. Gee, G.L. Ennis, and R.L. Sweeting. 1995. Kokanee. *In* Literature Reviews of the life history, habitat requirements and mitigation/compensation strategies for selected fish species in the Peace, Liard and Columbia River drainage's of British Columbia. Publication of the Province of British Columbia and Fisheries and Oceans Canada.

Gaboury, M., R. Newbury, and C. Bull. 2000. Okanagan River Habitat Restoration Feasibility. Prepared for the Ministry of Environment, Lands and Parks: Penticton, BC

Lister, D.B. and R.J. Finnigan. 1997. Rehabilitating off-channel habitat. *In* Slaney, P.A. and D. Zaldokas (Eds.). Watershed Restoration Technical Circular #9: British Columbia Ministry of Environment, Lands and Parks: Vancouver, BC.

MELP. 1997. British Columbia Ministry of Environment, Lands and Parks. Cottonwood Riparian Ecosystems of the Southern Interior. Ecosystems in British Columbia at Risk, Brochure series funded by Forest Renewal British Columbia.

MoWLAP. 2002. British Columbia Ministry of Water, Land and Air Protection, Okanagan Region. Press Release: November 27, 2002. File: 34560-20/Kokanee spawning.

Newbury, R. 2002. Spawning ramps below Okanagan Lake Dam. Report submitted to the Okanagan Nation Fisheries Commission. Newbury Hydraulics: Okanagan Centre, British Columbia.

ONFC. 2002. Okanagan Nation Fisheries Commission. Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 2 of 3. Prepared for the Colville Confederated Tribes.

Peters, C.N., D.P. Bernard and D.R. Marmorek. 1998. Should sockeye be re-introduced to Okanagan Lake? An exploration of potential benefits, impacts and uncertainties. ESSA Technologies Ltd., Vancouver, BC, 70pp.

Reiser, D.W. and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in the Western United States and Canada: 1 Habitat requirements of anadromous salmonids. US Forest Service General Technical Report PNW-96.

Schubert, B. 1983. Okanagan Flood Control System Maps. Drawing No. A-5221-19. Victoria, BC Ministry of Environment, Water Management Branch.

SOSCP. 2000. South Okanagan-Similkameen Conservation Program. Conserving Canada's Desert Country: A Prospectus. Environment Canada.

Summit (Summit Environmental Consultants Ltd.). 2000. Okanagan River Sockeye Spawning Habitat Assessment. Prepared for the Okanagan Nation Fisheries Commission.

Vedan, A. 2003. Literature review: Historical Habitat of the Okanagan River. Prepared for the Okanagan Nation Fisheries Commission.

FINAL

OBJECTIVE 3 Task D
Assessment of Juvenile *Oncorhynchus nerka* (Sockeye and Kokanee) Rearing Conditions of Skaha and Osoyoos Lakes 2002

Contribution No. *6* to an *Evaluation of an Experimental Re-Introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Authors: Howie Wright, BSc, R.P. Bio
Shayla Lawrence, BSc

Reviewed by: Chris Bull, R.P. Bio

Edited by: Howard Smith

EXECUTIVE SUMMARY

Data collected during the 2002 sampling season, and the relationship between total dissolved phosphorus and total biomass of fish, provide for estimates of the rearing capacity for Sockeye Salmon (*Oncorhynchus nerka*) smolts both 86mm and 100mm in length in three Okanagan Valley lakes: for Skaha Lake estimates of smolts per hectare are 2,781 and 1,977 and for Osoyoos Lake they are 2,981 and 2,119. Skaha Lake and Osoyoos Lake are similar in their rearing potential based on this relationship. However, there are many other factors, both biotic and abiotic, that affect the estimates
Secchi disc depths related well with the levels of productivity measured in both Skaha and Osoyoos Lakes where decreasing depths were associated with increases in phosphorus concentration. In terms of temperature and oxygen limitations, Skaha Lake had the greatest amount of optimal habitat for juveniles. Osoyoos Lake had suitable habitat in the north basin but was limited during the month of September. When comparing Skaha to current juvenile Okanagan sockeye rearing conditions (north basin of Osoyoos Lake), temperature and oxygen conditions are likely not an issue in Skaha Lake. In addition, in terms of adult holding habitat prior to spawning, Skaha Lake had conditions considered favourable when compared to Osoyoos Lake.

The total nitrogen to total phosphorus (TN:TP) ratio suggests that Skaha production is phosphorus limited and that the north basin of Osoyoos Lake is phosphorus limited from April to September but may be either nitrogen or phosphorus limiting in October and November. Chlorophyll *a* related well to the downstream increase in total phosphorus from Skaha Lake to Osoyoos Lake. Because silica levels did not vary greatly in both Skaha and Osoyoos lakes they are thought not to be limiting for either.

Zooplankton and *Mysis relicta* analysis were not completed in time for this report but preliminary results show that the mysid density in Osoyoos Lake has increased compared to 2001 sample session.

The kokanee escapement in Skaha Lake in 2002 was greater than 86,000 - the most observed since the early 1970's. Nevertheless, it is still thought to be low compared with historical numbers.

Physical and chemical features of Skaha Lake suggest that it has similar or better conditions for adult holding and juvenile rearing of Okanagan sockeye than those presently being used in Osoyoos Lake. Results from two years of monitoring of the rearing conditions suggest that an experimental reintroduction of sockeye to Skaha Lake is feasible.

However there are still, several unanswered questions arising from the second year of lake rearing assessment and subsequent monitoring during implementation and monitoring of experimental reintroduction project design:

1. Why has the kokanee population in Skaha Lake been smaller than historically except for 2002?
2. What part, if any has *M. relicta* played in the decline in Skaha Lake kokanee numbers?

3. What are the overall dynamics of *O. nerka* - *Mysis relicta* – zooplankton interactions in Skaha Lake?
4. Would these interactions affect the success of any re-introduction of sockeye into Skaha Lake?
5. Would these interactions affect the success of the present kokanee population in Skaha Lake?
6. Since preliminary results show that *Mysis relicta* abundance has increased in density in Osoyoos Lake, how will this affect the future survival of the Okanagan sockeye?

The following information is recommended to increase our rearing and limnological knowledge on the north basin of Osoyoos Lake and Skaha Lake.

1. A compilation of all available Skaha Lake kokanee information to begin to identify information gaps.
2. Compare historical predicted, versus observed kokanee population spawner numbers for Skaha Lake using the total phosphorus to fish biomass relationship to verify relationship.
3. Continue monthly water quality sampling regime (physical and chemical) of Skaha Lake and the north basin of Osoyoos Lake.
4. Biweekly *Mysis relicta* and zooplankton sampling from March to the bloom of cladoceran (usually June or July) and then monthly sampling to November. Sampling methodology used in 2001 and 2002 is recommended.
5. Continued collection of kokanee information from Skaha Lake and sockeye information on Osoyoos Lake to include juvenile abundance monitoring and growth rates of maturing fish.

ACKNOWLEDGEMENTS

The Okanagan Nation Fisheries Commission would like to acknowledge the following people and organizations for their valuable contribution towards Task 3d: Assessment of Juvenile *Oncorhynchus nerka* (Sockeye and Kokanee) Rearing Conditions of Skaha and Osoyoos Lakes 2002. Compilation of this report would not have been possible without the group effort of the staff of ONFC and all other parties involved.

Thanks to Kim Hyatt and Paul Rankin of Fisheries and Oceans Canada at the Pacific Biological Station and Steve Matthews of the Ministry of Water, Land and Air Protection (MoWLAP), Penticton Fisheries Branch, for their support and review of methodology, data analysis, and reporting. Vic Jensen and Geri Huggins of the Ministry of Water, Land and Air Protection (MoWLAP), Penticton Pollution Prevention Branch, for their support with water chemistry analysis, lab access, data analysis, and reporting.

Carol Cooper and Al Hirst of AMC Services conducted the Zooplankton and *Mysis relicta* analysis respectively. PSC Analytical Services conducted the water chemistry analysis.

Howard Smith provided a thorough and insightful senior review and editing of the report.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
ACKNOWLEDGEMENTS iii
TABLE OF CONTENTS iv
LIST OF FIGURES AND TABLES iv

1.0 INTRODUCTION 1

2.0 METHODOLOGY 2
2.1 Rearing Capacity 4
2.2 Physical Limnology and Water Chemistry 4
2.2.1 Physical Limnology 4
2.2.2 Water Chemistry 4
2.3 Macrozooplankton 5
2.4 Mysis Relicta 5

3.0 RESULTS 6
3.1 Juvenile Rearing Capacity 6
3.2 Physical Limnology and Water Chemistry 7
3.2.1 Physical Limnology 7
3.2.2 Water Chemistry 9

4.0 DISCUSSION AND CONCLUSIONS 11

5.0 RECOMMENDATIONS 13

6.0 REFERENCES 14

APPENDIX A Figures 2 through 15

LIST OF FIGURES AND TABLES

Figure 1. Rearing sampling sites 3

Table 1. Summary of Sampling Stations 4
Table 2. Summary of Predicted Juvenile *O. nerka* Rearing Capacities for Skaha Lake and Osoyoos Lake, 2002 7

1.0 INTRODUCTION

One of the last two significant sockeye salmon populations of the Columbia River system spawns in the Okanagan River in British Columbia (Figure 1). However, despite high spawner returns in 2000 and 2001, their population has been declining to levels causing concern (Hyatt & Rankin 1999). A long-term restoration goal is to reintroduce sockeye into Okanagan Lake in order to increase adult holding lake habitat, spawning, and juvenile rearing habitat. It has been proposed to first reintroduce sockeye into Skaha Lake. With funding from the Columbia Basin Fish and Wildlife Program of the Bonneville Power Administration, the Okanagan Nation Fisheries Commission (ONFC) and the Colville Confederated Tribes (CCT) are currently evaluating the Skaha introduction proposal. One concern is that adult holding and juvenile rearing conditions in Skaha Lake, may be limiting factors to the success of the reintroduction. This is the second and final year of the evaluation of the limnological conditions of Skaha and Osoyoos lakes.

The objective of this report is to assess adult holding habitat and calculate the juvenile rearing capacity of Skaha and Osoyoos lakes in relation to the factors influencing their rearing capacities. Due to time constraints, this report provides a data summary of the physical and chemical limnology of Skaha and Osoyoos Lakes. A summary of the zooplankton and *Mysis relicta* data will be integrated into the final report when complete.

2.0 METHODOLOGY

Selection of sample stations was based on recommendations from Wright (2002) and from the year –end review meeting for the project. Key recommendations for this report from the year-two review meeting are:

- Discontinue assessments of the south and central basins of Osoyoos Lake and Vaseux Lake as there was little rearing habitat potential due to temperature and oxygen extremes;
- Have two sites for each of Skaha and Osoyoos Lakes for comparison purposes;
- Increase frequency of zooplankton and Mysis relicta sampling to biweekly intervals;
- Increase frequency of temperature and dissolved oxygen sampling to biweekly intervals except to weekly from late August to October.

Table 1 lists sampling stations. Site ID's for sample locations were kept consistent with sample stations from the previous year for comparability. Physical limnology, water chemistry, phytoplankton (not analyzed), zooplankton, and *Mysis relicta* were sampled at all sites. Zooplankton and *Mysis relicta* samples are in the process of being analyzed. Physical limnology and water chemistry methodology was based on (OLAP) methodology for comparability and consistency, (Andrusak et al. 2000). Zooplankton and Mysis relicta sampling was based on methodology as described in Rankin et al. (2000).

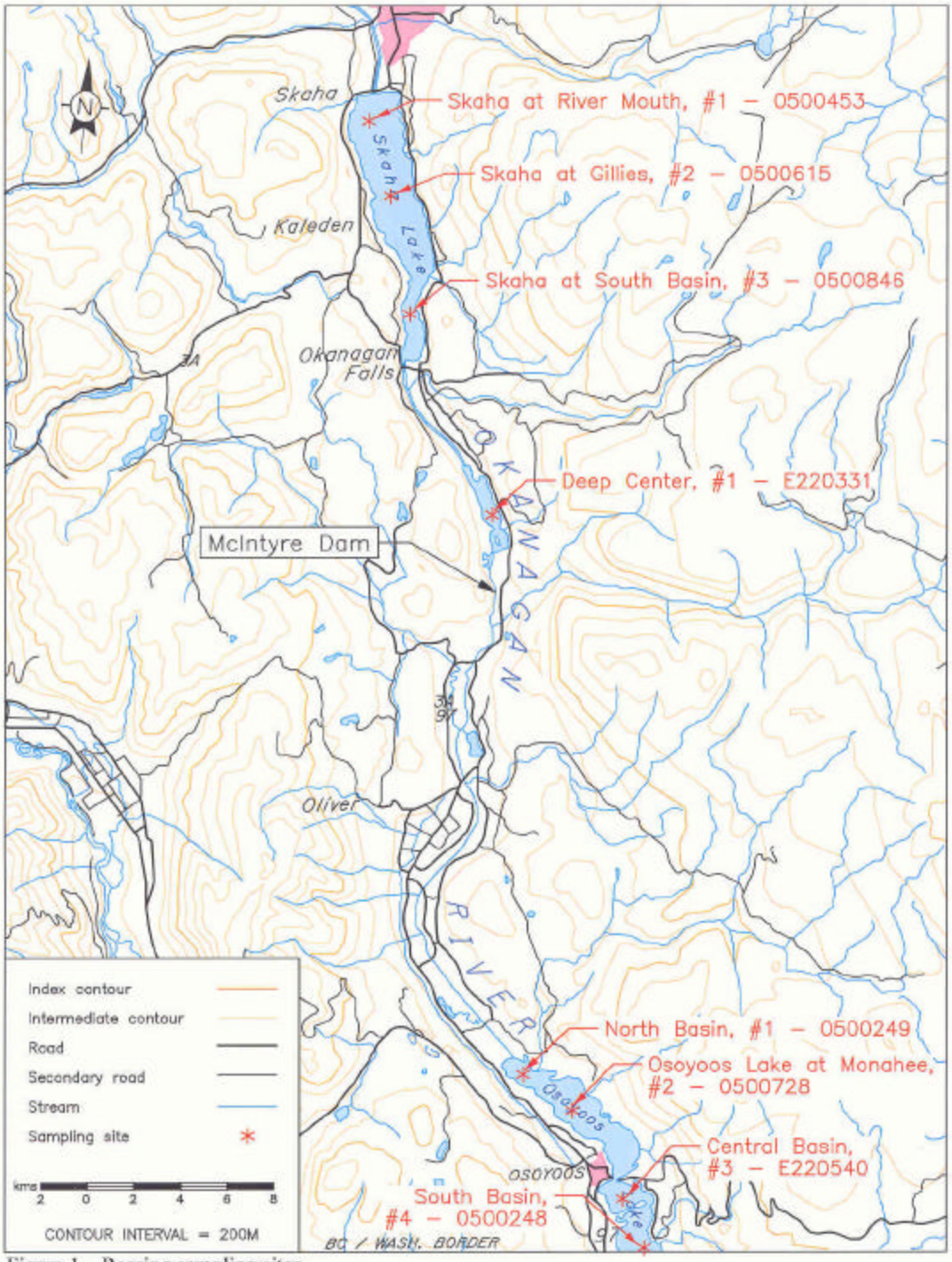


Figure 1. Rearing sampling sites.

Table 1. Summary of Sampling Stations

Lake	Site ID	Site No.	Site Name	Depth (m)
Skaha	0500615	2	Skaha @ Gillies	53.03
Skaha	0500846	3	Skaha @ South Basin	37.87
Osoyoos	0500249	1	Osoyoos @ North Basin	37.87
Osoyoos	0500728	2	Osoyoos @ Monashee Co-op	60.6 m

2.1 Rearing Capacity

For comparability and discussion of 2001 and 2002 data, the rearing capacities of Skaha and Osoyoos Lakes were calculated using the relationship between total phosphorus and total fish biomass (Downing et al. 1990; Hanson & Leggett 1982; Stockner 1987). This relationship is based on many years of data from northern temperate lakes and has also been used by Hyatt and Rankin (1999) to calculate the rearing capacity of Osoyoos Lake.. Total phosphorus concentrations and juvenile sockeye or kokanee biomass were used to develop a regression equation for predicting total fish biomass for lakes where total phosphorus concentrations are measured. It has worked well in other British Columbia lakes, including Osoyoos Lake and it also accounts for seasonal variability in environmental factors (Hyatt & Rankin 1999).

2.2 Physical Limnology and Water Chemistry

2.2.1 Physical Limnology

Temperature (^{0}C) and dissolved oxygen profiles (mg/L) were taken at least bimonthly for both lakes from April to August and weekly from September to early October. In addition, profiles were taken opportunistically when the field crew was out in the field.

At each sample site, temperature (^{0}C) and dissolved oxygen profiles (mg/L) were taken from the top surface down to 20 m in 2 m intervals and every 4 m thereafter to the bottom using a calibrated YSI model 52 dissolved oxygen meter and measurements to the nearest 0.1 mg/L. Secchi disk depth was also measured. A zone of tolerance was delineated for each lake, based upon water temperature (>17 ^{0}C), and dissolved oxygen (<4mg/L), tolerances of *O. nerka.* The zones of tolerance levels are approximately the amount of vertical habitat available in the hypolimnion (Rankin 2002, personal communication).

2.2.2 Water Chemistry

Water chemistry was measured monthly from April to November during daylight with three samples taken from each lake site. The samples from 1-10m depths were integrated, and in addition discrete samples of a volume equal to one third of a sample bottle were also taken at 1m, 5m, and 10m depths. Additional discrete samples were taken at 20m and as well a deep sample (32m and 45m at sites 1 and 2 respectively in

Osoyoos Lake and 36m and 45 m at sites 2 and 3 respectively in Skaha Lake). Plastic 1L bottles were rinsed three times prior to inserting samples. Separate bottles for total phosphorus bottle at each depth site, and lake and were taken to the field lab where Hydrogen Sulphate (H_2SO_4) was added.

Phytoplankton was collected at each site by an additional integrated sample and put in a clear 250mL glass jar and preserved with Lugol's iodine solution. The Lugol's preserved phytoplankton samples are stored at the Okanagan Nation Fisheries Commission storage in case it is later determined that phytoplankton analysis is required.

An additional integrated (0-10m) sample was taken and put in brown plastic 1 L bottles for chlorophyll *a* analysis. The samples were filtered and preserved with 2 drops of Magnesium Carbonate ($MgCO_3$), then frozen and shipped on ice in sealed plastic bags with a small amount of silica gel to the PSC Analytical Services Laboratory in North Vancouver along with water samples.

2.3 Macrozooplankton

Macrozooplankton sampling was conducted at biweekly intervals between April and November. Sampling was conducted at night using a plankton net (terminal mesh size of 105 microns). Flow measurements were also taken to determine net efficiency. Samples were put in 250mL glass jars and preserved in 4% formalin and shipped to the Pacific Biological Station (PBS) in Nanaimo, BC where they were picked up by AMC lab for analysis.

Sprules et al. (1981) provides a summary of the methodology used to analyze zooplankton and *Mysis relicta* samples. The samples were initially stained with methylene blue for contrast purposes (visibility) when measuring. The formalin solution was then decanted from the sample jar and poured into a Folsom splitter and split as required. Once the split number was determined it was poured into a round-bottomed graduated flask and the water level raised to 300 ml. Using an automatic pipette, subsamples of 3 mL and its multiples were taken and placed in a plankton wheel for identifying, enumerating, and measuring. Both a regular count and rare scan was conducted.

The samples were processed using an IBM computer based caliper measuring system and dissecting scope. A program called Zebra2 was used to generate a bench (summary) sheet and save individual measurements and counts to a file.

2.4 Mysis Relicta

Mysis relicta sampling was also conducted biweekly between April and November. Sampling was conducted at night using a *Mysis relicta* net (terminal mesh size of 300 microns). Samples were preserved in 4% formalin in 250mL glass jars. Samples were forwarded and processed much as described in the macrozooplankton abundance methodology.

3.0 RESULTS

3.1 Juvenile Rearing Capacity

Lake rearing capacities for 2001 and 2002 as determined from the described sampling are given in Table 2. Factors influencing these data are discussed later. Figure 2 shows the relationship between total phosphorus and fish biomass used to calculate total fish biomass per hectare for each lake. Figure 3 shows the length-weight regression used to calculate the number of smolts per hectare for each lake. Sockeye smolt lengths of 86mm and 100mm were used for the calculations so as to be consistent and comparable with Hyatt and Rankin's (1999) rearing estimate of Osoyoos Lake. With this relationship, juvenile sockeye smolt lengths of 86mm and 100mm would have mean weights of 6.79g and 9.55g respectively. The average total phosphorus was measured from April to November 2002. All measurements per site were summed and divided by their totals. For example, Skaha Lake had two sites with a total of 48 samples (approximately 24 for each site). The sum of all the total phosphorus readings was 384µg/L. Therefore, the seasonal average for Skaha Lake was about 8µg/L. Using the Figure 2 regression equation, a fish biomass of 15.88kg/ha was determined. This 15.88kg/ha of total fish biomass was divided by the mean weight of 86mm and 100mm sockeye smolts to calculate the number of smolts per hectare. The number of smolts per hectare for 86mm and 100mm are 2,339 and 1,663 respectively.

Table 2. Summary of Predicted Juvenile *O. nerka* Rearing Capacities for Skaha Lake and Osoyoos Lake, 2001 and 2002

Year	Lake	Lake Area (ha)	No. of Sites	TP (mg/L)	Fish Biomass (kg/ha)	No. of 86mm smolts /ha (6.79g)	No. of 100mm smolts/ha (9.55g)
2001	Skaha	2,010	3	12.0	18.88	2,781	1,977
2002	Skaha	2,010	2	8.00	15.88	2,339	1,663
2001	Osoyoos**	1,505	3	14.2	20.24	2,981	2,119
2002	Osoyoos**	1,505	2	14.75	20.54	3,025	2,151

****Canadian Portion only for lake area**

For Osoyoos Lake calculations the lower depth measurements were omitted because of the anoxic conditions that cause an irregular increase in total phosphorus in the hypolimnion (Johannes 2002, personal communication). For example, the epilimnion reading (0-10m) for Osoyoos Lake in September was 0.008mg/L at both sites yet the deep sample was 0.026mg/L (Figure 10d and f). This would have resulted in a larger fish biomass estimate for the lakes that would not accurately represent environmental conditions.

The Osoyoos Lake average total phosphorus measurement for 2002 is slightly lower than Hyatt and Rankin (1999) used for their calculation of a total phosphorus concentration of 22µg/L. However, there are other abiotic and biotic factors that affect this relationship.

3.2 Physical Limnology and Water Chemistry

3.2.1 Physical Limnology

Skaha Lake

Skaha Lake Secchi depth measurements at the two sites averaged 4.8m (Figure 4a). A maximum depth of 6.6m at Site 2 in September and a minimum depth of 3.9m at Site 3 in July were recorded.

A maximum surface temperature of 22.7^{0}C occurred at both Skaha Lake sites during July (Figure 5s and u).

Skaha Lake began to stratify in early June when the epilimnion boundary was at about 10m (Fig 5 l and m) and remained stratified until late October. The epilimnion layer at sites 2 and 3 settled to a maximum of 14m and 18m depth respectively (Figures 5bb and mm).

Dissolved oxygen levels in Skaha Lake ranged from 5.6 -16.26mg/L at site 2, and 6.72-16.4mg/L at Site 3. Summer profiles were slightly clinograde suggesting waters of moderate productivity (Horne & Goldman 1994). Dissolved oxygen measurements were recorded to lake bottom and demonstrated little, if any anoxic conditions in Skaha Lake.

Osoyoos Lake

Osoyoos Lake Secchi depth measurements averaged 3.5m at the two sites (Figure 4b). The maximum depth recorded was 4.4m and minimum 2.6m (Figure 4b). Maximum surface temperatures occurred in August and were 23.7^{0}C for sites 1 and 2 (Figures 6uu and 6vv).

The lake began to stratify at both sites in late May (Fig. 6e and f) and remained stratified until early November (Fig. 6yy and 6zz) when isothermal conditions reappeared and the epilimnion layer at sites 1 and 2 settled to a maximum 18m.

Dissolved oxygen levels in Osoyoos Lake ranged from <4mg/L (low oxygen conditions for *O. nerka*) and 16.56mg/L at sites 1 and 2 (Figures 6a to bbb). Summer profiles were slightly clinograde suggesting waters of moderate productivity (Horne & Goldman 1994).

Zone of Tolerance

Figures 7a-d show the zone of tolerance for all sites at both lakes, based on maximum temperature (17^{0}C) and minimum dissolved oxygen (4mg/L) tolerances for juvenile *O. nerka*. No suitable vertical habitat is predicted if the temperature tolerance line and dissolved oxygen tolerance line meet or cross. This area is the space between the two lines in the figures and is hypothesized to be an approximation of the optimal vertical habitat available for juvenile sockeye in the pelagic zone (Rankin 2002, personal communication). In addition, this zone of tolerance can also be considered to approximate the conditions required for adult sockeye holding in a lake until river spawning temperatures are optimal (about 15^{0}C).

Skaha Lake sites 2 and 3 had conditions suitable for juvenile *O. nerka* throughout the monitoring period. One observation of dissolved oxygen constraint occurred during the month of September, at site 2 when a maximum of 30m of optimal habitat was available over a maximum of 14 days based on sampling frequency (Figure 7a). The layer posing a vertical temperature constraint of 17^{0}C lasted at least from June 19 – September 26 and reached a maximum depth of 14m, again based on sampling frequency. Site 3 in the south basin had no dissolved oxygen constraints during the monitoring period but a vertical temperature constraint of 17^{0}C lasted from June 12 – September 30 and reached a maximum depth of 18m.

In Osoyoos Lake, September was the most critical month at Site 1 where it is estimated that 20 vertical meters of optimal hypolimnion habitat was available and lasted at most from September 6 – 19 (Figure 7c). At Site 2, only about two vertical meters of habitat were available from September to the beginning of October. This (2002) condition lasted a maximum period from September 13 – October 2 (Figure 7d). This was also seen in 2001 where September was observed to be the most critical month in terms of

optimal rearing habitat (Wright 2002). This 'squeeze' of optimal habitat is not new, but was poorly documented in previous years and with the long-term outlook of warmer conditions due to climate change, it could potentially become more severe (Rankin 2002).

During 2002 (as in 2001), Skaha Lake, in terms of temperature and oxygen limits, had more optimal habitat for sockeye adults holding, and juveniles rearing than did Osoyoos Lake. Based upon previous sampling, Osoyoos Lake is assumed to have suitable habitat in the north basin only and that becomes vertically constrained for both holding adult and rearing juvenile sockeye. In comparing Skaha conditions with those of the north basin of Osoyoos Lake it appears that temperature and oxygen are unlikely to be an issue in Skaha, and this may translate into increased survival for adult sockeye holding in the lake until spawning time.

3.2.2 Water Chemistry

Skaha Lake

Total nitrogen levels averaged 0.20mg/L from April to November at the two sites and ranged from 0.07 – 0.34mg/L (Figure 8a - c). Dissolved nitrogen (Nitrate-Nitrogen) levels averaged 0.003mg/L from April to November monthly sampling for the 0-10m integrated sample (Figure 9a - c). There were no differences in the Nitrate-Nitrogen concentrations at the two sample depths at Site 2 of Skaha Lake (Figures 9a - c). However, in Site 3, the dissolved nitrogen levels were greater (average 0.011mg/L) at the 36m sample depth (Fig. 9c). The difference may be due to photosynthetic biological uptake with limited mixing between the epilimnion and the hypolimnion, resulting in limited replenishment of nutrients from the hypolimnion into the epilimnion.

Total phosphorus levels averaged 0.008mg/L for the April to November monthly samples for all three sites and depths (Figures 10a- c). The 20m and deep section total phosphorus samples (45m and 36m) did not differ greatly from those of the epilimnion (Fig. 10a-c), nor did those for total dissolved phosphorus in the same period and depths (Fig. 11a-c).

Osoyoos Lake

Total nitrogen levels averaged 0.23mg/L from the April to November monthly samples at the two sites and ranging between 0.13 – 0.38mg/L (Figure 8d - f). Dissolved nitrogen (Nitrate-Nitrogen) levels averaged 0.005mg/L for the April to November monthly samples in the 0-10m integrated sample (Figure 9d). Both sites showed a difference between the 0-10m integrated sample and those from discrete sample depths (20m, 32m-site 1, and 45m-site 2) (Figures 9d - f). In addition, there was a large difference at both sites between the 20m discrete sample depth and the 32m-site 1 and 45m-site 2 (Fig. 9e and f). As in the case of Skaha Lake, the differences may be due to photosynthetic biological uptake with limited mixing between the epilimnion and the hypolimnion thus resulting in limited replenishment of nutrients from the hypolimnion into the epilimnion.

Total phosphorus levels averaged 0.014mg/L from April to November for all three sites and depths (Figures 10d- f) and the 20m and deep sections (32m-site 1 and 45m-site 2) samples did not differ appreciably from those of the epilimnion. The same was true of total dissolved phosphorous.

Nitrogen:Phosphorus Ratios

In most lakes there is a direct relationship between concentrations of the limiting nutrient and phytoplankton (Horne & Goldman 1994). Phosphorus is usually the limiting nutrient as most living matter requires a Total Phosphorus to Total Nitrogen (TN:TP) ratio of 16:1 (Horne & Goldman 1994). This can be further refined to: TN:TP>15, phosphorus limiting, TN:TP<10, nitrogen limiting, TN:TP between 10 and 15, can be neither, or both limiting (Andrusak et al. 2001; Wetzel 1983).

A measure of the available nutrients available to phytoplankton in the epilimnion is the amount of dissolved nitrogen and phosphorus in the 0-10m integrated sample depth (Andrusak et al. 2001). A ratio of 7:1 for nitrates to dissolved phosphorus (NO_3:TDP) is often used as an indicator of the bio-availability of nutrients. If the ratio is <7, then conditions are more favourable for cyanobacteria (blue-green algae) and if >7, then conditions are favourable for other phytoplankton such as diatoms. This is relevant in that blue-green algae are a poor food source for zooplankton (Andrusak et al. 2001).

At all Skaha Lake sites the TN:TP ratios were greater than 15 except for site 3 in October (N/P ratio of 9.33) suggesting that the lake is phosphorus limited (Figure 12a). Site 3 is in the south basin of Skaha Lake and nitrogen limiting during October but was close to 10 which translates to neither or both limiting. Considering the available dissolved nutrients (NO_3:TDP), the NO_3:TDP ratios were all <7 which suggests an environment favourable to blue-green algae (Figure 13a).

In Osoyoos Lake, average TN:TP ratios were above 15 from April to September and between 10-15 for October and November (Figure 12b). This suggests that the lake was either phosphorus limiting and then either, neither or both limiting. NO_3:TDP ratios, were all less than 7 suggesting conditions favourable for blue-green algae (Figure 13b).

Chlorophyll *a*

Chlorophyll *a* is often used as an indicator of phytoplankton standing crop (Horne & Goldman 1994). The average April-November chlorophyll *a* concentration in Skaha Lake, was 3.2µg/L (Figure 14a) whereas in Osoyoos Lake, was 4.87ug/L (Figure 14b). This relates well with the difference in average total phosphorus levels, which were greater in Osoyoos Lake than in Skaha Lake.

Silica

Silica is used by diatoms for their rigid cell walls, called frustules and it accounts for their success and if there is great variation in silica concentrations it may suggest that silica is potentially limiting (Horne & Goldman 1994). Diatoms are a preferred food source for zooplankton (Horne & Goldman 1994). Silica levels in all Skaha and Osoyoos lake sites averaged 4.7mg/L (Figure 15a - c; 15d - f). Silica does not seem to be limiting diatom production in either of these lakes as concentrations of silica did not fluctuate greatly.

4.0 DISCUSSION AND CONCLUSIONS

Based on data collected during the 2002 sampling season and on the relationship between total dissolved phosphorus and fish biomass of limnetic juvenile *O. nerka*, the rearing capacity for 86mm and 100mm *O. nerka* smolts in Skaha Lake is estimated to be 2,339 smolts/ha and 1,663 smolts/ha respectively. For Osoyoos Lake, the rearing capacity for 86mm and 100mm is estimated to be 3,025 smolts/ha and 2,151 smolts/ha.

As identified in the 2001 report, the carrying capacity of Osoyoos Lake was calculated by Hyatt and Rankin (1999) to be higher than this even though similar concentrations of total phosphorus were used. The main reason for the difference is the range of data used to develop the relationship between total phosphorus and fish biomass by Hyatt and Rankin (1999). They used a broader range of lake trophic conditions (<2µg/L-300µg/L of total phosphorus) while the lake trophic conditions used in Figure 2 of this report ranged only from <2µg/L-30µg/L. Another difference is that the lakes used in Hyatt and Rankin (1999) were not limited to those containing only *O. nerka*. Figure 2 of this report used lakes whose principal limnetic fish species was *O. nerka* but some also contained *Mysis relicta*. The impacts of *Mysis relicta* on the rearing production of sockeye or kokanee lakes are relatively unknown but may have some influence. The main outcome of these differences is a more conservative rearing estimate based upon our data. Nevertheless, the value is in comparing the lakes rearing capacities even though Skaha has slightly less productive capacity in their total phosphorus levels for 2002. Osoyoos Lake has a demonstrated capacity to sustain a relatively large biomass of juvenile sockeye, so this suggests that the rearing capacity of Skaha Lake is currently not limited.

In addition, the 2002 kokanee spawning escapement was over 86,000 (Matthews 2002) a population size which has not been seen since the early 1970's when Skaha Lake was considered to be in a eutrophic state. That was prior to tertiary treatment of the Penticton municipal wastewater treatment plant on the Okanagan River Channel (Truscott & Kelso 1979).

Secchi depths related well with the productivity of Skaha Lake and Osoyoos Lake decreasing in depth as phosphorus concentrations increased, In terms of temperature and oxygen limits, Skaha Lake had the greatest amount of suitable habitat for rearing juvenile *O. nerka*. Osoyoos Lake also had suitable habitat but had vertical plane habitat limitations for a period of about 14 days. This conclusion is based on increased sampling frequency in 2002 as compared to that of 2001. On the basis of the current somewhat marginal rearing conditions for sockeye in the north basin of Osoyoos Lake, and the comparatively favourable circumstances in Skaha Lake, temperature and oxygen conditions limitations are not seen in Skaha Lake. This temperature and oxygen squeeze seen in Osoyoos Lake is not a new physical feature, but is poorly documented. With the potential of climate change and warmer conditions in the Okanagan Basin, this 'squeeze' may be more extreme in the future (Rankin 2002, personal communication). Temperature and dissolved oxygen conditions are more suitable in Skaha Lake than in Osoyoos Lake for adult sockeye holding there until spawning conditions are favourable. Therefore, if sockeye are reintroduced into Skaha Lake through adult migration, it appears that over summer survival for adults and juvenile rearing survival in Skaha Lake would be greater.

The total nitrogen to total phosphorus (TN:TP) ratio suggests that both Skaha Lake and the north basin of Osoyoos Lake are primarily phosphorus limited. However, for Osoyoos Lake in October and November, the (TN:TP) ratio was between 10-15 and suggests that the lake was either phosphorus limiting and then either, neither or both limiting. Both lakes had a dissolved TN:TP ratio less than 7 indicating that conditions are likely favourable for cyanobacteria. Because Osoyoos Lake and Skaha Lake are quite similar in these respects one might expect that the conditions for sockeye in Skaha Lake would not be very different, if not improved, from those in the north basin of Osoyoos Lake.

The relationship of an increase in total phosphorus to an increase in chlorophyll *a* can be seen for Skaha and Osoyoos Lakes. Silica levels did not vary greatly which suggests that it is not limiting.

Zooplankton and *Mysis relicta* samples have been collected and are currently being analyzed and are thought likely to provide further insight into the juvenile rearing conditions in Skaha and Osoyoos Lakes.

Physical and chemical features of Skaha Lake suggest that it has similar or better conditions for sockeye adult holding and juvenile rearing than those presently being used in Osoyoos Lake. The information collected over the past two years suggest that, in terms of rearing conditions, an experimental reintroduction is feasible. However, several unanswered questions remain after the second year of lake rearing assessment:

1. Other than 2002, why have recent kokanee populations in Skaha Lake been smaller than historically?
2. What part, if any has *M. relicta* played in the decline in Skaha Lake kokanee numbers?
3. What are the dynamics of *O. nerka* and *Mysis relicta* interactions with zooplankton in Skaha Lake?
4. How might these interactions affect the success of any re-introduction of sockeye and the present kokanee population in Skaha Lake?
5. Since preliminary results suggest that *Mysis relicta* have increased in density in Osoyoos Lake, how might this affect the future survival of the Okanagan sockeye?

5.0 RECOMMENDATIONS

To help answer the foregoing questions during implementation of the experimental reintroduction, further physical limnology, water chemistry, zooplankton and *Mysis relicta* abundance sampling and comparison of these features in Skaha Lake and the north basin of Osoyoos Lake is recommended.

In addition, information on the Skaha Lake kokanee population and rearing behaviour of *O. nerka* in the north basin of Osoyoos Lake is lacking. The following information is recommended to increase our rearing and limnological knowledge on the north basin of Osoyoos Lake and Skaha Lake.

1. A compilation of all available Skaha Lake kokanee information to begin to identify information gaps.

2. Compare historical predicted, versus observed kokanee population spawner numbers for Skaha Lake using the total phosphorus to fish biomass relationship to verify relationship.

3. Continue monthly water quality sampling regime (physical and chemical) of Skaha Lake (two sites) and the north basin of Osoyoos Lake (two sites) as follows:
   - Measure temperature/oxygen profiles at or near lake-bottom at all sites.
   - During August - October on Skaha and Osoyoos Lakes when temperature and dissolved oxygen conditions for juvenile *O. nerka* habitat are most likely to become critical, increase the frequency of sampling to twice weekly at the sample sites.

4. Biweekly *Mysis relicta* and zooplankton sampling from March to the bloom of cladoceran (usually June or July) and then monthly sampling to November. Sampling methodology used in 2001 and 2002 is recommended. It is also recommended to increase the number of sites for *M. relicta* to 10 for each lake to increase the confidence limits (Rankin 2002, personal communication).

5. Continued collection of kokanee information from Skaha Lake and sockeye information on Osoyoos Lake to include juvenile abundance monitoring and growth rates of maturing fish. This can be accomplished by:
   - Hydroacoustic and trawl surveys to determine juvenile abundance. Fisheries and Oceans Canada is currently conducting this work.
   - Trawl surveys in Skaha Lake to determine age structure and species composition of limnetic fish from Hydroacoustic surveys.
   - Seasonal gill netting of Skaha Lake and sampling of Skaha adult spawners to collect biological information (age structure, growth rates, sex, diet analysis, and genetic analysis).

6.0 REFERENCES

Andrusak, H., S. Matthews, I. McGregor, K. Ashley, G. Wilson, D. Sebastion, G. Scholten, L. Vidmanic, J. Stockner, K. Hall, G. Andrusak, J. Sawada, D. Cassidy, and J. Webster. 2001. Okanagan Lake Action Plan Year 5 (2000). Fisheries Project Report RD 89. Fisheries Management Branch, Ministry of Water, Land and Air Protection, Province of British Columbia, Victoria.

Andrusak, H., D. Sebastion, I. McGregor, S. Matthews, D. L. Smith, K. Ashley, S. Pollard, G. Scholten, J. Stockner, P. Ward, R. Kirk, D. Lasenby, J. Webster, J. Whall, G. Wilson, and H. Yassien. 2000. Okanagan Lake Action Plan Year 4 (1999). Fisheries Project Report RD 83. Fisheries Management Branch, Ministry of Agriculture, Food and Fisheries, Province of British Columbia, Victoria.

Downing, J. A., C. Plante, and S. Lalonde. 1990. Fish Production Correlated with Primary Productivity, not the Morphoedaphic Index. Canadian Journal of Fisheries and Aquatic Sciences **47**:1929-1936.

Hanson, J. M., and M. F. Leggett. 1982. Empirical Prediction of Fish Biomass and Yield. Canadian Journal of Fisheries and Aquatic Sciences **39**:257-263.

Horne, A. J., and C. R. Goldman 1994. Limnology. McGraw-Hill, Inc., New York.

Hyatt, K. D., and D. P. Rankin. 1999. A Habitat Based Evaluation of Okanagan Sockeye Salmon Escapement Objectives. Canadian Stock Assessment Secretariat **99**:59pp.

Johannes, M. J. 2002. Scientist, Northwest Ecosystem Institute, February 6, 2002.

Matthews, S. 2002. Okanagan Kokanee Spawning Summary for 2002. Ministry of Water Land and Air Protection, Penticton.

Rankin, D. P. 2002. Personal communication. Research Scientist, Department of Fisheries and Oceans Canada, Nanaimo.

Rankin, D. P., B. Hanslit, and K. D. Hyatt. 2000. Okanagan lakes mysid sampling guidelines. Data Management Section, Fisheries and Oceans Canada, Nanaimo.

Sprules, W. G., L. B. Holtby, and G. Griggs. 1981. A microcomputer-based measuring device for biological research. Canadian Journal of Zoology **59**:1611-1614.

Stockner, J. 1987. Lake fertilization: the enrichment cycle and lake sockeye salmon production. Canadian Special Publication of Fisheries and Aquatic Sciences **96**:198-215.

Truscott, S. J., and B. W. Kelso. 1979. Trophic Changes in Lakes Okanagan, Skaha and Osoyoos, B.C., Following Implementation of Tertiary Municipal Waste Treatment.

Canada-British Columbia Okanagan Basin Implementation Agreement. Department of Environment, Environmental Protection Service, Pacific Region, Penticton.

Wetzel, R. G. 1983. Limnology. Saunders College Publishing, Toronto.

Wright, R. H. 2002. Assessment of Juvenile Sockeye/Kokanee Rearing Capacity of Okanagan Lake, Skaha Lake, Vaseux Lakes and Osoyoos Lake 2001. Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake, Year 2 of 3. Okanagan Nation Fisheries Commission, Westbank.

APPENDIX A

Figures 2 through 15

Figure 2.	Total phosphorus – *O. nerka* biomass relationship
Figure 3.	Length-weight regression for Osoyoos Lake sockeye smolts (1957-2000)
Figure 4a-c.	Secchi depth transparencies 2002
Figure 5a-ww.	Temperature/oxygen profiles for Skaha Lake for 2002
Figure 6a-bbb.	Temperature/oxygen profiles for Osoyoos Lake for 2002
Figure 7a-d.	Zones of Tolerance for *O. nerka* in Skaha and Osoyoos Lakes
Figure 8a-f.	Total Nitrogen levels for Skaha and Osoyoos Lakes
Figure 9a-f.	Nitrate-Nitrogen levels for Skaha and Osoyoos Lakes
Figure 10a-f.	Total Phosphorus levels for Skaha and Osoyoos Lakes
Figure 11a-f.	Total dissolved phosphorus levels for Skaha and Osoyoos Lakes
Figure 12a-b.	Total Nitrogen : Total Phosphorus Ratios for Skaha, Vaseux, and Osoyoos Lake
Figure 13a-b.	NO3/TDP ratio at 0 to 10m for Skaha and Osoyoos Lakes
Figure 14a-b.	Chlorophyll *a* levels at 0-10m for Skaha and Osoyoos Lakes
Figure 15a-f.	Silica levels for Skaha and Osoyoos Lakes

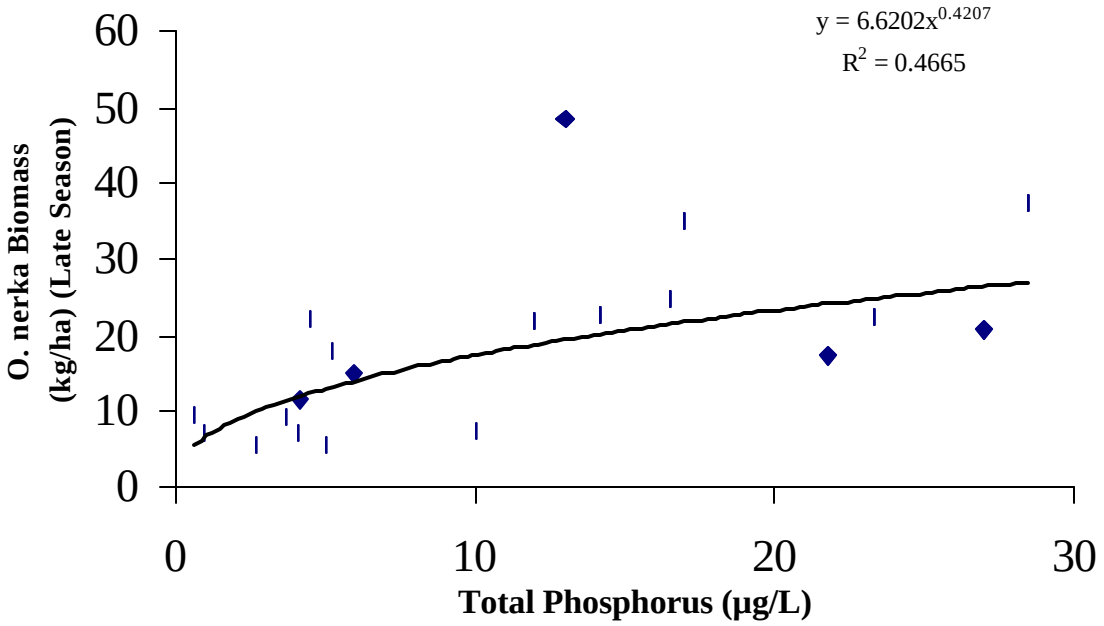


Figure 2: Total phosphorus – O. nerka biomass relationship. Data include biomass and TP estimates from a series of sockeye and kokanee lakes. Methods used to derive nerkid biomass estimates include standard acoustic / trawl surveys. For details see Stockner (1987), Hyatt and Rankin (1999)

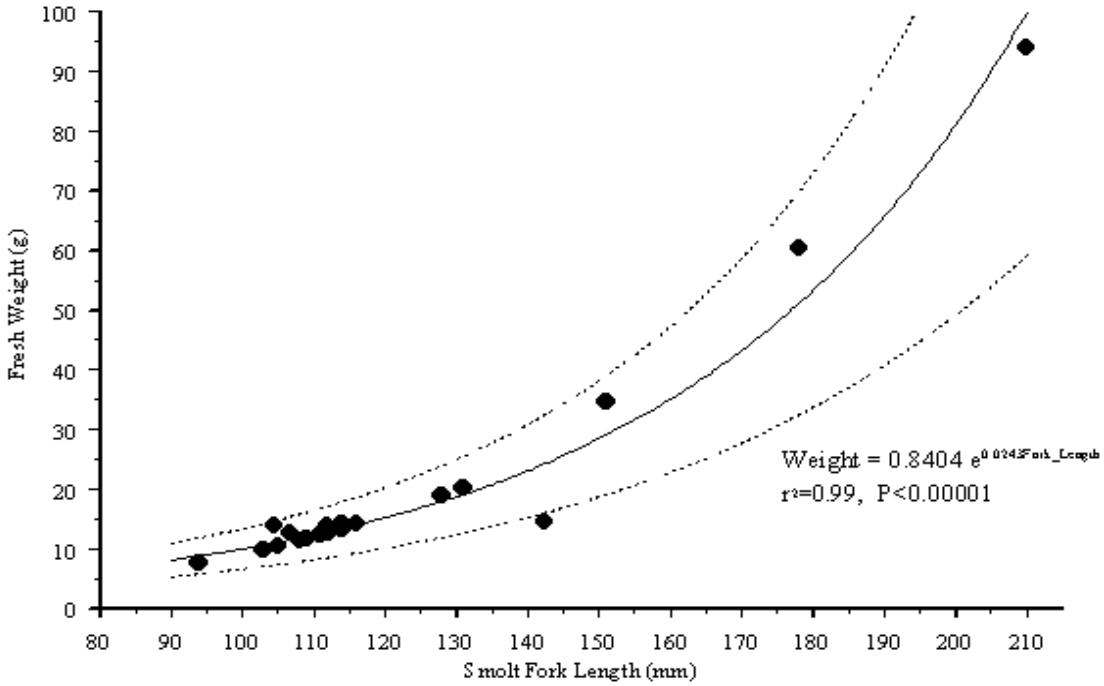


Figure 3: Length – Weight Regression for Osoyoos Lake Sockeye Smolts (1957-2000)
Weight = 0.8404 $e^{0.0243 * \text{Fork Length}}$

Figure 4: Secchi Depth Transparancies 2002

Figure 4a Skaha Lake

2002	Site 2	Site 3
F		
M		
A	4.1	4.1
M	5.0	4.8
J	4.3	4.2
J	4.5	3.9
A	4.6	4.4
S	6.6	6.0
O	5.4	5.4
N		
Average	4.9	4.7

Lake average 4.8

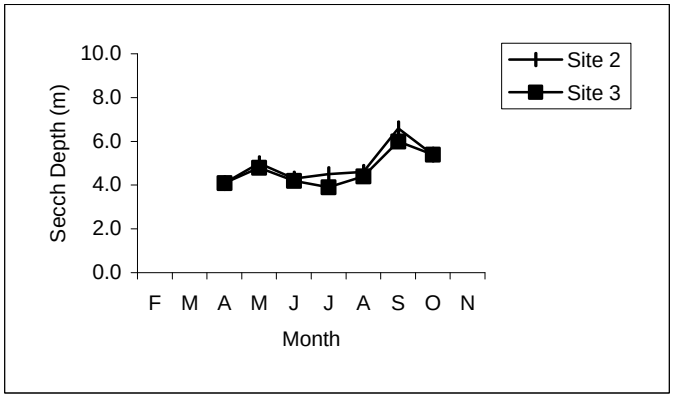


Figure 4b Osoyoos Lake

2002	Site 1	Site 2
F		
M		
A	3.3	3.9
M	3.0	3.1
J	3.0	2.6
J	2.6	3.0
A	4.1	5.0
S	3.6	3.6
O	4.4	4.4
N		
D		
Average	3.4	3.7

Lake Average 3.5

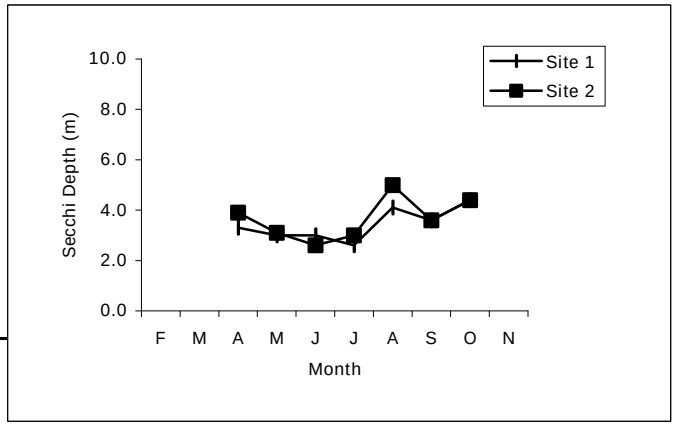


Figure 5: Temperature/Oxygen Profiles for Skaha Lake for 2002

Figure 5a Site 2 April 10

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
4.0	0	13.5	0
3.8	2	13.6	2
3.8	4	13.3	4
3.7	6	13.6	6
3.6	8	14.2	8
3.6	10	13.9	10
3.6	12	13.9	12
3.6	14	14.1	14
3.6	16	13.8	16
3.6	18	13.9	18
3.6	20	13.9	20
3.6	24	13.9	24
3.6	28	13.5	28
	32		32
	36		36
	40		40

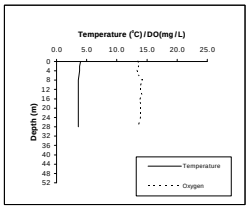


Figure 5b Site 3 April 10

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
4.6	0	14.0	0
4.5	2	14.0	2
4.4	4	14.3	4
4.3	6	14.3	6
4.3	8	14.3	8
4.3	10	14.5	10
4.2	12	14.4	12
4.2	14	14.5	14
4.2	16	14.2	16
4.2	18	14.4	18
4.2	20	14.1	20
4.2	24	14.2	24
4.2	28	14.1	28
	32		32
	36		36
	40		40

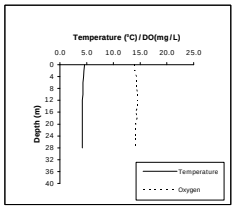


Figure 5c Site 2 April 25

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
7.0	0	14.34	0
7.0	2	16.00	2
7.0	4	16.13	4
6.8	6	16.18	6
6.6	8	16.26	8
6.4	10	15.72	10
6.3	12	15.91	12
6.2	14	15.56	14
6.2	16	15.50	16
6.2	18	15.49	18
6.1	20	15.32	20
6.0	24	15.19	24
5.9	28	15.06	28
	32		32
	36		36
	40		40

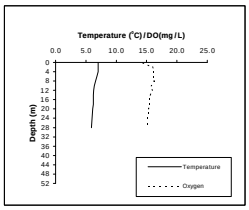


Figure 5d Site 3 April 25

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
6.8	0	13.6	0
6.6	2	15.5	2
6.5	4	15.8	4
6.4	6	16.3	6
6.2	8	16.1	8
6.0	10	16.3	10
5.8	12	16.4	12
7.9	14	15.0	14
7.3	16	15.5	16
7.4	18	14.9	18
7.3	20	14.5	20
7.3	24	13.4	24
7.3	28	13.1	28
	32		32
	36		36
	40		40

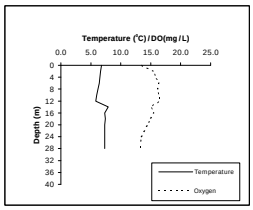


Figure 5e Site 2 May 8

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
11.7	0	14.77	0
10.7	2	12.15	2
10.4	4	10.96	4
10.2	6	10.38	6
9.9	8	10.20	8
9.7	10	9.81	10
9.5	12	9.67	12
9.3	14	9.76	14
9.2	16	9.85	16
8.4	18	9.86	18
8.3	20	9.90	20
8.2	24	9.94	24
7.7	28	10.40	28
7.0	32	9.92	32
6.4	36	9.73	36
	40		40

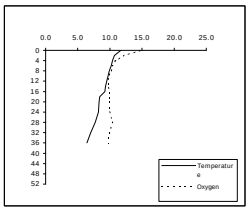


Figure 5f Site 3 May 9

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
10.40	0	8.40	0
10.00	2	8.40	2
9.70	4	8.00	4
9.10	6	8.08	6
9.00	8	8.09	8
9.00	10	8.11	10
9.00	12	7.99	12
8.90	14	8.10	14
8.60	16	8.16	16
7.10	18	8.23	18
7.00	20	8.33	20
6.60	24	8.27	24
6.30	28	8.24	28
6.20	32	8.89	32
6.00	36	6.29	36
6.00	40	5.14	40

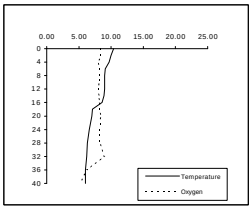


Figure 5g Site 2 May 23

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
12.4	0	11.20	0
12.3	2	10.58	2
12.3	4	9.86	4
12.2	6	9.66	6
12.3	8	9.52	8
12.2	10	9.58	10
12.3	12	9.56	12
12.4	14	9.38	14
12.4	16	9.39	16
12.1	18	9.58	18
11.2	20	9.52	20
9.9	24	9.79	24
8.6	28	10.32	28
7.9	32	10.51	32
7.7	36	10.59	36
7.7	40	10.55	40
7.4	44	10.71	44

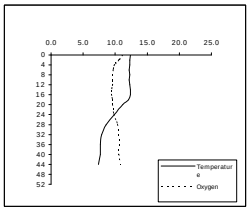


Figure 5h Site 3 May 23

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
13.2	0	9.2	0
13.8	2	9.4	2
13.8	4	9.0	4
13.9	6	9.0	6
13.9	8	8.9	8
13.8	10	9.5	10
13.8	12	9.4	12
13.6	14	9.5	14
13.5	16	9.3	16
13.2	18	9.5	18
13.1	20	9.7	20
12.8	24	9.9	24
12.1	28	10.2	28
10.4	32	10.5	32
9.0	36	10.9	36
	40		40

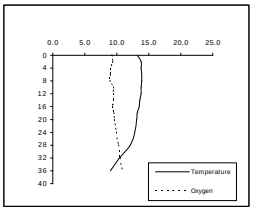


Figure 5i Site 2 May 28

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
15.3	0	10.79	0
15.2	2	12.02	2
15.2	4	11.95	4
14.8	6	13.16	6
13.2	8	13.31	8
12.6	10	13.38	10
12.1	12	13.55	12
11.8	14	13.55	14
11.2	16	13.55	16
10.9	18	13.45	18
10.6	20	13.44	20
9.4	24	13.66	24
7.6	28	14.10	28
7.6	32	13.85	32
7.5	36	13.59	36
6.9	40	13.56	40
	44		44

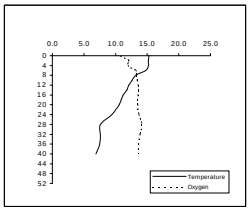


Figure 5j Site 2 June 7

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
10.4	0	11.73	0
12.2	2	11.73	2
13.1	4	10.56	4
13.2	6	10.08	6
13.4	8	10.55	8
13.3	10	10.91	10
13.1	12	10.56	12
12.5	14	11.14	14
12.1	16	11.21	16
11.6	18	11.21	18
11.1	20	11.17	20
10.5	24	11.26	24
9.3	28	12.17	28
8.7	32	11.98	32
8.4	36	11.94	36
7.8	40	11.96	40
7.4	44	12.02	44
7.0	48	12.38	48
6.6	52	12.51	52

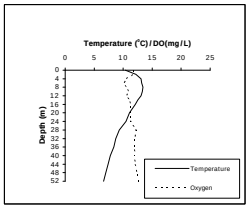


Figure 5k Site 3 June 7

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
9.6	0	12.01	0
11.3	2	10.79	2
12.8	4	12.10	4
13.7	6	11.45	6
14.2	8	10.82	8
14.4	10	10.39	10
14.3	12	10.16	12
14.1	14	10.49	14
13.6	16	10.59	16
12.2	18	10.07	18
11.5	20	10.66	20
10.5	24	10.75	24
9.5	28	10.62	28
9.1	32	10.67	32
8.5	36	11.03	36
7.9	40	11.23	40

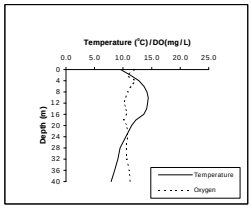


Figure 5l Site 2 June 11

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
15.3	0	10.44	0
14.5	2	13.44	2
14.2	4	13.60	4
14	6	13.60	6
14.2	8	13.60	8
13.8	10	12.70	10
13.7	12	12.14	12
13.6	14	12.11	14
12.8	16	12.07	16
12.3	18	12.18	18
10.8	20	12.11	20
10	24	12.02	24
8.2	28	12.96	28
7.6	32	13.99	32
6.7	36	13.90	36
6.5	40	14.40	40
6.2	44	14.17	44
6.1	48	13.81	48
6.0	52	13.59	52

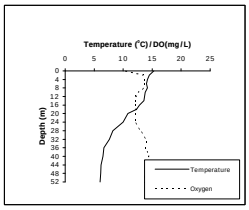


Figure 5m Site 3 June 11

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
15.1	0	8.42	0
14.9	2	8.95	2
14.4	4	9.30	4
12.4	6	9.87	6
11.8	8	9.82	8
10.6	10	10.20	10
8.7	12	10.84	12
8.5	14	11.82	14
8.2	16	11.87	16
8.0	18	11.42	18
7.9	20	11.51	20
7.7	24	11.82	24
7.2	28	12.12	28
6.9	32	12.10	32
6.9	36	12.02	36
	40		40

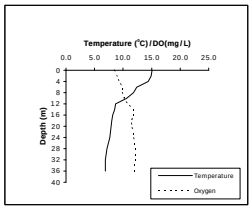


Figure 5n Site 2 June 19

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
17.0	0	7.56	0
17.1	2	9.16	2
16.9	4	10.33	4
14.7	6	10.30	6
13.5	8	9.10	8
12.6	10	9.80	10
11.6	12	9.48	12
10.4	14	9.81	14
9.2	16	10.17	16
7.9	18	10.64	18
7.3	20	10.40	20
6.9	24	10.59	24
6.5	28	10.60	28
6.2	32	10.80	32
6.1	36	10.75	36
6.1	40	10.70	40
5.8	44	10.60	44
5.8	48	10.16	48
6.0	52	9.45	52

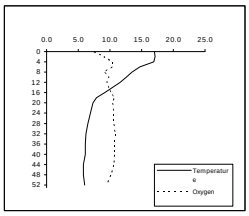


Figure 5o Site 3 June 19

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
17.5	0	6.8	0
17.7	2	7.7	2
17.4	4	8.7	4
17.4	6	9.4	6
15.4	8	9.1	8
12.6	10	10.2	10
9.6	12	10.3	12
7.8	14	11.7	14
7.5	16	11.5	16
7.2	18	11.0	18
7.2	20	11.1	20
7.1	24	11.0	24
7.1	28	10.8	28
6.9	32	10.8	32
7.1	36	10.7	36
7.2	40	4.2	40

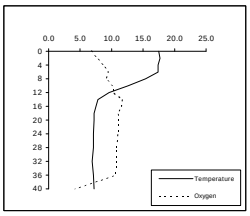


Figure 5p Site 2 June 27

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
21.8	0	9.66	0
21.9	2	9.98	2
19.0	4	11.29	4
17.9	6	11.75	6
17.3	8	11.55	8
16.6	10	11.39	10
12.3	12	12.00	12
11.2	14	12.04	14
10.2	16	12.30	16
9.2	18	12.76	18
8.6	20	12.87	20
8.1	24	13.04	24
7.3	28	13.59	28
6.6	32	13.08	32
6.4	36	13.92	36
6.1	40	13.70	40
6.2	44	13.34	44
5.6	48	12.20	48
	52		52

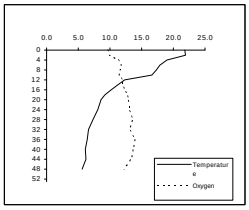


Figure 5q Site 2 July 10

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
19.3	0	9.57	0
19.2	2	9.81	2
18.4	4	10.25	4
18.2	6	10.38	6
17.9	8	10.41	8
16.5	10	10.25	10
12.2	12	10.34	12
10.9	14	10.75	14
10.2	16	10.89	16
9.5	18	11.15	18
8.3	20	11.67	20
7.6	24	12.45	24
7	28	12.84	28
6.7	32	13.34	32
6.3	36	13.37	36
6	40	13.46	40

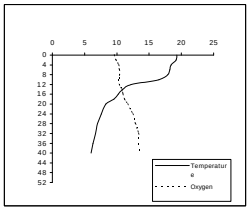


Figure 5r Site 3 July 10

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
20.7	0	9.91	0
20.6	2	9.31	2
20.2	4	9.52	4
19.5	6	9.75	6
18.9	8	9.75	8
16.4	10	9.76	10
14.7	12	9.80	12
11.9	14	9.98	14
10.3	16	10.52	16
8.7	18	10.81	18
8.1	20	11.11	20
7.4	24	11.47	24
7.0	28	11.57	28
6.9	32	11.46	32
6.8	36	11.39	36
6.7	40	10.04	40

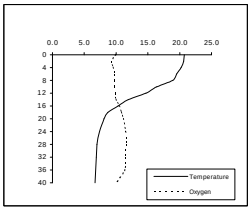


Figure 5s Site 2 July 17

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
22.7	0	9.58	0
22.2	2	10.05	2
21.6	4	10.29	4
21.1	6	10.71	6
18.7	8	10.87	8
16	10	10.73	10
13	12	10.21	12
11.2	14	10.90	14
9.2	16	11.60	16
8.5	18	12.00	18
8	20	12.30	20
7.5	24	12.80	24
7	28	13.12	28
6.6	32	13.47	32
6.4	36	13.47	36
6.2	40	13.24	40
6	44	12.60	44
5.8	48	12.54	48

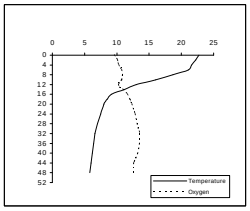


Figure 5t Site 2 July 23

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
22.3	0	8.25	0
22.1	2	8.32	2
22.0	4	8.39	4
21.8	6	8.22	6
19.9	8	8.32	8
17.0	10	8.35	10
13.6	12	8.20	12
11.9	14	8.05	14
10.2	16	8.60	16
9.3	18	8.86	18
8.7	20	9.25	20
7.8	24	9.90	24
7.2	28	10.28	28
6.8	32	10.35	32
6.4	36	10.59	36
6.2	40	10.30	40
6.0	44	10.13	44
5.9	48	9.20	48
5.7	52	7.14	52

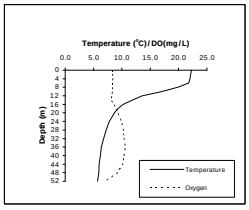


Figure 5u Site 3 July 23

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
22.7	0	8.14	0
22.5	2	7.90	2
22.4	4	7.69	4
22.2	6	7.90	6
16.8	8	8.26	8
14.8	10	8.32	10
12.2	12	8.50	12
10.0	14	9.11	14
9.3	16	9.10	16
8.6	18	9.25	18
8.1	20	9.33	20
7.7	24	9.61	24
7.4	28	9.55	28
7.3	32	9.56	32
7.2	36	8.40	36
7.2	40	2.56	40

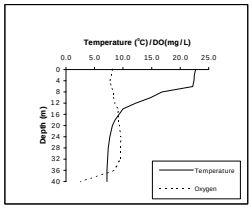


Figure 5v Site 2 August 9

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
20.2	0	9.43	0
20.1	2	9.29	2
19.9	4	9.34	4
19.8	6	9.38	6
19.5	8	9.44	8
19.3	10	9.40	10
17.4	12	8.64	12
11.5	14	8.55	14
10.0	16	8.94	16
8.9	18	9.47	18
8.6	20	9.93	20
7.8	24	10.33	24
7.3	28	10.64	28
6.9	32	10.55	32
6.3	36	10.98	36
6.1	40	10.80	40
5.9	44	9.51	44
5.8	48	8.30	48
5.7	52	7.49	52

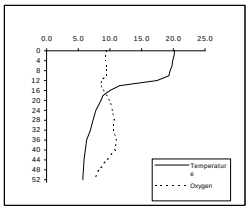


Figure 5w Site 3 August 9

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
20.6	0	8.77	0
20.6	2	8.98	2
20.3	4	9.11	4
19.8	6	9.24	6
19.7	8	9.20	8
19.5	10	9.16	10
15.3	12	8.81	12
12.7	14	8.98	14
11.0	16	9.16	16
9.4	18	8.47	18
8.4	20	9.69	20
7.8	24	9.74	24
7.4	28	9.74	28
7.3	32	9.64	32
7.3	36	9.46	36
	40		40

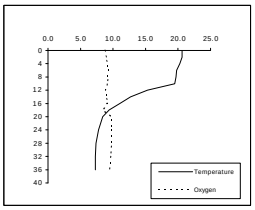


Figure 5x Site 2 August 18

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
20.6	0	8.57	0
20.0	2	8.96	2
19.7	4	9.27	4
19.7	6	9.36	6
19.6	8	9.45	8
19.5	10	9.54	10
18.2	12	9.23	12
11.3	14	9.34	14
10.5	16	9.66	16
10.0	18	9.60	18
9.1	20	9.91	20
8.2	24	10.62	24
7.6	28	11.00	28
7.1	32	11.21	32
6.8	36	11.29	36
6.5	40	11.21	40
6.2	44	11.21	44
5.9	48	9.72	48
5.9	52	9.34	52

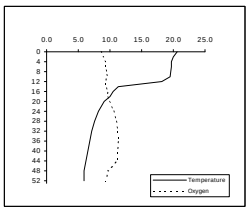


Figure 5y Site 3 August 18

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
20.8	0	8.31	0
20.7	2	8.39	2
20.5	4	8.77	4
20.4	6	9.08	6
20.3	8	9.17	8
19.7	10	9.41	10
16.3	12	9.27	12
9.5	14	10.34	14
9.4	16	10.39	16
8.3	18	10.45	18
8.1	20	9.83	20
7.9	24	9.98	24
7.7	28	10.14	28
7.5	32	10.21	32
7.4	36	10.18	36
	40		40

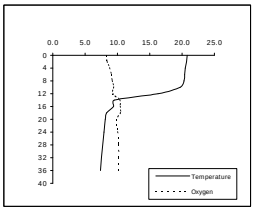


Figure 5z Site 2 August 21

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
19.9	0	8.55	0
19.8	2	8.80	2
19.8	4	9.09	4
19.7	6	9.21	6
19.6	8	9.37	8
19.6	10	9.28	10
16.8	12	8.79	12
11.1	14	9.28	14
9.9	16	9.35	16
8.9	18	9.66	18
8.5	20	9.81	20
7.8	24	10.20	24
7.3	28	10.27	28
6.9	32	10.40	32
6.5	36	10.24	36
6.2	40	9.86	40
6.0	44	8.91	44
6.0	48	7.96	48

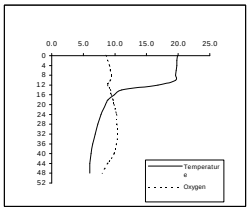


Figure 5aa Site 3 August 21

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
20.6	0	8.37	0
20.6	2	8.35	2
20.5	4	8.51	4
20.4	6	8.60	6
20.4	8	8.72	8
20.3	10	8.75	10
18.5	12	8.49	12
12.6	14	8.46	14
10.9	16	8.52	16
10.4	18	8.55	18
9.5	20	8.84	20
8.3	24	9.11	24
7.8	28	9.13	28
7.6	32	9.10	32
7.5	36	8.98	36
7.3	40	8.61	40

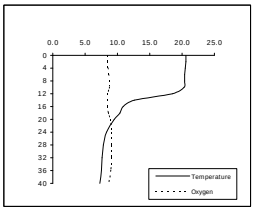


Figure 5bb Site 2 August 30

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
22.5	0	8.19	0
22.6	2	8.22	2
22.6	4	8.35	4
22.3	6	8.48	6
20.9	8	8.51	8
20.0	10	8.38	10
19.4	12	8.12	12
13.4	14	7.56	14
10.0	16	7.92	16
9.2	18	8.12	18
8.6	20	8.21	20
8.1	24	8.26	24
	28		28
	32		32
	36		36
	40		40
	44		44
	48		48

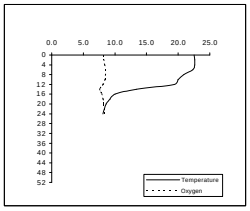


Figure 5cc Site 3 August 30

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
21.9	0	8.23	0
22.0	2	8.31	2
21.8	4	8.40	4
20.9	6	8.37	6
20.1	8	8.20	8
19.6	10	7.98	10
18.6	12	7.60	12
13.1	14	7.43	14
10.3	16	7.64	16
9.6	18	7.77	18
8.3	20	8.12	20
8.2	24	8.36	24
	28		28
	32		32
	36		36
	40		40

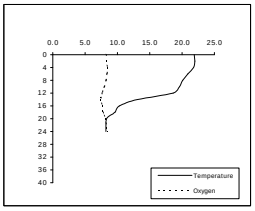


Figure 5dd Site 2 September 3

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
20.7	0	9.08	0
20.6	2	9.20	2
20.6	4	9.22	4
20.6	6	9.34	6
20.5	8	9.39	8
20.5	10	9.21	10
16.2	12	9.30	12
	14		14
	16		16
	18		18
	20		20
	24		24
	28		28
	32		32
	36		36
	40		40
	44		44
	48		48

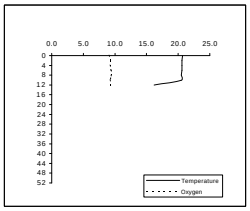


Figure 5ee Site 3 September 3

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
20.9	0	9.01	0
20.8	2	9.28	2
20.7	4	9.55	4
20.7	6	9.64	6
20.6	8	9.71	8
20.5	10	9.55	10
19.5	12	9.97	12
17.9	14	8.81	14
	16		16
	18		18
	20		20
	24		24
	28		28
	32		32
	36		36
	40		40

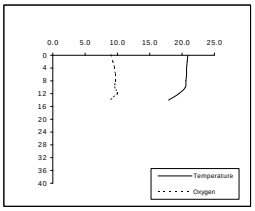


Figure 5ff Site 2 September 5

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
19.7	0	7.56	0
19.7	2	7.68	2
19.7	4	7.93	4
19.7	6	8.11	6
19.7	8	8.28	8
19.6	10	8.11	10
17.9	12	7.69	12
15.2	14	7.34	14
11.6	16	7.44	16
9.9	18	7.63	18
9.1	20	7.91	20
8.1	24	8.45	24
7.5	28	8.98	28
7.1	32	9.25	32
6.6	36	9.24	36
6.3	40	8.94	40
6.0	44	8.05	44

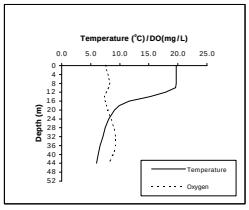


Figure 5gg Site 3 September 5

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
19.6	0	7.88	0
19.7	2	7.56	2
19.8	4	7.68	4
19.8	6	8.00	6
19.8	8	8.07	8
19.8	10	8.01	10
10.8	12	7.87	12
9.3	14	7.85	14
8.5	16	8.06	16
8.2	18	7.95	18
8.0	20	7.97	20
7.7	24	7.95	24
7.5	28	7.87	28
7.5	32	7.81	32
7.3	36	7.72	36
	40		40

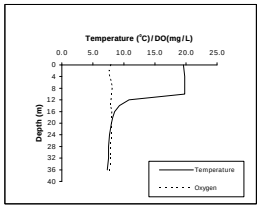


Figure 5hh Site 2 September 12

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
19.6	0	7.45	0
19.3	2	7.98	2
19.3	4	8.05	4
19.2	6	8.01	6
19.1	8	8.07	8
19.0	10	8.19	10
18.9	12	8.06	12
13.3	14	7.87	14
10.5	16	7.54	16
9.5	18	7.58	18
8.8	20	7.81	20
8.0	24	8.22	24
7.6	28	8.40	28
7.1	32	8.88	32
6.7	36	9.18	36
6.1	40	7.83	40
5.9	44	6.90	44
6.1	48	3.89	48

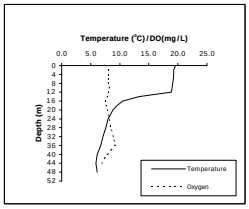


Figure 5ii Site 2 September 22

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
16.7	0	9.41	0
17.5	2	8.61	2
17.5	4	8.98	4
17.5	6	9.25	6
17.5	8	9.43	8
17.5	10	9.31	10
17.3	12	9.31	12
12.4	14	8.96	14
10.5	16	8.51	16
10.6	18	8.07	18
9.9	20	7.83	20
9.1	24	7.69	24
8.3	28	7.88	28
7.8	32	8.09	32
7.3	36	8.42	36
7.0	40	8.40	40
6.8	44	7.73	44
6.7	48	7.53	48
6.4	52	7.42	52

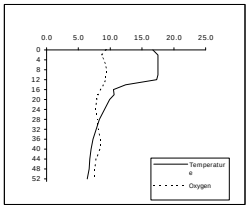


Figure 5jj Site 3 September 22

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
17.7	0	7.84	0
17.7	2	8.10	2
17.7	4	8.59	4
17.7	6	9.04	6
17.6	8	9.42	8
17.6	10	9.16	10
17.5	12	9.07	12
17.5	14	9.08	14
17.4	16	8.81	16
14.2	18	8.53	18
11.1	20	8.12	20
8.6	24	7.86	24
8.1	28	7.68	28
7.8	32	7.40	32
7.6	36	7.21	36
	40		40

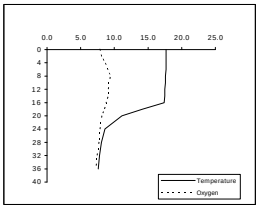


Figure 5kk Site 2 September 27

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
16.7	0	9.25	0
16.7	2	9.31	2
16.7	4	9.43	4
16.7	6	9.50	6
16.7	8	9.52	8
16.7	10	9.28	10
16.7	12	9.38	12
15.1	14	9.16	14
11.9	16	8.92	16
10.2	18	8.35	18
9.5	20	8.32	20
8.0	24	9.14	24
7.4	28	9.69	28
6.9	32	9.96	32
6.5	36	9.68	36
6.3	40	9.66	40
6.2	44	8.92	44
6.1	48	8.25	48
	52		52

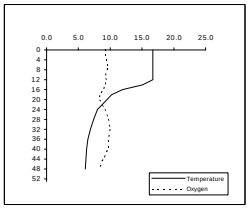


Figure 5ll Site 2 October 1

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
16.2	0	9.21	0
16.1	2	9.45	2
16.0	4	9.72	4
16.0	6	9.92	6
15.9	8	10.09	8
15.9	10	10.00	10
15.9	12	10.00	12
13.7	14	8.83	14
11.1	16	7.81	16
9.5	18	7.81	18
9.0	20	7.99	20
7.6	24	8.72	24
7.1	28	8.93	28
6.7	32	9.13	32
6.4	36	8.74	36
6.2	40	7.80	40
6.1	44	6.83	44
6.1	48	6.17	48
6.1	52	5.74	52

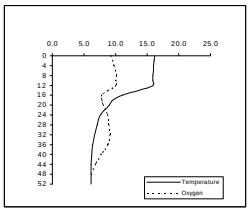


Figure 5mm Site 3 October 1

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
16.3	0	9.83	0
16.3	2	9.33	2
16.2	4	9.43	4
16.1	6	9.48	6
16.1	8	9.45	8
16.1	10	9.47	10
16.0	12	9.43	12
16.0	14	9.43	14
16.0	16	9.37	16
14.8	18	8.85	18
9.9	20	7.98	20
9.2	24	7.61	24
8.3	28	7.64	28
7.8	32	7.64	32
7.6	36	7.46	36
	40		40

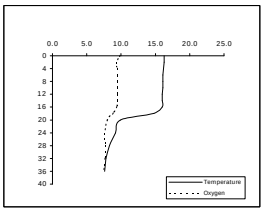


Figure 5nn Site 2 October 3

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
15.7	0	8.96	0
15.7	2	9.02	2
15.7	4	8.96	4
15.7	6	9.05	6
15.6	8	9.22	8
15.6	10	9.33	10
15.5	12	9.42	12
15.5	14	9.39	14
10.2	16	7.65	16
9.3	18	7.73	18
8.6	20	7.92	20
8.1	24	8.17	24
7.5	28	8.26	28
7.2	32	8.31	32
6.8	36	8.43	36
6.6	40	8.05	40
6.4	44	7.63	44
6.1	48	7.16	48

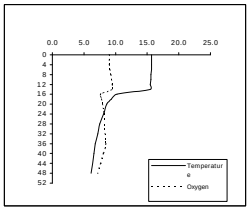


Figure 5oo Site 3 October 3

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
15.7	0	9.13	0
15.7	2	9.23	2
15.8	4	9.22	4
15.7	6	9.05	6
15.7	8	9.14	8
15.7	10	9.16	10
15.6	12	8.95	12
15.2	14	8.72	14
13.1	16	7.74	16
11.8	18	7.16	18
10.1	20	7.05	20
8.4	24	7.12	24
7.9	28	6.93	28
7.6	32	8.86	32
7.5	36	6.72	36
	40		40

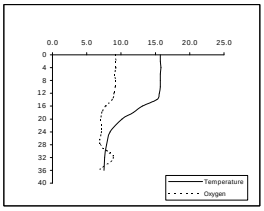


Figure 5pp Site 2 October 17

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
13.5	0	9.40	0
13.5	2	9.70	2
13.4	4	9.76	4
13.4	6	10.22	6
13.3	8	10.25	8
13.3	10	10.39	10
13.3	12	10.37	12
13.2	14	10.50	14
12.2	16	8.35	16
11.3	18	8.02	18
9.8	20	7.85	20
8.8	24	8.17	24
8.1	28	8.28	28
7.5	32	8.61	32
6.9	36	8.87	36
6.7	40	8.32	40
6.4	44	7.72	44
6.2	48	6.76	48
6.1	52	5.60	52

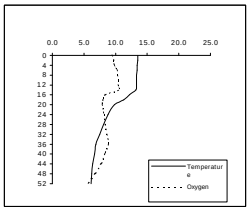


Figure 5qq Site 3 October 17

Temperature		Oxygen	
Temp	Depth	Oxygen	Depth
13.0	0	11.75	0
13.5	2	10.44	2
13.5	4	10.21	4
13.5	6	10.52	6
13.5	8	10.60	8
13.5	10	10.46	10
13.5	12	10.54	12
13.5	14	10.61	14
13.4	16	10.59	16
10.2	18	8.52	18
9.2	20	7.84	20
8.3	24	7.80	24
8.1	28	7.58	28
7.9	32	7.43	32
	36		36

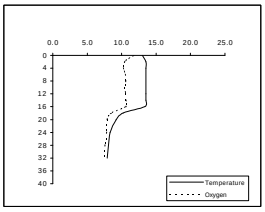


Figure 5rr Site 2 October 31

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
10.5	0	18.16	0
10.5	2	18.24	2
10.5	4	18.39	4
10.5	6	18.14	6
10.5	8	18.07	8
10.5	10	17.92	10
10.5	12	17.84	12
10.5	14	17.85	14
10.5	17	17.81	17
10.5	19	17.73	19
9.8	21	16.02	21
8.7	25	13.84	25
8.1	29	13.33	29

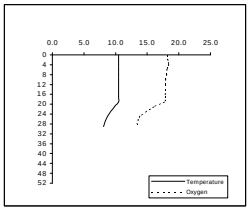


Figure 5ss Site 3 October 31

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
10.6	0	18.55	0
10.6	2	18.77	2
10.6	4	18.95	4
10.6	6	18.74	6
10.6	8	18.57	8
10.6	10	18.57	10
10.6	12	18.54	12
10.6	14	18.49	14
13.4	17	18.34	17
10.2	19	18.29	19
9.2	21	18.23	21
8.3	25	16.34	25
8.1	29	13.69	29

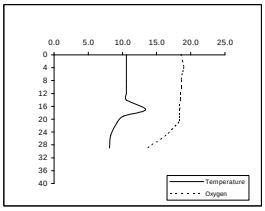


Figure 5tt Site 2 November 12

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
8.8	0	10.56	0
8.8	2	9.99	2
8.8	4	9.52	4
8.8	6	9.45	6
8.8	8	9.38	8
8.8	10	9.29	10
8.8	12	9.27	12
8.9	14	9.22	14
8.8	16	9.12	16
8.8	18	9.13	18
8.8	20	9.14	20
8.8	24	9.11	24
8.8	28	9.12	28
	32		32
	36		36
	40		40

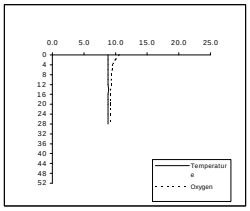


Figure 5uu Site 3 November 12

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
8.6	0	10.29	0
8.6	2	8.79	2
8.6	4	8.65	4
8.6	6	8.60	6
8.6	8	8.49	8
8.5	10	8.47	10
8.5	12	8.43	12
8.5	14	8.34	14
8.5	16	7.92	16
8.5	18	7.94	18
8.4	20	7.97	20
7.9	24	6.91	24
7.7	28	5.84	28
7.5	32	5.36	32
7.4	36	5.15	36
7.3	40	4.44	40

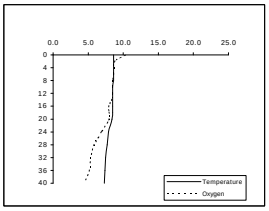


Figure 5vv Site 2 November 27

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
7.4	0	15.33	0
7.5	2	15.08	2
7.5	4	14.93	4
7.5	6	14.86	6
7.6	8	14.85	8
7.6	10	14.76	10
7.6	12	14.70	12
7.6	14	14.69	14
7.6	16	14.68	16
7.6	18	14.66	18
7.6	20	14.59	20
7.6	24	14.57	24
7.6	28	14.45	28
	32		32
	36		36
	40		40

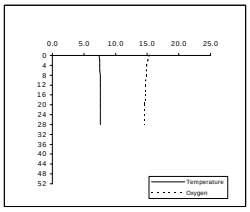


Figure 5ww Site 3 November 27

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
7.6	0	14.65	0
7.6	2	14.67	2
7.6	4	14.65	4
7.6	6	14.60	6
7.6	8	14.63	8
7.6	10	14.62	10
7.6	12	14.64	12
7.6	14	14.51	14
7.6	16	14.64	16
7.6	18	14.60	18
7.6	20	14.53	20
7.6	24	14.50	24
7.6	28	14.43	28
	32		32
	36		36
	40		40

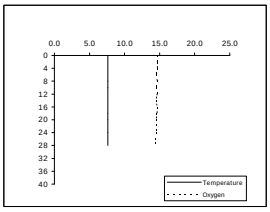


Figure 6: Temperature/Oxygen Profiles for Osoyoos Lake for 2002

Figure 6a Site 1 April 10

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
7.1	0	11.70	0
6.5	2	11.80	2
5.8	4	12.20	4
5.5	6	12.60	6
5.3	8	13.10	8
5.2	10	13.50	10
5.1	12	13.40	12
5.1	14	13.20	14
4.9	16	13.50	16
4.8	18	13.50	18
4.8	20	13.50	20
4.7	24	13.50	24
4.6	28	13.50	28
	32		32
	36		36
	40		40

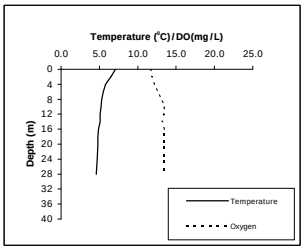


Figure 6b Site 2 April 10

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
5.7	0	13.50	0
5.4	2	12.70	2
5.2	4	13.70	4
5.1	6	14.00	6
4.9	8	13.80	8
4.8	10	13.90	10
4.6	12	14.10	12
4.5	14	13.90	14
4.4	16	14.10	16
4.4	18	14.00	18
4.4	20	14.00	20
4.3	24	13.70	24
4.2	28	13.90	28
	32		32
	36		36
	40		40

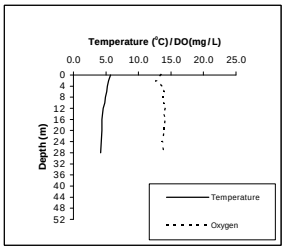


Figure 6c Site 1 April 24

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
8.0	0	11.25	0
7.9	2	12.28	2
7.9	4	12.84	4
7.9	6	13.01	6
7.9	8	13.08	8
7.8	10	13.35	10
7.7	12	13.15	12
7.4	14	13.44	14
7.4	16	12.87	16
7.3	18	12.64	18
7.0	20	12.99	20
6.5	24	12.99	24
6.4	28	12.97	28
	32		32
	36		36
	40		40

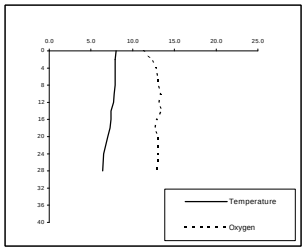


Figure 6d Site 2 April 24

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
8.2	0	10.78	0
8.0	2	11.36	2
7.9	4	11.69	4
7.9	6	11.97	6
7.9	8	12.20	8
7.9	10	12.21	10
8.1	12	11.98	12
7.7	14	12.23	14
7.4	16	12.11	16
7.3	18	12.21	18
7.3	20	12.13	20
7.3	24	12.16	24
7.3	28	11.97	28
	32		32
	36		36
	40		40

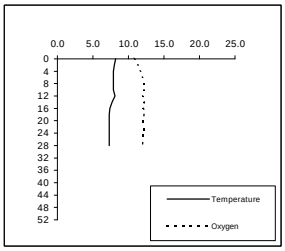


Figure 6e Site 1 May 8

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
9.8	0	7.99	0
9.3	2	6.82	2
9.2	4	7.40	4
9.1	6	8.66	6
9.1	8	8.89	8
9.1	10	9.40	10
9.0	12	10.07	12
8.5	14	9.95	14
7.6	16	9.85	16
6.8	18	10.07	18
6.6	20	10.00	20
6.2	24	8.22	24
6.4	28	2.72	28
6.4	32	2.61	32
	36		36
	40		40

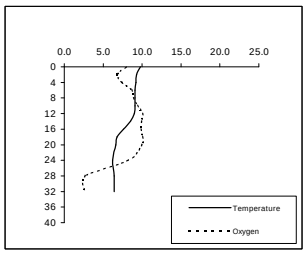


Figure 6f Site 2 May 8

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
10.8	0	12.7	0
9.9	2	12.7	2
9.7	4	12.8	4
9.6	6	12.2	6
9.6	8	12.0	8
9.5	10	11.7	10
9.1	12	11.8	12
8.1	14	11.8	14
7.0	16	11.9	16
6.7	18	11.7	18
6.5	20	11.3	20
6.4	24	10.4	24
6.3	28	10.7	28
6.3	32	10.2	32
6.2	36	10.1	36
6.1	40	9.6	40

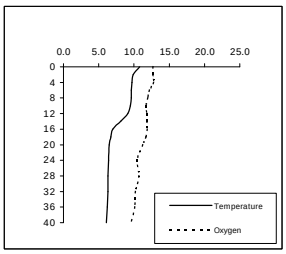


Figure 6g Site 1 May 22

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
13.4	0	9.60	0
13.0	2	11.32	2
12.6	4	12.15	4
12.5	6	12.34	6
12.1	8	12.50	8
11.8	10	12.39	10
11.5	12	12.33	12
10.9	14	13.57	14
10.5	16	13.80	16
10.0	18	12.88	18
9.2	20	13.91	20
8.2	24	14.82	24
7.6	28	14.97	28
7.4	32	14.78	32
7.3	36	14.45	36
7.2	40	11.63	40

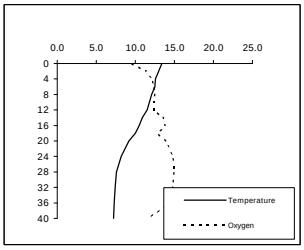


Figure 6h Site 2 May 22

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
13.4	0	14.05	0
13.4	2	12.00	2
13.4	4	13.17	4
13.3	6	12.89	6
13.3	8	12.90	8
13.2	10	12.84	10
13.2	12	12.76	12
13.0	14	12.70	14
12.6	16	12.71	16
12.5	18	12.65	18
12.3	20	12.65	20
11.5	24	12.76	24
9.5	28	13.21	28
9.0	32	13.32	32
8.7	36	13.25	36
8.3	40	13.23	40
8.2	44	13.10	44
8.2	48	12.87	48
7.9	52	12.69	52

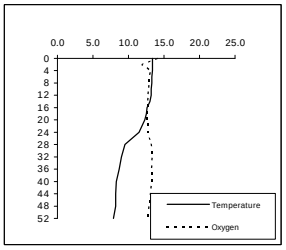


Figure 6i Site 1 June 6

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
12.6	0	10.40	0
12.7	2	12.80	2
13.2	4	13.40	4
13.9	6	12.10	6
14.4	8	11.80	8
14.5	10	11.37	10
14.3	12	11.96	12
13.8	14	11.31	14
13.4	16	11.52	16
12.9	18	12.21	18
12.0	20	11.80	20
11.3	24	12.05	24
10.4	28	12.46	28
9.7	32	12.98	32
9.0	36	13.39	36
9.1	40	17.38	40
	44		44

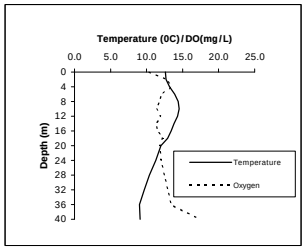


Figure 6j Site 2 June 6

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
12.1	0	11.81	0
13.1	2	14.80	2
13.6	4	15.30	4
14.0	6	14.51	6
14.6	8	15.18	8
14.9	10	14.39	10
15.1	12	14.89	12
15.2	14	14.95	14
15.2	16	14.74	16
15.3	18	14.94	18
15.2	20	13.53	20
14.7	24	14.53	24
13.1	28	13.59	28
12.4	32	13.63	32
11.3	36	14.69	36
10.4	40	14.27	40
9.4	44	16.56	44
8.7	48	15.93	48
8.3	52	15.67	52

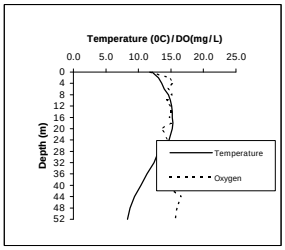


Figure 6k Site 1 June 10

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
15.8	0	10.93	0
14.7	2	9.99	2
14.3	4	10.25	4
14.4	6	10.57	6
14.4	8	10.34	8
14.3	10	10.42	10
14.3	12	10.32	12
14.2	14	10.71	14
13.9	16	10.61	16
13.5	18	10.41	18
12.4	20	10.44	20
8.6	24	11.25	24
8.0	28	11.48	28
7.6	32	11.64	32
7.7	36	11.56	36
7.6	40	11.35	40
7.5	44	10.34	44

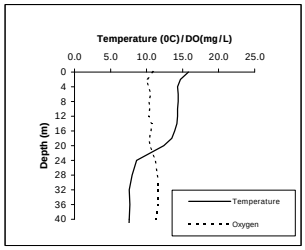


Figure 6l Site 2 June 10

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
16.3	0	10.43	0
14.9	2	10.56	2
14.6	4	11.04	4
14.4	6	11.10	6
14.3	8	11.08	8
14.2	10	10.96	10
14.1	12	10.96	12
14.0	14	10.96	14
13.9	16	10.87	16
13.9	18	10.81	18
13.8	20	10.62	20
13.6	24	10.48	24
13.6	28	10.42	28
12.3	32	10.58	32
9.3	36	10.84	36
8.0	40	11.10	40
7.8	44	11.29	44
7.6	48	11.77	48
7.4	52	11.87	52

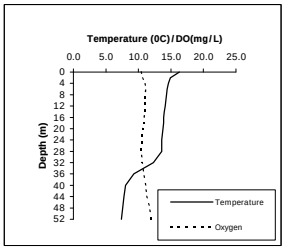


Figure 6m Site 1 June 18

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
17.2	0	9.16	0
16.9	2	9.04	2
16.6	4	9.43	4
16.4	6	9.50	6
15.0	8	9.51	8
14.9	10	9.41	10
13.3	12	9.49	12
12.1	14	9.61	14
9.7	16	9.98	16
10.7	18	9.55	18
9.3	20	9.98	20
8.3	24	10.34	24
7.9	28	10.38	28
7.7	32	10.42	32
7.7	36	10.35	36
7.5	40	10.56	40
7.4	44	10.53	44

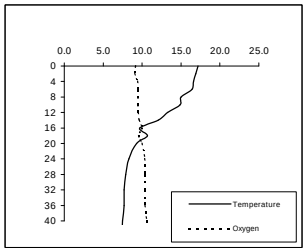


Figure 6n Site 2 June 18

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
17.5	0	9.77	0
17.5	2	9.93	2
17.5	4	10.24	4
17.5	6	10.61	6
17.4	8	10.30	8
13.2	10	10.30	10
13.1	12	10.27	12
17.7	14	10.41	14
11.6	16	10.61	16
10.4	18	10.99	18
8.2	20	11.20	20
7.8	24	11.72	24
7.7	28	11.20	28
7.5	32	11.18	32
7.4	36	11.39	36
7.4	40	11.08	40
7.4	44	11.17	44
7.3	48	10.66	48
7.3	52	10.72	52

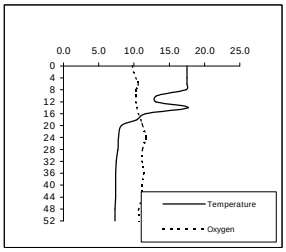


Figure 6o Site 2 June 25

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
22.7	0	6.51	0
20.3	2	7.14	2
19.8	4	8.31	4
19.4	6	8.23	6
17.6	8	8.19	8
15.9	10	8.28	10
14.6	12	7.77	12
12.2	14	8.39	14
11.1	16	8.10	16
9.7	18	8.25	18
8.5	20	8.70	20
7.9	24	8.96	24
7.7	28	8.90	28
7.5	32	8.73	32
7.5	36	8.53	36
7.5	40	8.42	40
7.4	44	8.18	44
7.4	48	8.01	48
7.4	52	7.86	52

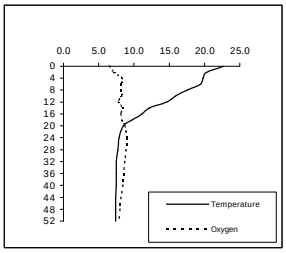


Figure 6p Site 1 July 9

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
21.9	0	8.76	0
21.3	2	9.41	2
19.6	4	9.89	4
18.9	6	10.21	6
18.4	8	10.13	8
18.0	10	9.71	10
14.8	12	9.32	12
12.2	14	9.01	14
9.7	16	9.28	16
8.5	18	9.49	18
8.1	20	9.68	20
7.8	24	9.73	24
7.7	28	9.45	28
7.7	32	9.04	32
7.6	36	8.05	36
7.5	40	6.04	40
7.5	44	1.47	44

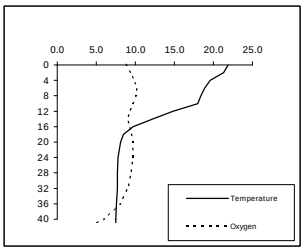


Figure 6q Site 2 July 9

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
21.0	0	8.56	0
20.3	2	8.55	2
19.3	4	9.07	4
18.8	6	9.23	6
18.4	8	9.20	8
17.8	10	9.07	10
14.8	12	9.06	12
13.1	14	8.25	14
9.8	16	9.13	16
8.9	18	9.43	18
8.5	20	9.70	20
8.0	24	9.83	24
7.8	28	9.95	28
7.8	32	9.81	32
7.7	36	9.66	36
7.7	40	9.45	40

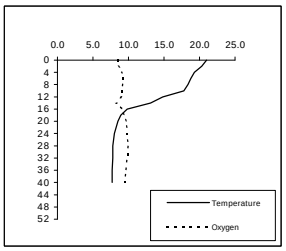


Figure 6r Site 2 July 15

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
22.0	0	8.95	0
21.3	2	9.08	2
21.1	4	9.11	4
20.9	6	9.16	6
20.5	8	9.19	8
19.3	10	9.25	10
16.8	12	7.78	12
14.7	14	7.44	14
12.9	16	7.62	16
10.9	18	8.04	18
9.7	20	8.41	20
8.2	24	8.68	24
7.9	28	8.83	28
7.8	32	8.73	32
7.7	36	8.66	36
7.7	40	8.61	40
7.7	44	8.91	44
7.7	48	8.88	48

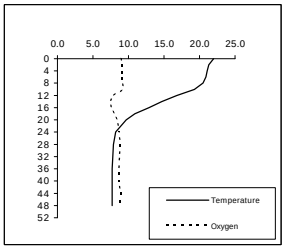


Figure 6s Site 1 July 22

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
23.2	0	8.34	0
22.2	2	8.44	2
21.6	4	8.60	4
21.4	6	8.65	6
20.8	8	8.35	8
19.4	10	7.91	10
14.7	12	6.66	12
12.1	14	6.73	14
10.0	16	7.39	16
8.7	18	7.75	18
8.5	20	7.72	20
8.2	24	7.63	24
8.0	28	7.61	28
7.8	32	7.23	32
7.8	36	6.20	36
7.9	40	5.08	40

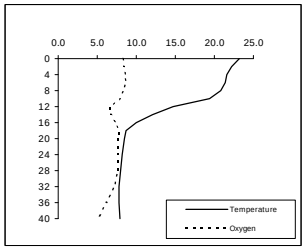


Figure 6t Site 2 July 22

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
23.5	0	8.34	0
21.8	2	8.24	2
21.7	4	8.45	4
21.7	6	8.45	6
21.3	8	8.47	8
19.1	10	7.75	10
15.4	12	7.03	12
12.8	14	7.01	14
10.0	16	7.67	16
9.2	18	7.79	18
8.6	20	7.86	20
8.2	24	7.91	24
8.0	28	7.75	28
8.0	32	7.54	32
7.9	36	7.55	36
7.9	40	7.48	40
7.9	44	7.31	44
7.8	48	7.34	48
7.8	52	7.29	52

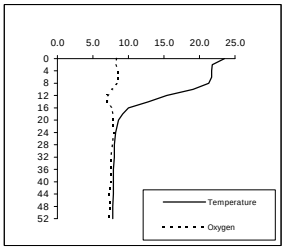


Figure 6u Site 1 August 7

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
19.7	0	8.35	0
19.6	2	8.11	2
19.6	4	8.13	4
19.6	6	8.10	6
19.2	8	7.77	8
18.8	10	7.14	10
17.4	12	6.12	12
10.9	14	5.71	14
9.5	16	6.18	16
8.6	18	6.41	18
8.5	20	6.54	20
8.2	24	6.53	24
8.1	28	6.41	28
8.0	32	6.18	32
7.9	36	4.60	36
	40		40

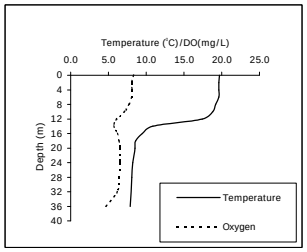


Figure 6v Site 2 August 7

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
19.8	0	8.52	0
19.6	2	8.32	2
19.6	4	8.36	4
19.5	6	8.30	6
19.5	8	8.35	8
19.4	10	8.31	10
15.8	12	5.84	12
13.0	14	5.78	14
10.0	16	6.31	16
9.0	18	6.51	18
8.8	20	6.49	20
8.5	24	6.26	24
8.3	28	6.23	28
8.2	32	6.22	32
8.1	36	6.30	36
8.1	40	6.14	40
8.0	44	6.08	44
8.0	48	6.07	48
8.0	52	6.04	52

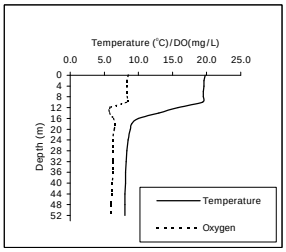


Figure 6w Site 1 August 8

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
21.4	0	9.29	0
21.2	2	9.31	2
20.1	4	9.41	4
19.7	6	9.63	6
19.5	8	9.30	8
19.2	10	8.57	10
18.4	12	7.87	12
11.5	14	6.82	14
9.6	16	6.82	16
9.0	18	7.11	18
8.6	20	7.15	20
8.3	24	7.27	24
8.1	28	7.24	28
8.0	32	6.94	32
7.9	36	2.34	36
7.9	40	1.45	40

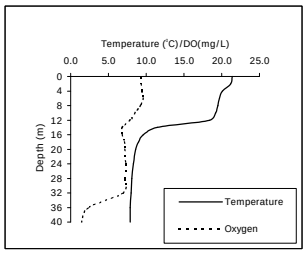


Figure 6x Site 2 August 8

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
20.4	0	9.44	0
20.4	2	9.32	2
20.0	4	9.57	4
19.8	6	9.65	6
19.6	8	9.37	8
19.5	10	8.95	10
18.8	12	8.35	12
14.1	14	6.01	14
11.0	16	6.57	16
9.7	18	6.74	18
9.1	20	6.85	20
8.4	24	6.84	24
8.2	28	6.69	28
8.2	32	6.61	32
8.1	36	6.51	36
8.1	40	6.47	40
8.1	44	6.43	44
8.0	48	6.40	48
8.0	52	6.22	52

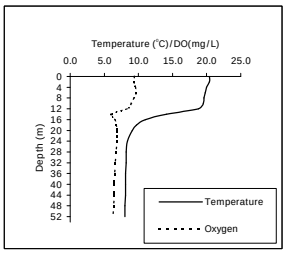


Figure 6y Site 1 August 17

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
19.8	0	9.00	0
19.5	2	9.08	2
19.3	4	9.03	4
19.3	6	8.98	6
19.3	8	8.60	8
19.2	10	8.69	10
19.0	12	8.35	12
17.0	14	7.68	14
12.5	16	6.58	16
9.0	18	6.18	18
9.0	20	6.42	20
8.6	24	6.45	24
8.5	28	6.49	28
8.3	32	7.02	32
8.1	36	3.39	36
	40		40

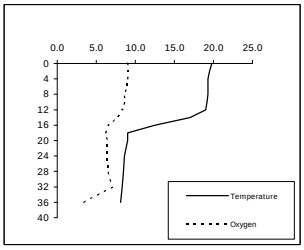


Figure 6z Site 2 August 17

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
20.9	0	9.31	0
20.3	2	9.50	2
19.8	4	9.47	4
19.6	6	9.57	6
19.5	8	9.47	8
19.5	10	9.65	10
19.3	12	9.52	12
17.8	14	9.05	14
12.3	16	8.29	16
9.0	18	9.30	18
9.0	20	7.18	20
8.7	24	7.08	24
8.5	28	6.92	28
8.4	32	6.83	32
8.4	36	6.80	36
8.3	40	6.71	40
8.3	44	6.61	44
8.3	48	6.50	48
8.2	52	6.37	52

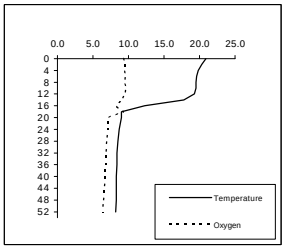


Figure 6aa Site 2 August 19

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
21.5	0	8.73	0
20.5	2	9.09	2
20.2	4	9.31	4
19.8	6	9.48	6
19.5	8	9.23	8
19.1	10	8.80	10
18.7	12	8.55	12
15.1	14	7.47	14
10.7	16	7.06	16
9.9	18	6.88	18
9.0	20	6.95	20
8.6	24	6.85	24
8.5	28	6.83	28
8.4	32	6.76	32
8.4	36	6.75	36
8.3	40	6.67	40
8.3	44	6.42	44
8.2	48	6.30	48
	52		52

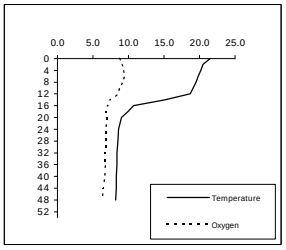


Figure 6bb Site 1 August 27

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
23.7	0	8.67	0
22.5	2	9.49	2
22.0	4	9.51	4
21.6	6	9.34	6
20.6	8	9.02	8
19.5	10	8.29	10
18.0	12	7.16	12
17.0	14	6.60	14
11.3	16	5.36	16
9.6	18	5.46	18
9.1	20	5.54	20
8.6	24	5.16	24
	28		28
	32		32
	36		36
	40		40

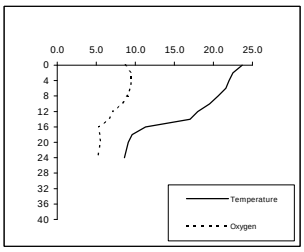


Figure 6cc Site 2 August 27

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
23.7	0	8.84	0
23.1	2	9.22	2
21.9	4	9.44	4
21.1	6	9.18	6
19.9	8	8.98	8
19.4	10	8.46	10
18.7	12	7.90	12
16.5	14	7.01	14
13.0	16	5.73	16
9.8	18	5.60	18
9.1	20	5.63	20
8.6	24	5.69	24
	28		28
	32		32
	36		36
	40		40
	44		44
	48		48
	52		52

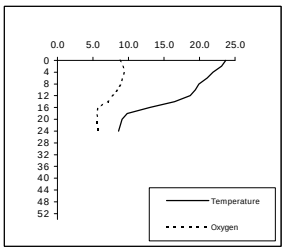


Figure 6dd Site 1 September 3

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
20.3	0	8.31	0
20.3	2	8.32	2
20.3	4	8.40	4
20.2	6	8.50	6
18.8	8	7.21	8
18.3	10	7.52	10
17.8	12	7.21	12
	14		14
	16		16
	18		18
	20		20
	24		24
	28		28
	32		32
	36		36
	40		40

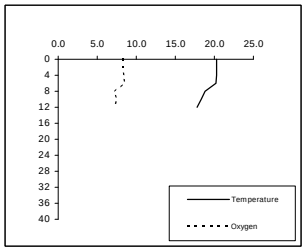


Figure 6ee Site 2 September 3

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
20.8	0	8.82	0
20.8	2	8.88	2
20.8	4	8.95	4
20.7	6	9.07	6
20.7	8	8.83	8
20.6	10	8.77	10
19.1	12	7.85	12
16.1	14	6.49	14
14.0	16	6.15	16
11.3	18	6.10	18
10.7	20	6.11	20
	24		24
	28		28
	32		32
	36		36
	40		40
	44		44
	48		48
	52		52

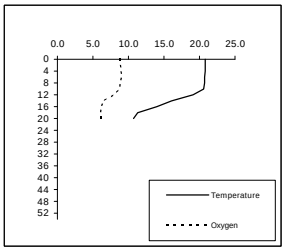


Figure 6ff Site 1 September 5

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
19.4	0	7.51	0
19.4	2	7.54	2
19.4	4	7.85	4
19.4	6	7.87	6
19.1	8	7.34	8
18.7	10	6.51	10
17.3	12	5.75	12
14.1	14	5.84	14
10.6	16	5.41	16
9.1	18	6.43	18
8.8	20	5.94	20
8.6	24	5.21	24
8.5	28	4.84	28
8.4	32	4.63	32
	36		36
	40		40

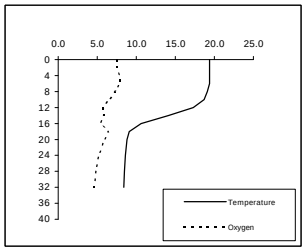


Figure 6gg Site 2 September 5

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
19.5	0	8.10	0
19.6	2	8.66	2
19.6	4	7.98	4
19.6	6	8.13	6
19.6	8	8.45	8
19.6	10	8.41	10
18.2	12	7.43	12
16.8	14	5.96	14
13.6	16	4.98	16
10.4	18	4.91	18
9.1	20	4.91	20
8.9	24	4.45	24
8.6	28	4.51	28
8.5	32	4.34	32
8.4	36	4.20	36
8.4	40	3.99	40
8.4	44	3.92	44
8.3	48	3.99	48
8.3	52	3.96	52

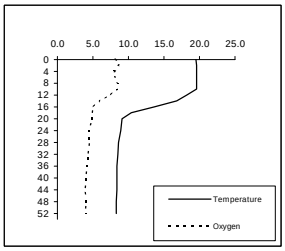


Figure 6hh Site 1 September 12

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
21.1	0	8.61	0
20.1	2	9.11	2
19.5	4	9.84	4
19.1	6	9.94	6
18.8	8	9.62	8
18.6	10	9.31	10
18.4	12	8.85	12
18.1	14	9.49	14
14.7	16	7.99	16
10.6	18	7.35	18
9.5	20	6.01	20
8.9	24	5.75	24
8.6	28	5.63	28
8.5	32	5.23	32
8.4	36	4.65	36
8.4	40	2.48	40
8.5	44	1.46	44

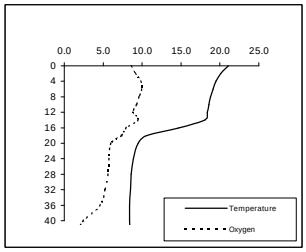


Figure 6ii Site 2 September 12

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
21.2	0	8.35	0
20.5	2	8.22	2
19.4	4	8.81	4
19.3	6	8.91	6
19.0	8	8.77	8
18.9	10	8.74	10
18.5	12	8.30	12
17.5	14	7.48	14
15.1	16	6.45	16
10.0	18	5.90	18
9.3	20	4.95	20
8.8	24	4.94	24
8.6	28	4.82	28
8.5	32	4.52	32
8.5	36	4.36	36
8.4	40	4.21	40
8.4	44	4.19	44
8.3	48	4.09	48
8.3	52	3.93	52

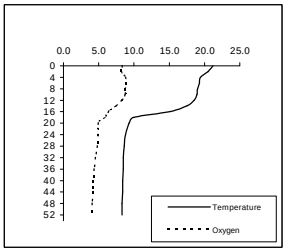


Figure 6jj Site 1 September 20

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
17.7	0	8.86	0
17.9	2	8.26	2
18.0	4	8.37	4
17.9	6	8.31	6
17.9	8	8.22	8
17.1	10	7.81	10
17.3	12	7.48	12
16.8	14	7.50	14
14.6	16	6.89	16
11.9	18	5.61	18
9.9	20	5.16	20
9.2	24	4.91	24
8.9	28	4.71	28
8.7	32	4.65	32
8.5	36	4.34	36
	40		40

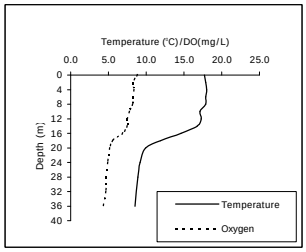


Figure 6kk Site 2 September 20

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
18.1	0	8.24	0
18.1	2	8.44	2
18.1	4	8.31	4
17.9	6	8.28	6
17.8	8	8.25	8
17.7	10	8.24	10
17.9	12	7.85	12
17.5	14	7.86	14
17.4	16	7.06	16
14.1	18	6.75	18
10.9	20	4.73	20
9.3	24	3.76	24
8.9	28	3.29	28
8.8	32	3.20	32
8.7	36	3.01	36
8.8	40	2.61	40
9.0	44	2.29	44
9.1	48	2.20	48
9.0	52	2.33	52

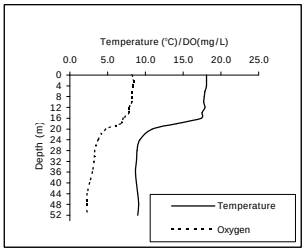


Figure 6ll Site 2 September 26

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
17.4	0	8.98	0
17.4	2	9.17	2
17.4	4	9.33	4
17.3	6	9.17	6
17.3	8	9.09	8
17.3	10	9.23	10
17.3	12	9.29	12
17.2	14	9.16	14
14.8	16	9.03	16
10.2	18	4.47	18
9.5	20	3.86	20
8.9	24	3.79	24
8.7	28	3.74	28
8.7	32	3.33	32
8.6	36	3.41	36
8.6	40	3.11	40
8.6	44	3.01	44
8.7	48	3.12	48
8.6	52		52

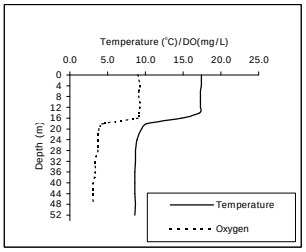


Figure 6mm Site 1 October 1

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
15.9	0	8.58	0
15.8	2	8.55	2
15.8	4	8.45	4
15.8	6	8.43	6
15.8	8	8.39	8
15.8	10	8.39	10
15.8	12	8.37	12
15.8	14	8.32	14
15.7	16	8.23	16
13.1	18	5.95	18
10.0	20	4.15	20
9.1	24	3.23	24
8.9	28	2.79	28
8.7	32	2.58	32
	36		36
	40		40

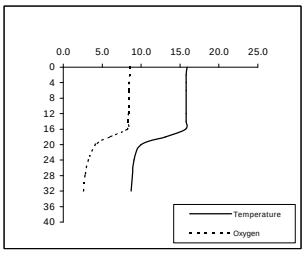


Figure 6nn Site 2 October 1

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
16.1	0	8.58	0
16.0	2	8.59	2
16.0	4	8.79	4
15.9	6	8.93	6
15.9	8	9.13	8
15.9	10	9.19	10
15.9	12	9.26	12
15.9	14	9.07	14
15.3	16	8.36	16
11.8	18	5.36	18
9.9	20	4.21	20
9.2	24	3.78	24
8.9	28	3.45	28
8.7	32	3.25	32
8.7	36	3.12	36
8.6	40	2.86	40
8.6	44	2.76	44
8.6	48	2.73	48
8.5	52	2.65	52

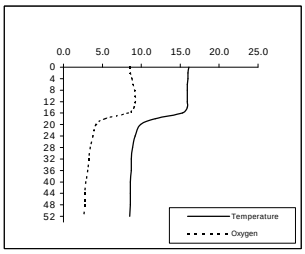


Figure 6oo Site 1 October 3

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
16.0	0	8.56	0
16.1	2	8.94	2
16.0	4	9.10	4
15.7	6	9.23	6
15.7	8	9.12	8
15.6	10	9.11	10
15.6	12	8.97	12
15.5	14	9.06	14
15.3	16	9.17	16
10.5	18	5.11	18
9.4	20	3.87	20
9.1	24	3.26	24
8.8	28	3.17	28
8.7	32	2.84	32
8.4	36	1.26	36
	40		40

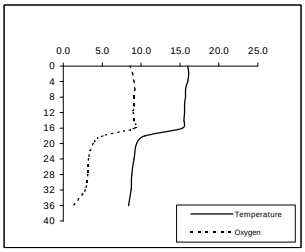


Figure 6pp Site 2 October 3

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
15.6	0	8.6	0
15.7	2	8.7	2
15.7	4	8.9	4
15.7	6	8.9	6
15.7	8	8.6	8
15.6	10	8.6	10
15.6	12	8.6	12
15.4	14	8.7	14
14.9	16	8.6	16
10.4	18	4.3	18
9.5	20	3.3	20
9.0	24	2.9	24
8.8	28	2.5	28
8.7	32	2.3	32
8.7	36	2.2	36
8.6	40	2.1	40
8.6	44	1.99	44
8.6	48	1.95	48
8.5	52	1.93	52

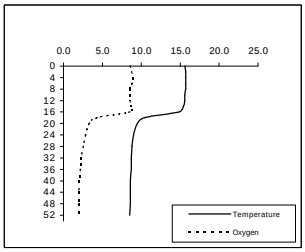


Figure 6qq Site 1 October 12

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
14.7	0	9.08	0
14.6	2	10.30	2
14.6	4	11.02	4
14.4	6	11.29	6
14.3	8	11.37	8
14.3	10	11.08	10
14.3	12	10.86	12
14.2	14	10.88	14
14.1	16	10.56	16
13.8	18	10.06	18
11.8	20	6.23	20
9.2	24	3.73	24
8.8	28	2.64	28
8.7	32	2.46	32
	36		36
	40		40

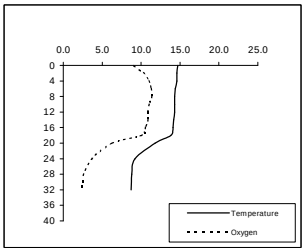


Figure 6rr Site 2 October 12

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
14.7	0	8.65	0
14.7	2	9.17	2
14.7	4	9.60	4
14.6	6	9.68	6
14.5	8	9.68	8
14.5	10	9.41	10
14.5	12	9.43	12
14.5	14	9.49	14
13.8	16	8.16	16
12.5	18	5.45	18
9.8	20	2.91	20
9.3	24	2.63	24
8.9	28	2.28	28
8.8	32	2.19	32
8.7	36	2.15	36
8.6	40	2.02	40
8.6	44	1.99	44
8.6	48	1.88	48
8.6	52	1.76	52

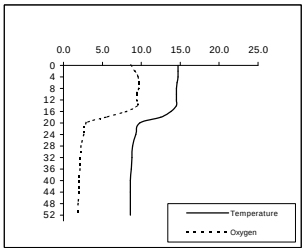


Figure 6ss Site 1 October 17

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
13.5	0	9.90	0
13.6	2	10.14	2
13.6	4	10.24	4
13.6	6	10.32	6
13.5	8	9.95	8
13.5	10	9.98	10
13.4	12	10.34	12
13.4	14	10.26	14
13.3	16	10.34	16
13.1	18	10.63	18
10.2	20	2.82	20
9.0	24	2.23	24
8.8	28	2.18	28
8.7	32	2.07	32
	36		36
	40		40

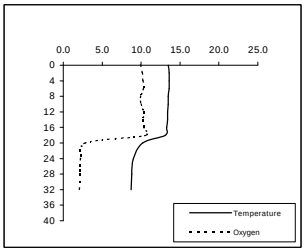


Figure 6tt Site 2 October 17

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
13.5	0	9.98	0
13.7	2	10.26	2
13.7	4	10.49	4
13.7	6	10.64	6
13.7	8	10.67	8
13.7	10	10.62	10
13.7	12	10.61	12
13.6	14	10.11	14
13.5	16	10.10	16
13.1	18	9.19	18
12.1	20	6.66	20
9.4	24	3.17	24
9.0	28	2.18	28
8.9	32	1.98	32
8.8	36	1.82	36
8.7	40	1.69	40
8.7	44	1.51	44
8.6	48	1.39	48
8.6	52	1.39	52

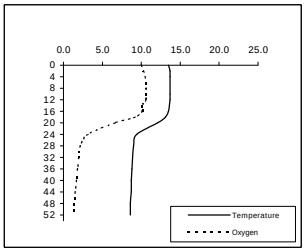


Figure 6uu Site 1 October 23

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
12.6	0	8.64	0
12.9	2	8.68	2
12.9	4	8.69	4
12.9	6	8.71	6
12.9	8	8.64	8
12.9	10	9.63	10
12.8	12	8.63	12
12.8	14	8.62	14
12.7	16	8.67	16
12.6	18	8.49	18
12.5	20	8.42	20
9.4	24	2.66	24
9.0	28	1.81	28
8.8	32	1.42	32
8.7	36	1.24	36
8.5	40	0.71	40
8.4	44	0.63	44

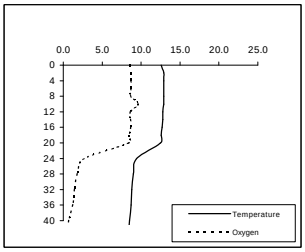


Figure 6vv Site 2 October 23

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
12.7	0	8.91	0
13.0	2	8.77	2
13.0	4	8.77	4
13.0	6	8.81	6
13.0	8	8.73	8
13.0	10	8.68	10
12.9	12	8.57	12
12.7	14	8.55	14
12.9	16	8.30	16
12.6	18	8.38	18
10.0	20	8.46	20
9.1	24	2.44	24
9.0	28	1.87	28
8.9	32	1.60	32
8.8	36	1.43	36
8.7	40	1.26	40
8.7	44	1.17	44
8.7	48	1.10	48
8.7	52	1.04	52

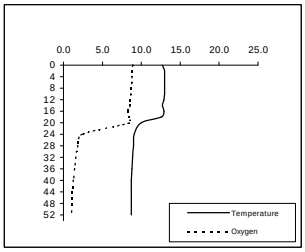


Figure 6ww Site 1 October 29

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
10.7	0	14.93	0
11.0	2	14.74	2
11.1	4	14.73	4
11.1	6	14.72	6
11.2	8	14.73	8
11.2	10	14.72	10
11.2	12	14.60	12
10.3	14	8.34	14
10.0	17	6.32	17
9.3	19	4.03	19
8.9	21	2.87	21
8.8	23	2.47	23
8.8	25	2.34	25
8.7	27	2.27	27
8.7	29	2.25	29

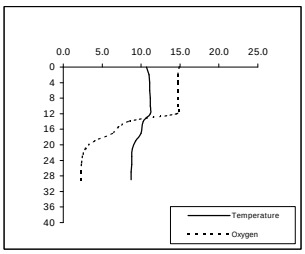


Figure 6xx Site 2 October 29

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
11.3	0	15.20	0
11.3	2	15.19	2
11.3	4	15.22	4
11.3	6	15.23	6
11.3	8	15.13	8
11.3	10	15.46	10
11.3	12	15.22	12
11.3	14	14.01	14
10.2	17	7.10	17
9.2	19	4.63	19
9.2	21	3.35	21
9.0	23	3.05	23
9.0	25	2.56	25
8.8	27	2.45	27
8.8	29	2.32	29

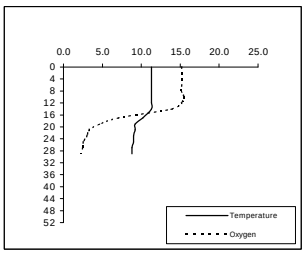


Figure 6yy Site 1 November 12

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
9.2	0	10.11	0
9.2	2	9.41	2
9.2	4	9.21	4
9.2	6	9.22	6
9.2	8	9.24	8
9.2	10	9.22	10
9.3	12	9.32	12
9.3	14	9.31	14
9.3	16	9.29	16
9.3	18	9.28	18
9.3	20	9.26	20
9.3	24	9.31	24
9.2	28	9.43	28
9.3	32	9.54	32
9.2	36	9.54	36
9.2	40	9.59	40

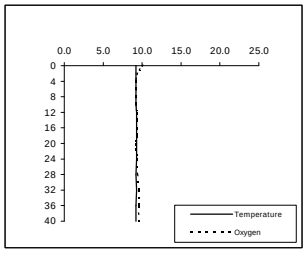


Figure 6zz Site 2 November 12

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
9.3	0	9.72	0
9.3	2	9.14	2
9.3	4	9.01	4
9.3	6	9.01	6
9.3	8	8.79	8
9.3	10	8.81	10
9.3	12	8.90	12
9.3	14	8.87	14
9.3	16	8.84	16
9.3	18	8.84	18
9.3	20	8.82	20
9.3	24	8.74	24
9.3	28	8.61	28
9.2	32	8.15	32
9.1	36	5.01	36
9.0	40	3.27	40
8.9	44	1.46	44
8.8	48	0.71	48
8.8	52	0.57	52

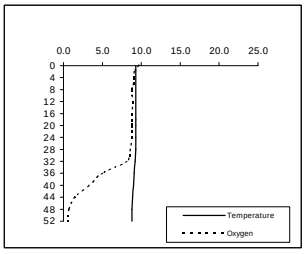


Figure 6aaa Site 1 November 25

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
7.9	0	10.69	0
8.1	2	9.78	2
8.1	4	9.76	4
8.1	6	9.62	6
8.1	8	9.60	8
8.1	10	9.56	10
8.1	12	9.53	12
8.1	14	9.49	14
8.1	16	9.49	16
8.1	18	9.49	18
8.1	20	9.47	20
8.1	24	9.46	24
8.1	28	9.54	28
8.0	32	9.61	32
7.8	36	9.62	36
	40		40

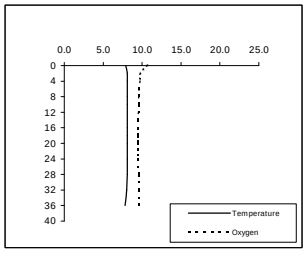


Figure 6bbb Site 2 November 25

Temperature		Oxygen	
Temp	Depth	Oxyger	Depth
7.4	0	7.53	0
8.1	2	7.16	2
8.2	4	7.09	4
8.3	6	6.99	6
8.3	8	6.95	8
8.3	10	6.92	10
8.3	12	6.89	12
8.3	14	6.91	14
8.3	16	6.90	16
8.3	18	6.90	18
8.3	20	6.88	20
8.3	24	6.87	24
8.3	28	6.70	28
8.3	32	6.70	32
8.3	36	6.78	36
8.3	40	6.82	40
8.3	44	6.81	44
8.3	48	6.81	48
8.3	52	6.81	52

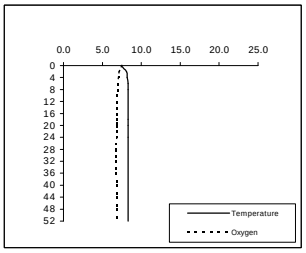


Figure 7: Zones of Tolerance for *Oncorhynchus nerka* in Skaha and Osoyoos Lakes

Figure 7a Skaha Lake Site 2 Gillies

Temp (17 ^{0}C)		DO (4 mg/L)	
Month	Depth	Month	Depth
J		J	
F		F	
M		M	
A 10	0	A 10	53
A 25	0	A 25	53
M 8	0	M 8	53
M 23	0	M 23	53
M 28	0	M 28	53
Jn 7	0	Jn 7	53
Jn 11	0	Jn 11	53
Jn 19	0	Jn 19	53
Jn 27	10	Jn 27	53
Jl 10	10	Jl 10	53
Jl 17	10	Jl 17	53
Jl 23	10	Jl 23	53
A 9	14	A 9	53
A18	14	A 18	53
A 21	12	A 21	53
A 30	14	A 30	53
S 3	12	S 3	53
S 5	14	S 5	53
S 12	14	S12	44
S 22	14	S 22	53
S 27	0	S 27	53
O 1	0	O 1	53
O 3	0	O 3	53
O 17	0	O 17	53
O 31	0	O 31	53
N 12	0	N 12	53
N 27	0	N 27	53
D		D	

*max depth, assume ≥ 4mg/L

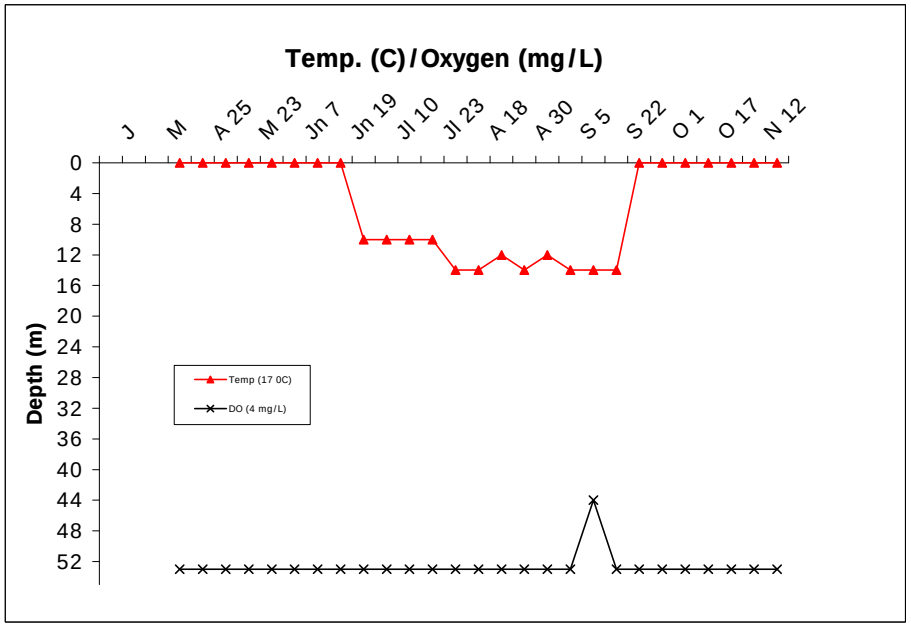


Figure 7b Skaha Lake Site 3 South Basin

Temp (17 ^{0}C)		DO (4 mg/L)	
Month	Depth	Month	Depth
J		J	
F		F	
M		M	
A 10	0	A 10	37
A 25	0	A 25	37
M 9	0	M 9	37
M 23	0	M 23	37
Jn 7	0	Jn 7	37
Jn 11	0	Jn 11	37
Jn 19	8	Jn 19	37
Jl 10	10	Jl 10	37
Jl 23	8	Jl 23	37
A 9	12	A 9	37
A 18	12	A 18	37
A 21	14	A 21	37
A 30	14	A 30	37
S 5	12	S 5	37
S 22	18	S 22	37
O 1	0	O 1	37
O 3	0	O 3	37
O 17	0	O 17	37
O 31	0	O 31	37
N 12	0	N 12	37
N 27	0	N 27	37
D		D	

*max depth, assume ≥ 4mg/L

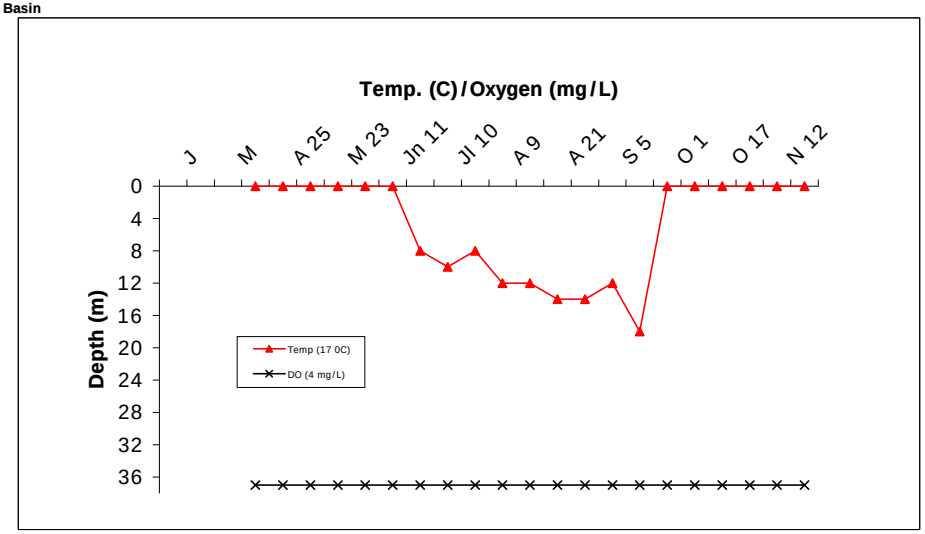
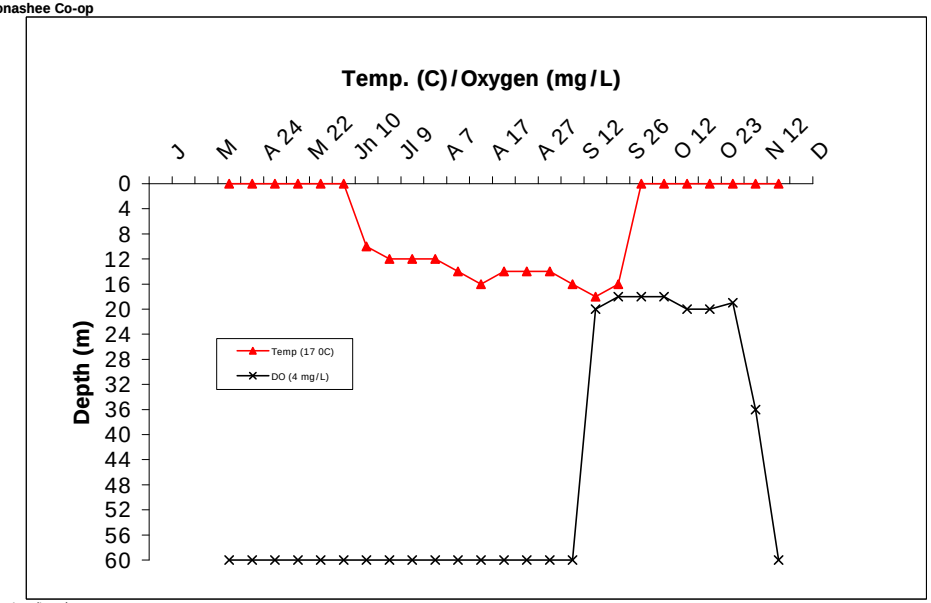


Figure 7c Osoyoos Lake Site 2 Monashee Co-op

Temp (17 ^{0}C)		DO (4 mg/L)		
Month	Depth	Month	Depth	
J		J		
F		F		
M		M		
A 10	0	A 10	60	
A 24	0	A 24	60	
M 8	0	M 8	60	
M 22	0	M 22	60	
Jn 6	0	Jn 6	60	
Jn 10	0	Jn 10	60	
Jn 18	10	Jn 18	60	
Jl 9	12	Jl 9	60	
Jl 22	12	Jl 22	60	
A 7	12	A 7	60	
A 8	14	A 8	60	
A 17	16	A 17	60	
A 19	14	A 19	60	
A 27	14	A 27	60	*
S 5	14	S 5	60	
S 12	16	S 12	60	
S 20	18	S 20	20	
S 26	16	S 26	18	
O 3	0	O 3	18	
O 12	0	O 12	18	
O 17	0	O 17	20	
O 23	0	O 23	20	
O 29	0	O 29	19	
N 12	0	N 12	36	
N 25	0	N 25	60	
D		D		



*measured only to 24m assume above 4mg/L to bottom

Figure 7d Osoyoos Lake Site 1 North Basin

Temp (17 ^{0}C)		DO (4 mg/L)		
Month	Depth	Month	Depth	
J		J		
F		F		
M		M		
A 10	0	A 10	37	
A 24	0	A 24	37	
M 8	0	M 8	37	*
M 22	0	M 22	37	
Jn 6	0	Jn 6	37	
Jn 10	0	Jn 10	37	
Jn 18	2	Jn 18	37	
Jl 9	12	Jl 9	37	
Jl 22	12	Jl 22	37	
A 7	14	A 7	37	
A 8	14	A 8	32	
A 17	14	A 17	32	
A 27	14	A 27	37	
S 3	14	S 3	37	
S 5	14	S 5	37	
S 12	16	S 12	36	
S 20	14	S 20	36	
O 1	0	O 1	20	
O 3	0	O 3	18	
O 12	0	O 12	20	
O 17	0	O 17	18	
O 23	0	O 23	20	
O 29	0	O 29	19	
N 12	0	N 12	37	
N 25	0	N 25	37	
D		D		

*assumed

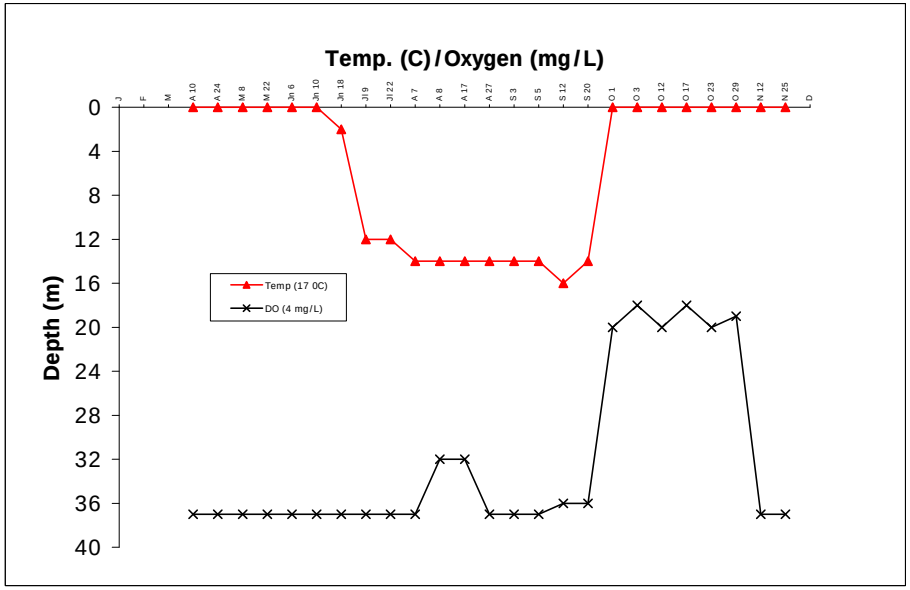


Figure 8a: Total Nitrogen Levels at 0 to 10m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.18	0.19
	M	0.20	0.19
	J	0.21	0.20
	J	0.28	0.25
	A	0.21	0.21
	S	0.19	0.20
	O	0.34	0.07
	N	0.19	0.20
	D		
	Average	0.23	0.19

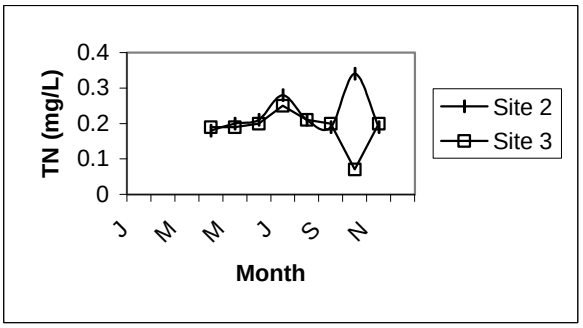


Figure 8b: Total Nitrogen Levels at 20m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.19	0.19
	M	0.20	0.19
	J	0.24	0.18
	J	0.20	0.19
	A	0.20	0.19
	S	0.19	0.19
	O	0.15	0.07
	N	0.19	0.21
	D		
	Average	0.20	0.18

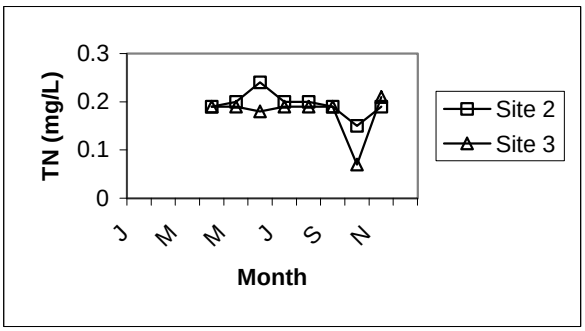


Figure 8c: Total Nitrogen Levels at Deep Sections for Skaha Lake

	Depth	45m	36m
Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.18	0.18
	M	0.18	0.22
	J	0.17	0.18
	J	0.26	0.17
	A	0.17	0.19
	S	0.17	0.20
	O	0.08	0.12
	N	0.20	0.25
	D		
	Average	0.18	0.19

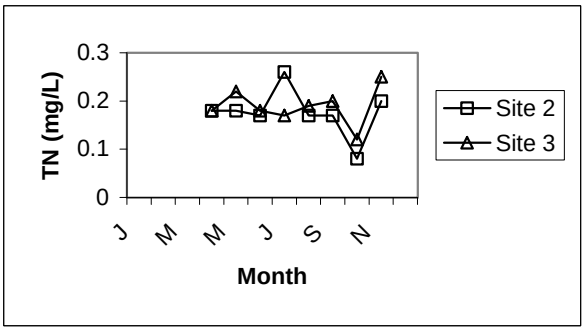


Figure 8d: Total Nitrogen Levels at 0 - 10 m for Osoyoos Lake

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.22	0.22
	M	0.24	0.24
	J	0.24	0.23
	J	0.38	0.21
	A	0.22	0.23
	S	0.25	0.28
	O	0.36	0.13
	N	0.25	0.24
	D		
	Average	0.27	0.22

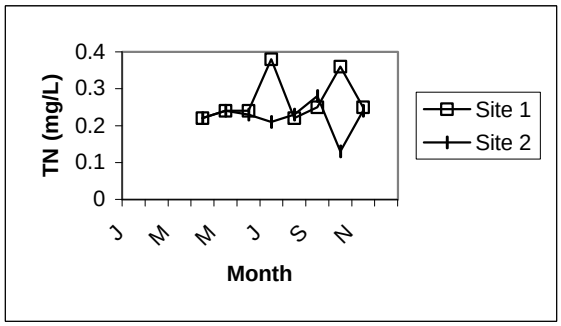


Figure 8e: Total Nitrogen Levels at 20 m for Osoyoos Lake

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.21	0.21
	M	0.21	0.20
	J	0.22	0.22
	J	0.19	0.28
	A	0.22	0.20
	S	0.20	0.19
	O	0.20	0.18
	N	0.25	0.25
	D		
	Average	0.21	0.22

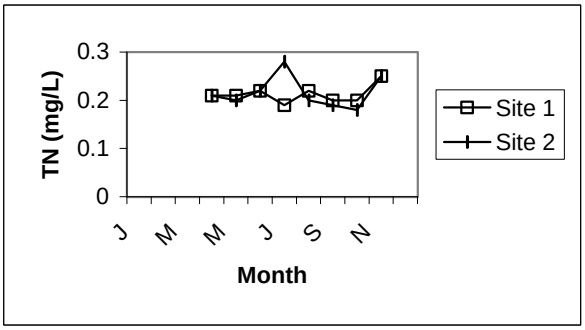


Figure 8f: Total Nitrogen Levels at Deep Sections for Osoyoos Lake

	Depth	32m	45m
Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.19	0.21
24m	M	0.21	0.20
	J	0.21	0.21
	J	0.20	0.21
	A	0.22	0.25
	S	0.25	0.30
	O	0.26	0.30
	N	0.24	0.31
	D		
	Average	0.22	0.25

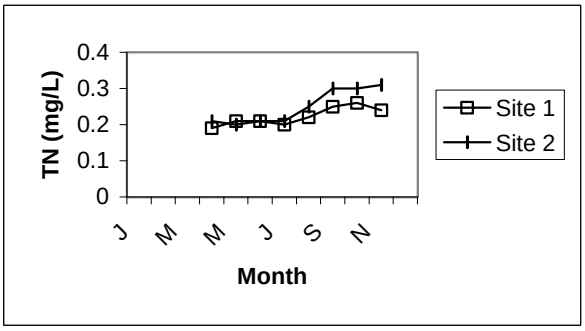


Figure 9a: Nitrate-Nitrogen levels at 0-10m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.002	0.002
	M	0.002	0.002
	J	0.005	0.005
	J	0.002	0.002
	A	0.005	0.004
	S	0.002	0.002
	O	0.002	0.002
	N	0.002	0.002
	D		
	Average	0.003	0.003

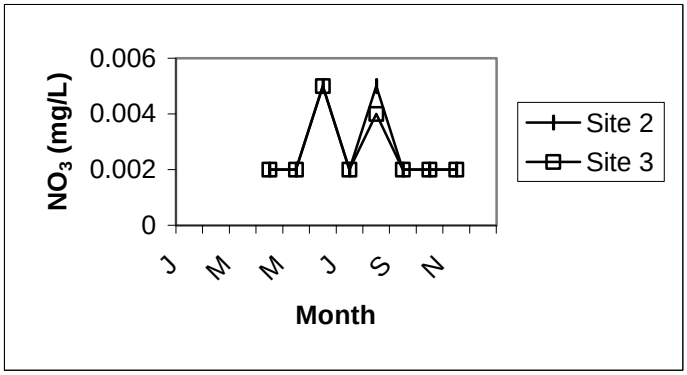


Figure 9b: Nitrate-Nitrogen Levels at 20m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.002	0.002
	M	0.002	0.002
	J	0.005	0.004
	J	0.002	0.002
	A	0.005	0.006
	S	0.002	0.008
	O	0.002	0.002
	N	0.003	0.004
	D		
	Average	0.003	0.004

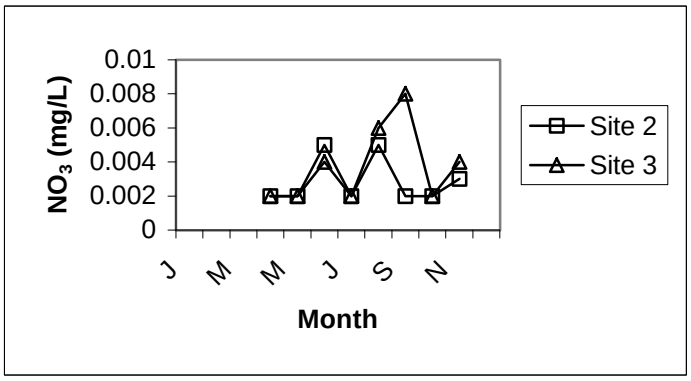


Figure 9c: Nitrate-Nitrogen Levels at Deep Sections for Skaha Lake

	Depth	45m	36m
Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.002	0.002
	M	0.002	0.002
	J	0.007	0.013
	J	0.002	0.002
	A	0.005	0.005
	S	0.004	0.024
	O	0.002	0.034
	N	0.003	0.003
	D		
	Average	0.003	0.011

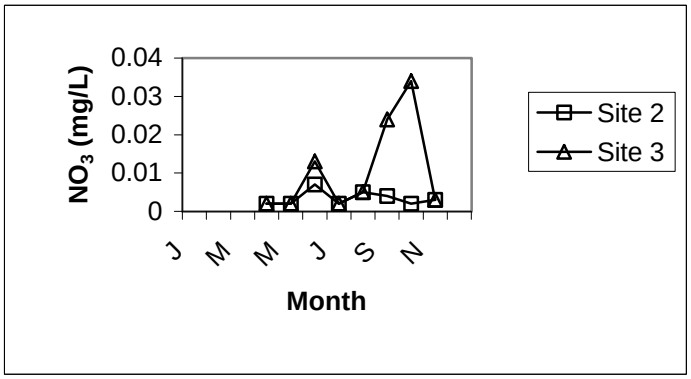


Figure 9d: Nitrate-Nitrogen Levels at 0 - 10 m for Osoyoos Lake

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.002	0.002
	M	0.002	0.002
	J	0.003	0.007
	J	0.002	0.002
	A	0.003	0.003
	S	0.005	0.002
	O	0.002	0.002
	N	0.010	0.016
	D		
	Average	0.004	0.005

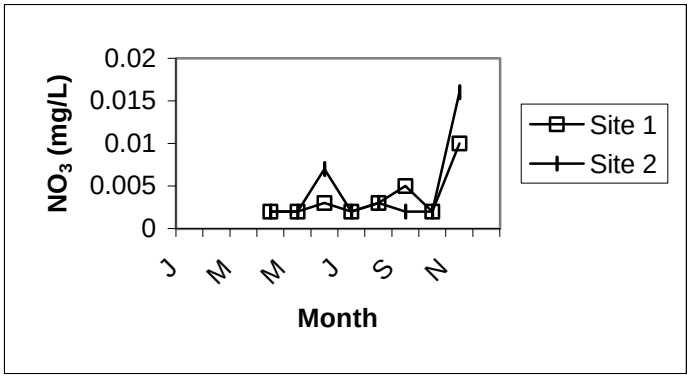


Figure 9e: Nitrate-Nitrogen Levels at 20 m for Osoyoos Lake

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.002	0.002
	M	0.002	0.002
	J	0.002	0.003
	J	0.002	0.002
	A	0.004	0.003
	S	0.002	0.002
	O	0.066	0.065
	N	0.009	0.015
	D		
	Average	0.011	0.012

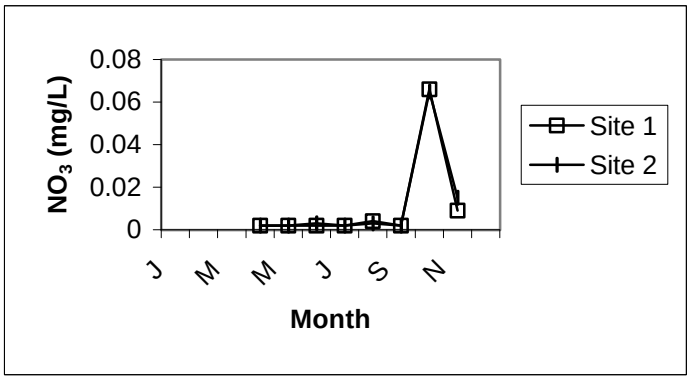


Figure 9f: Nitrate-Nitrogen Levels at Deep Sections for Osoyoos Lake

	Depth	32m	45m
Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.002	0.002
24m	M	0.002	0.003
	J	0.006	0.002
	J	0.002	0.006
	A	0.002	0.002
	S	0.009	0.044
	O	0.111	0.121
	N	0.002	0.094
	D		
	Average	0.017	0.034

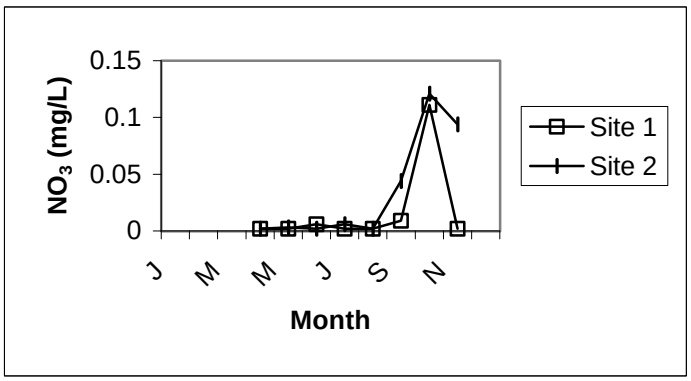


Figure 10a: Total Phosphorous Levels at 0 to 10m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.005	0.011
	M	0.007	0.009
	J	0.010	0.016
	J	0.005	0.005
	A	0.008	0.007
	S	0.010	0.005
	O	0.005	0.007
	N	0.010	0.006
	D		
	Average	0.008	0.008

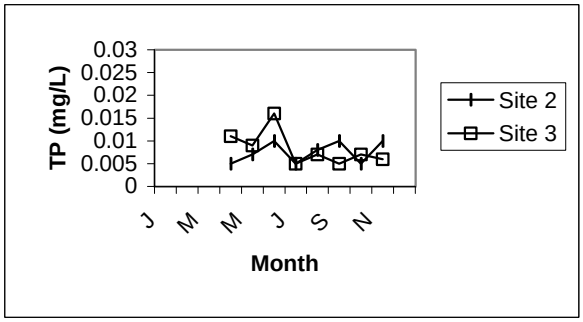


Figure 10b: Total Phosphorous Levels at 20m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.015	0.009
	M	0.005	0.009
	J	0.010	0.009
	J	0.005	0.004
	A	0.014	0.007
	S	0.009	0.008
	O	0.006	0.005
	N	0.008	0.012
	D		
	Average	0.009	0.008

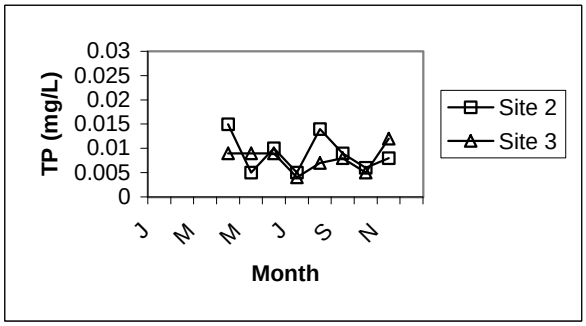


Figure 10c: Total Phosphorous Levels at Deep Sections for Skaha Lake

	Depth	45m	36m
Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.005	0.006
	M	0.005	0.009
	J	0.006	0.009
	J	0.003	0.006
	A	0.007	0.010
	S	0.004	0.012
	O	0.006	0.015
	N	0.008	0.012
	D		
	Average	0.006	0.010

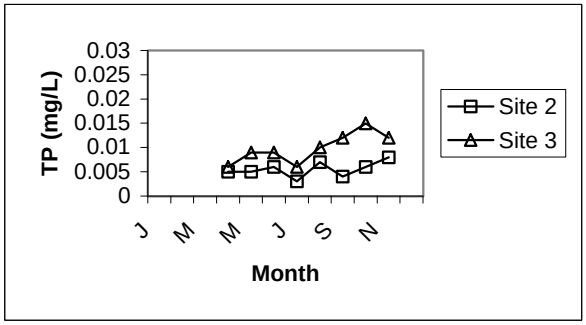


Figure 10d: Total Phosphorous Levels at 0 - 10 m for Osoyoos Lake

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.009	0.008
	M	0.015	0.007
	J	0.018	0.013
	J	0.020	0.017
	A	0.013	0.012
	S	0.010	0.008
	O	0.016	0.006
	N	0.023	0.019
	D		
	Average	0.016	0.011

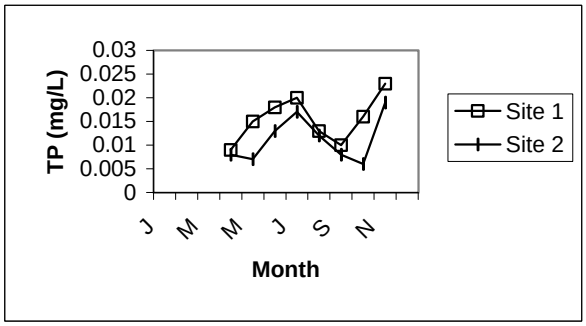


Figure 10e: Total Phosphorous Levels at 20 m for Osoyoos Lake

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.012	0.009
	M	0.008	0.007
	J	0.012	0.010
	J	0.004	0.014
	A	0.010	0.009
	S	0.009	0.005
	O	0.011	0.013
	N	0.022	0.019
	D		
	Average	0.011	0.011

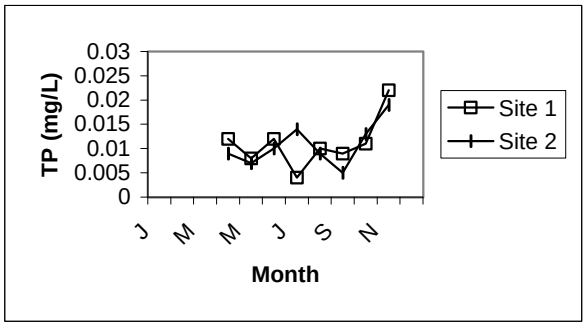


Figure 10f: Total Phosphorous Levels at Deep Sections for Osoyoos Lake

	Depth	32m	45m
Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.007	0.009
24m	M	0.012	0.012
	J	0.009	0.009
	J	0.005	0.019
	A	0.019	0.021
	S	0.012	0.026
	O	0.022	0.032
	N	0.018	0.034
	D		
	Average	0.013	0.020

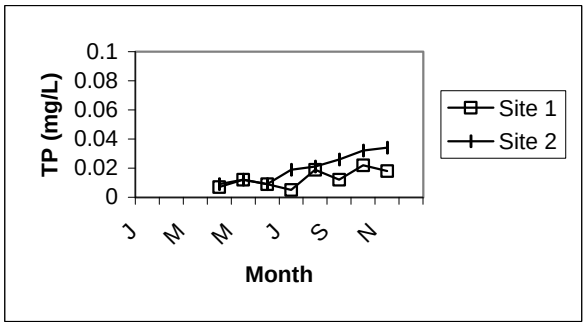


Figure 11a: Total Dissolved Phosphorous Levels at 0 to 10m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.006	0.003
	M	0.006	0.004
	J	0.007	0.009
	J	0.004	0.007
	A	0.010	0.005
	S	0.007	0.004
	O	0.009	0.011
	N	0.004	0.003
	D		
	Average	0.007	0.006

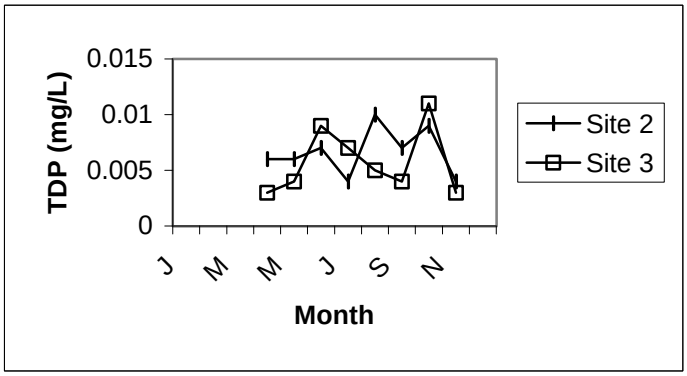


Figure 11b: Total Dissolved Phosphorous Levels at 20m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.002	0.005
	M	0.005	0.004
	J	0.006	0.006
	J	0.005	0.003
	A	0.004	0.007
	S	0.005	0.004
	O	0.007	0.007
	N	0.005	0.007
	D		
	Average	0.005	0.005

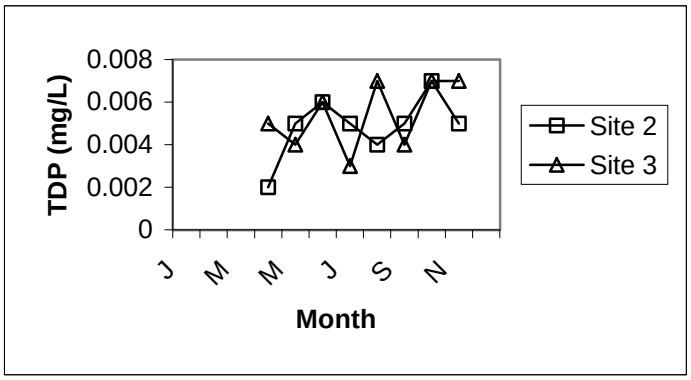


Figure 11c: Total Dissolved Phosphorous Levels at Deep Sections for Skaha

	Depth	45m	36m
Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	0.002	0.004
	M	0.003	0.004
	J	0.006	0.005
	J	0.003	0.003
	A	0.005	0.006
	S	0.003	0.007
	O	0.008	0.005
	N	0.005	0.008
	D		
	Average	0.004	0.005

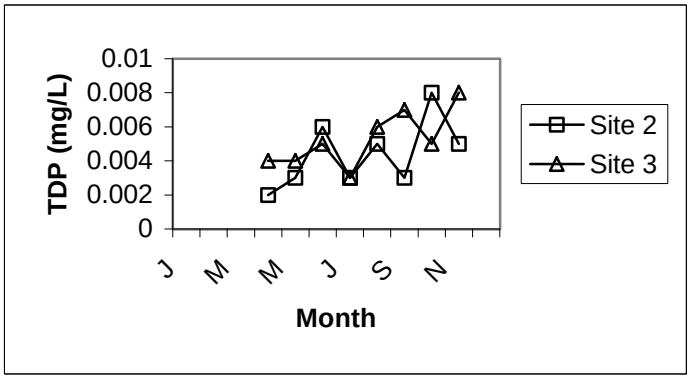


Figure 11d: Total Dissolved Phosphorous Levels at 0 - 10 m for Osoyoos Lak

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.008	0.004
	M	0.008	0.006
	J	0.011	0.005
	J	0.012	0.003
	A	0.007	0.007
	S	0.007	0.004
	O	0.010	0.005
	N	0.012	0.010
	D		
	Average	0.009	0.006

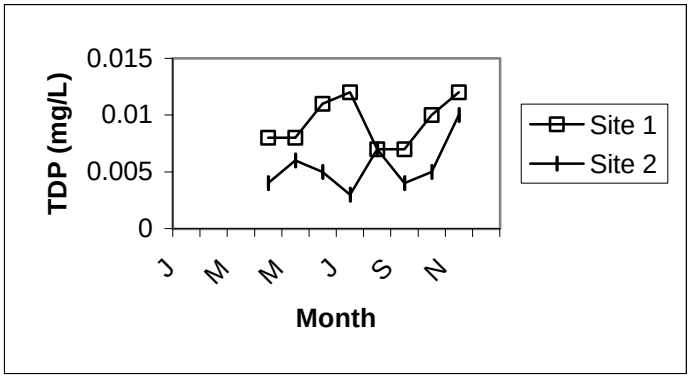


Figure 11e: Total Dissolved Phosphorous Levels at 20 m for Osoyoos Lake

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.003	0.002
	M	0.008	0.005
	J	0.007	0.008
	J	0.003	0.005
	A	0.011	0.005
	S	0.005	0.003
	O	0.005	0.007
	N	0.012	0.010
	D		
	Average	0.007	0.006

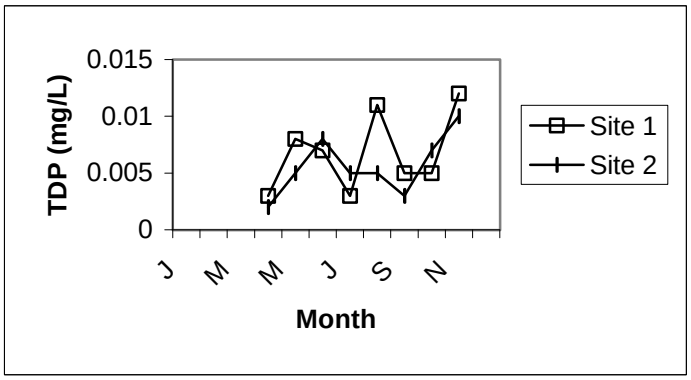


Figure 11f: Total Dissolved Phosphorous Levels at Deep Sections for Osoyo

	Depth	32m	45m
Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	0.004	0.004
	M	0.007	0.005
	J	0.002	0.004
	J	0.005	0.009
	A	0.005	0.011
	S	0.008	0.022
	O	0.011	0.024
	N	0.013	0.028
	D		
	Average	0.007	0.013

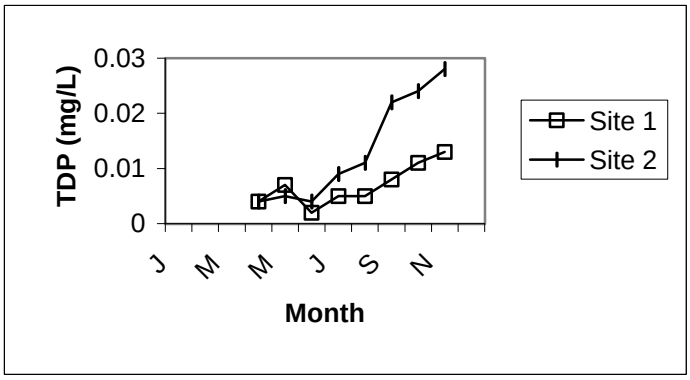
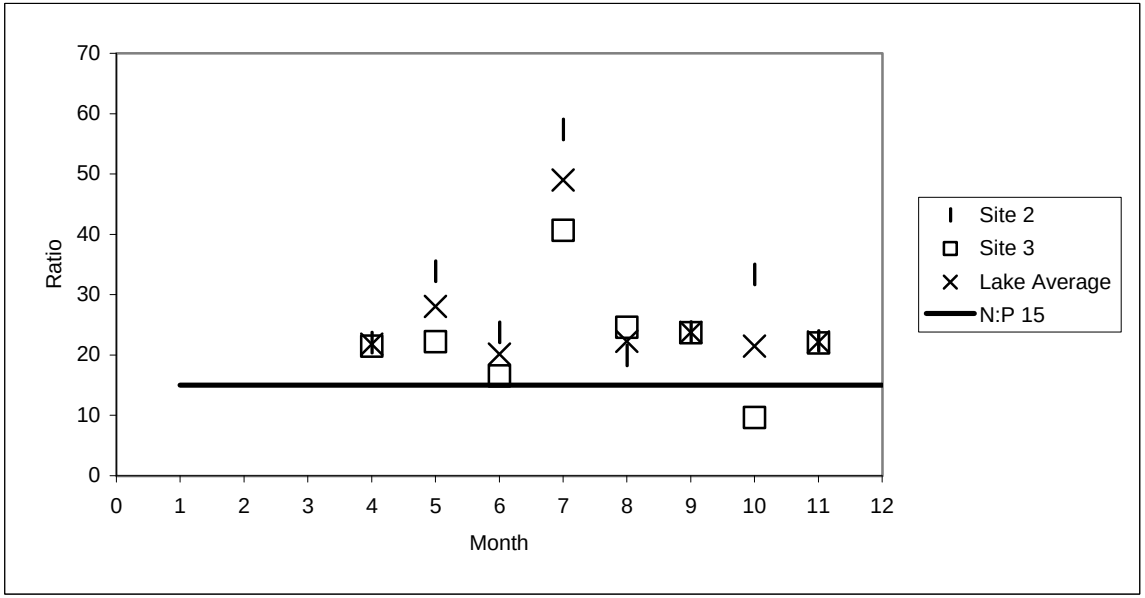
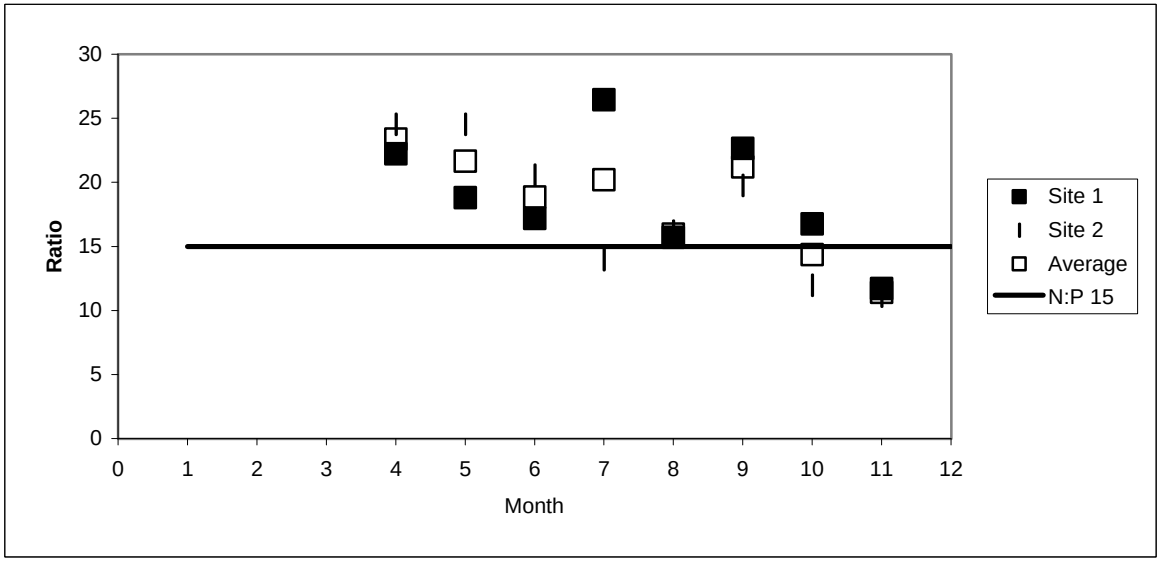


Figure 12a: Total Nitrogen:Total Phosphorous Ratio for Skaha Lake



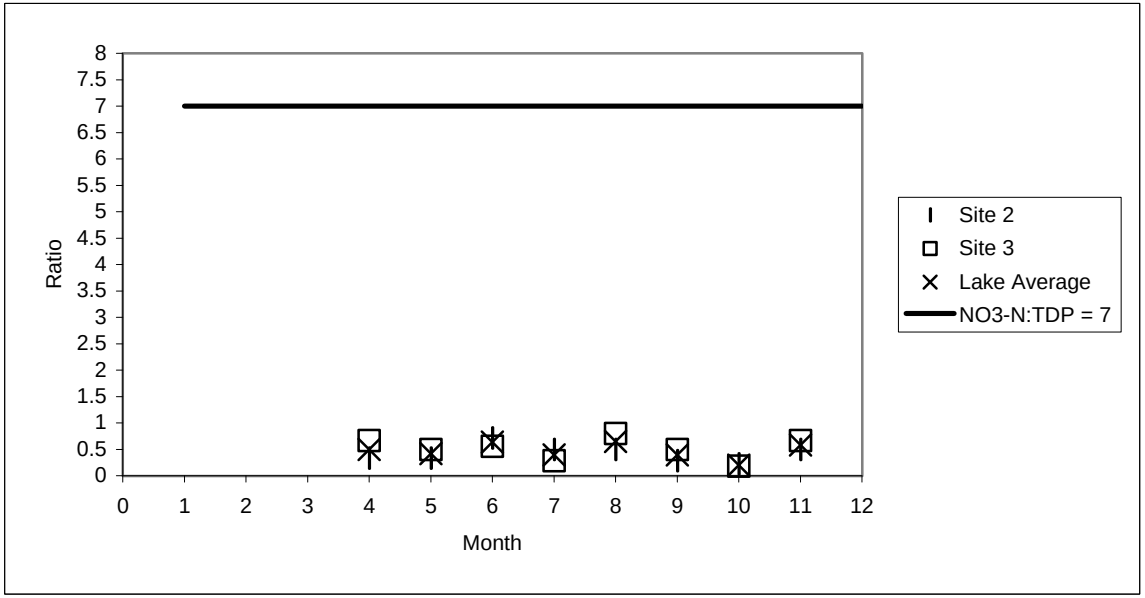
Year		TN:TP		
2002	Month	Site 2	Site 3	Lake Average
January	1			
February	2			
March	3			
April	4	22.1	21.5	21.8
May	5	33.9	22.2	28.1
June	6	23.8	16.5	20.1
July	7	57.4	40.7	49.0
August	8	19.9	24.6	22.3
September	9	23.8	23.7	23.8
October	10	33.3	9.6	21.5
November	11	22.3	22.0	22.2
December	12			

Figure 12b: Total Nitrogen:Total Phosphorous Ratio for Osoyoos Lake



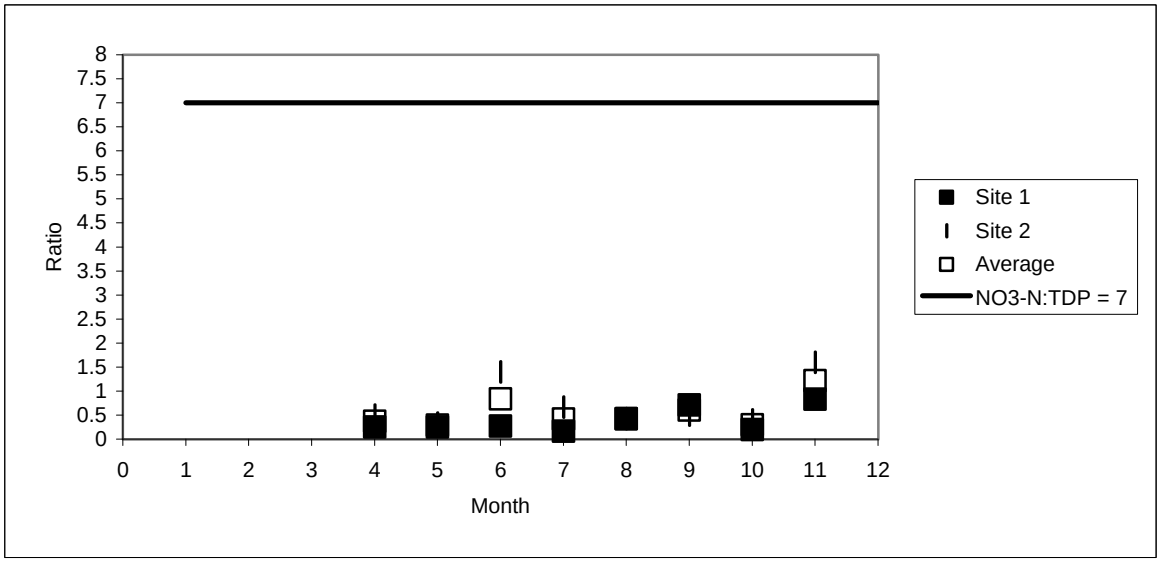
Year 2002	Month	Site 1	Site 2	Average
January	1			
February	2			
March	3			
April	4	22.2	24.5	23.4
May	5	18.8	24.5	21.7
June	6	17.2	20.6	18.9
July	7	26.5	14.0	20.2
August	8	15.7	16.2	16.0
September	9	22.7	19.7	21.2
October	10	16.8	12.0	14.4
November	11	11.7	11.1	11.4
December	12			

Figure 13a: N03/TDP ratio at 0 to 10m for Skaha Lake



Year		N03:TDP		
2002	Month	Site 2	Site 3	Lake Average
January	1			
February	2			
March	3			
April	4	0.33	0.67	0.50
May	5	0.33	0.50	0.42
June	6	0.71	0.56	0.63
July	7	0.50	0.29	0.39
August	8	0.50	0.80	0.65
September	9	0.29	0.50	0.39
October	10	0.22	0.18	0.20
November	11	0.50	0.67	0.58
December	12			

Figure 13b: N03/TDP ratio at 0 to 10m for Osoyoos Lake



Year 2001	Month	Site 1	Site 2	Average
January	1			
February	2			
March	3			
April	4	0.25	0.50	0.38
May	5	0.25	0.33	0.29
June	6	0.27	1.40	0.84
July	7	0.17	0.67	0.42
August	8	0.43	0.43	0.43
September	9	0.71	0.50	0.61
October	10	0.20	0.40	0.30
November	11	0.83	1.60	1.22
December	12			

Figure 14a: Chlorophyll a levels at 0-10m for Skaha Lake

	Month	Site 2	Site 3
###	J		
	F		
	M		
	A	4.50	2.70
	M	2.40	2.10
	J	3.10	3.50
	J	3.40	3.20
	A*		
	S	3.00	2.50
	O	4.30	3.60
	N	3.20	3.30
	D		
	AVERAGE	3.41	2.99

*Samples lost

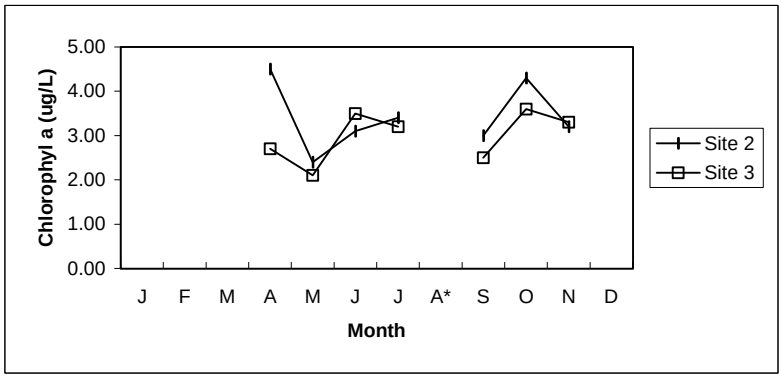


Figure 14b: Chlorophyll a levels at 0-10m for Osoyoos Lake

	Month	Site 1	Site 2
###	F		
	M		
	A	5.50	5.00
	M	3.20	3.60
	J	2.90	4.00
	J	2.60	3.50
	A*		
	S	4.60	6.80
	O	5.30	6.30
	N	7.50	7.40
	D		
	AVERAGE	4.51	5.23

*samples lost

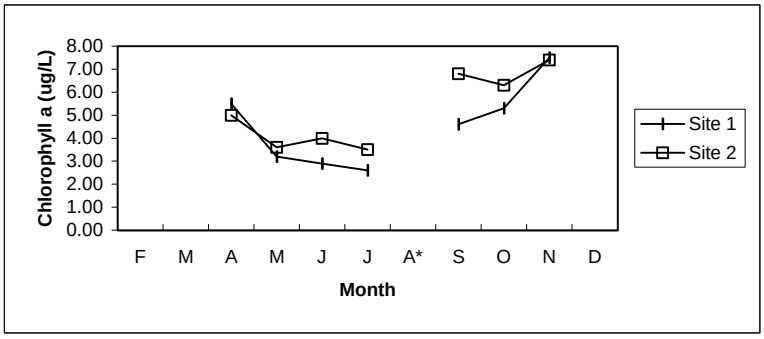


Figure 15a: Silica Levels at 0 to 10m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	3.2	3.1
	M	4.0	3.7
	J	5.5	5.4
	J	5.7	5.6
	A	6.4	6.3
	S	5.9	5.9
	O	5.9	5.8
	N	5.3	5.2
	D		

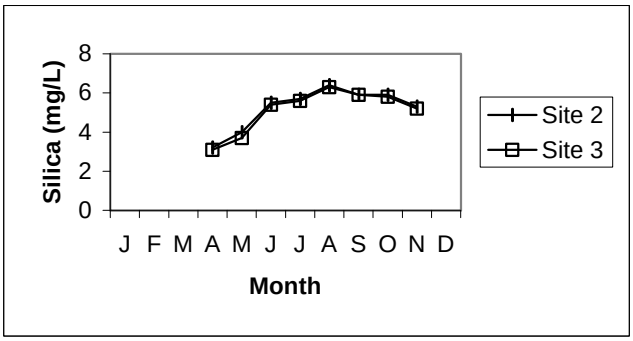


Figure 15b: Silica Levels at 20m for Skaha Lake

Year	Month	Site 2	Site 3
2002	J		
	F		
	M		
	A	3.2	3.0
	M	3.8	3.6
	J	5.2	4.4
	J	5.7	4.8
	A	5.3	5.3
	S	4.9	5.1
	O	4.7	5.1
	N	5.3	5.2
	D		

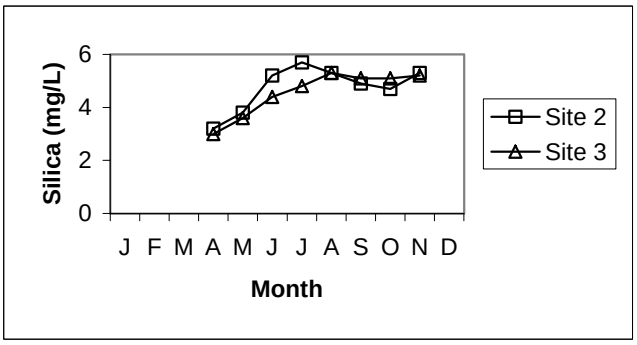


Figure 15c: Silica Levels at Deep Sections for Skaha Lake

	Depth	45m	36m
Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	3.2	3.1
	M	3.6	3.6
	J	3.8	4.2
	J	3.8	4.3
	A	4.6	5.3
	S	4.8	5.2
	O	4.7	5.7
	N	5.2	5.3
	D		

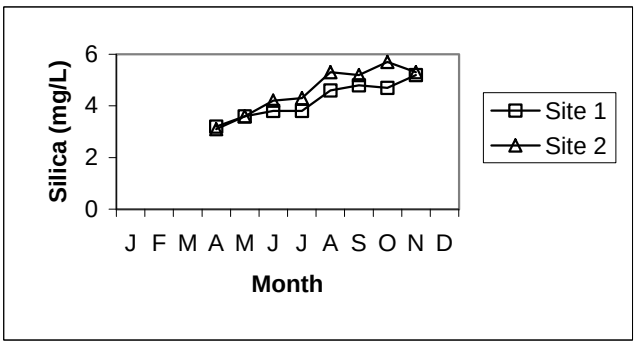


Figure 15d: Silica Levels at 0 - 10 m for Osoyoos Lake

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	2.4	1.5
	M	3.4	3.0
	J	5.4	5.4
	J	5.6	5.4
	A	5.9	5.8
	S	6.1	5.9
	O	6.2	6.1
	N	6.5	6.6
	D		

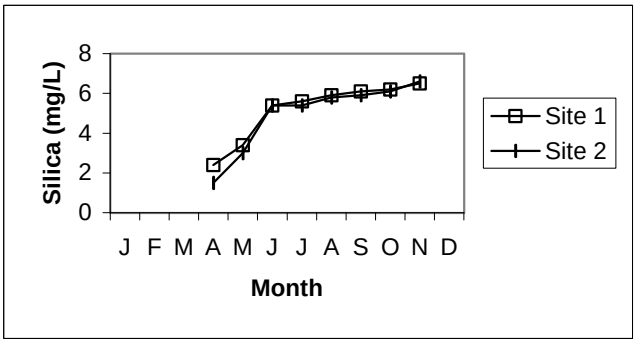


Figure 15e: Silica Levels at 20 m for Osoyoos Lake

Year	Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	1.7	1.5
	M	2.8	2.3
	J	5.1	5.3
	J	4.9	4.6
	A	4.6	5.0
	S	5.5	5.3
	O	5.8	6.4
	N	6.6	6.6
	D		

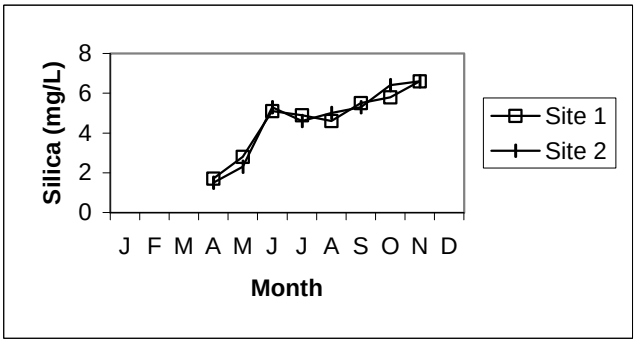
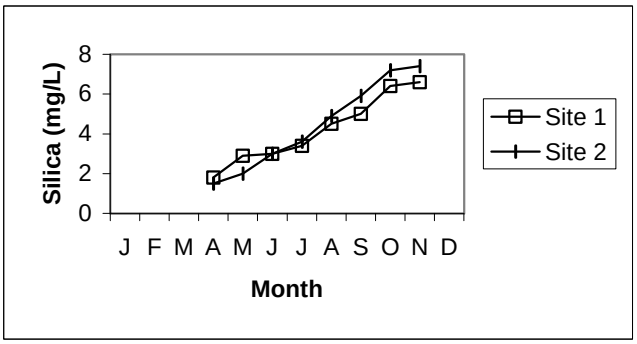


Figure 15f: Silica Levels at Deep Sections for Osoyoos Lake

Year	Depth Month	Site 1	Site 2
2002	J		
	F		
	M		
	A	1.8	1.5
	M	2.9	2.0
	J	3.0	3.0
	J	3.4	3.6
	A	4.5	4.9
	S	5.0	5.9
	O	6.4	7.2
	N	6.6	7.4
	D		



FINAL

OBJECTIVE 2 TASK C
Historical habitat of salmon of the Okanagan River

Contribution No. *7* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Author: Adrienne Vedan

Reviewed by : Chris Bull, R.P. Bio

Edited by: Howard Smith

1.0 INTRODUCTION

The Okanagan River is known to support: sockeye, chinook, and steelhead and there is historical accounts of possibly coho, chum and pink (Vedan 2002). Objective 2 of the re-introduction of sockeye salmon into Skaha Lake examines the historical habitat of salmon of the Okanagan River in order to provide a framework for restoration work. In order to sustain salmonids along with other fish species, the habitat needed to include areas where there were waters of suitable depth and velocity along with trees and shrubs along the banks to provide nutrients or stability. The following excerpts are from observations and comments on the historical habitat of the Okanagan River.

2.0 SOURCES

The following search areas were utilized:

- Okanagan Nation Fisheries Commission
- Okanagan University College
- University of British Columbia
- Oliver and District Archives
- South Okanagan Similkameen Conservation Program
- British Columbia Archives
- Internet

3.0 HISTORICAL PHOTO DOCUMENTATION

The following photographs show features of the Okanagan River before modification of the channel, circa 1930.

Photo 1. Illustrating the meandering the Okanagan River near Oliver.

Photo 1 illustrates the meandering that characterized portions of the river. Edith Rinehart captured this photo just south of the town of Oliver in 1945. Some portions of the river were at that time narrow and lined by brush. This photo is courtesy of the Oliver and District Archives.

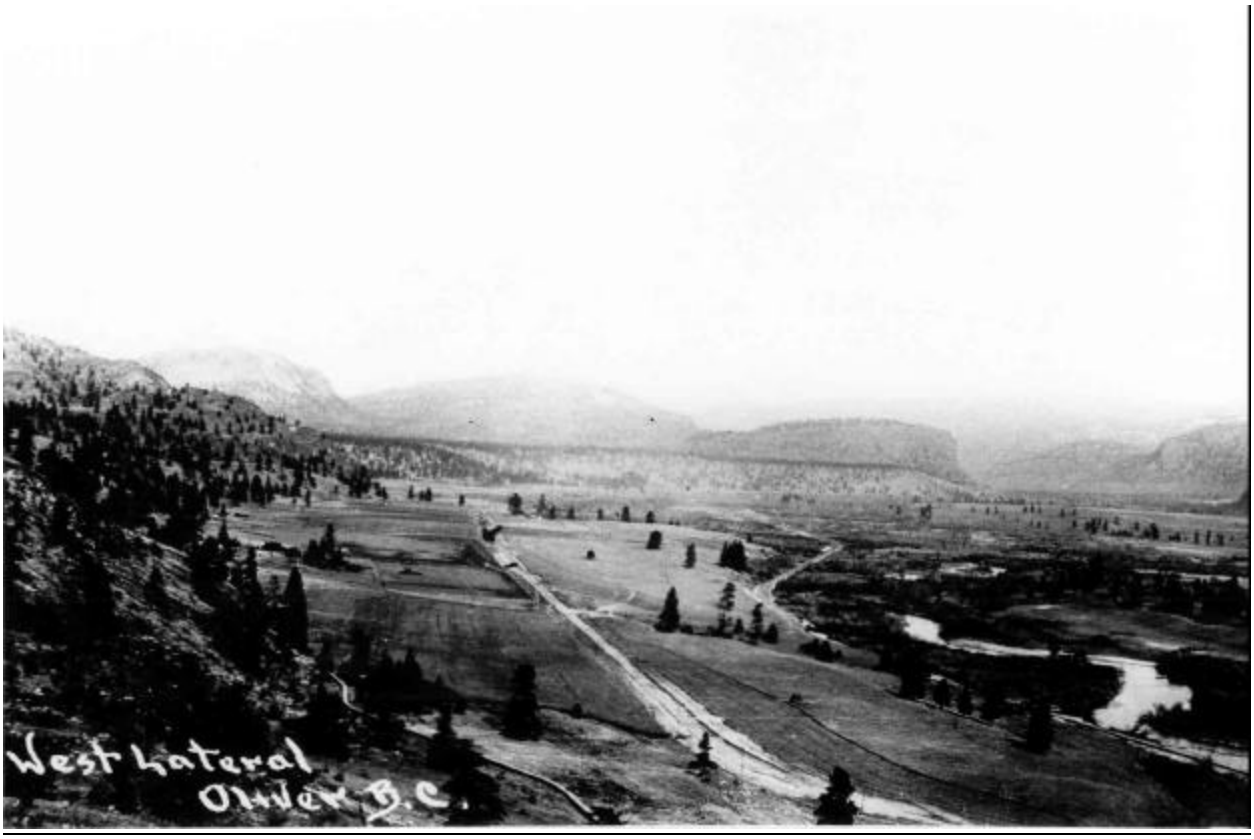


Photo 2. Okanagan River north of the town of Oliver showing the meandering.

The river from the town of Oliver looking northward and showing meanders. It also shows vegetation closely following the meanders. This photo circa 1920 is courtesy of the Oliver and District Archives.

Photo 3. Okanagan River at the town of Oliver showing the width of the river.

Okanagan River in the town of Oliver at a location known as the “swimming hole”, showing how wide portions of the river could be lined with vegetation. The photo circa 1930’s is courtesy of the Oliver and District Archives.

Photo 4. Okanagan River near the city of Penticton, South of Skaha Lake.

Okanagan River through Penticton near Skaha Lake. This portion of the river contained oxbows lined with trees and shrubs. Photo is courtesy of the South Okanagan Similkameen Conservation Program.

Photo 5. Ellis Creek during spring run-off showing the amount of riparian habitat present.

Ellis Creek during high water in the spring as seen from a location in today's downtown Penticton. This creek runs into Okanagan River and illustrates the characteristic riparian habitat, which was common along the Okanagan River and most tributary creeks. In *Historical Souvenir of Penticton* it is noted that this was a great area for spawning. Photo courtesy of the South Okanagan Similkameen Conservation Program

4.0 HISTORICAL ACCOUNTS

The following are excerpts from historical descriptions and accounts of the Okanagan River.

A.L. Fortune's Biography (Ormsby 1951)

- "At Okanagan Falls there is a small Fishing Reserve for the Inkameep Indians. This is isolated from their home Reserve, but the northern boundary of the latter was surveyed just to include the rocky rapids a little way below McIntyre Bluff, for this was an old time fishing spot for the Indians. Here they camped when the runs were on, spearing the salmon as they made their way up the shallows..."
- "...in the Okanagan River near the bridge at Oliver where there is good spawning gravel"

Maggie Victor – Wha-hul-kin-malks: An Okanagan (1966)

- "Salmon were speared along the Okanagan River through the Reserve and on the gravel bars below McIntyre Bluff."

Atkinson R.N. 1967 - Historical Souvenir of Penticton

- "The Huth Avenue village was chosen for several reasons, but chiefly because the river at that point had a gravel bottom, low banks and was shallow, permitting a safe ford and it was the easiest point between the two lakes at which to harvest the spring and fall runs of fish, the most important species of which were the spring spawning Kamloops trout which would use Ellis and Shingle Creeks both of which join the river close at hand, and the fall spawning Humpback and Chum (Dog) salmon from the sea, and the land-locked Kokanee."

Barlee, N.L. - The Sagebrush Country

- "Okanagan River still flows hard by the base of McIntyre's Bluff, here, in the past, the Okanagan Indians paused to spear the Redfish and Salmon as they swam upriver to spawn, for the channel narrows considerably at this spot."
- "Ancient Okanagan River Channel (before Flood Control dredged the canal through the river now flows) – the original river channel meandered back and forth across the lowlands to provide exceptional bird hunting and fishing in the early days"

Joe Pierre (Ernst2000)

- "Here at the river today it is called a river channel it was called ox bows before. It used to be rich in fish. Steelhead, Coho, and sockeye and the King Salmon."

Raymond George (Ernst 2000)

- "...they would just fish everywhere. Down in Oliver below the bridge."

Vernon News (1914)

- "For about a mile the river glides and twists calmly and quietly between low banks covered, for the most part, with reeds, or (as they are locally known) tullies."
- "After passing this interesting stretch the new bridge of the Kettle Valley Railway is approached and just below this the water quickens and for nearly two miles we dash around turns, each seemingly a little harder than the last to negotiate. Such twists as would break a snake's back and here – first east, then south, then west and (though we are bound south) sometimes almost due south."

5.0 Summary

The banks of the Okanagan River appear to have once supported a good riparian habitat, which included shrubs and trees. This habitat would have acted as a temperature buffer by providing shade along with cover for sockeye. Furthermore, this vegetation would have restricted erosion of the riverbanks and streambeds because the soil would have been bound together by the roots. The historical accounts of the river

also describe the gravel beds used for spawning. The notes about gravel refer to the river near McIntyre Dam and also between Skaha and Okanagan Lake.

6.0 References

1. Atkinson, R.N. 1967. Historical Souvenir of Penticton, BC 1867-1967. Harris, J.G., ed. Penticton Branch of the Okanagan Historical Society, Penticton.

2. Barlee, N.L. The Sagebrush Country. Canada West.

3. Ernst, A. 2000. Aboriginal Fisheries Information within the Okanagan Basin. Vedan, A., ed. Okanagan Nation Fisheries Commission: Westbank, BC.

4. Hargrave, Anne and Janelle Parchomchuck. 2002. Personal Communication. South Okanagan Similkameen Conservation Program.

5. Oliver and District Archives Photograph Collection.

6. Ormsby, Margaret A. 1951. A.L. Fortune's Autobiography. Okanagan Historical Society 15: 25-40.

7. Vedan, Adrienne. 2002. Traditional Okanagan Environmental Knowledge and Fisheries Management. Okanagan Nation Fisheries Commission: Westbank, BC.

8. Victor, Maggie. 1966. Wha-hul-kin-malks, An Okanagan. Okanagan Historical Society 30: 138-143.

9. A Trip Through Okanagan River and Skaha Lake. Vernon News 1914.

FINAL

OBJECTIVE 2 TASK C
North American Lakes where Kokanee, Rainbow Trout and Sockeye occur with Exotic Species

Contribution No. *8* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Author: Adrienne Vedan

Reviewed by: Chris Bull, R.P. Bio

Edited by: Howard Smith

1.0 INTRODUCTION

The Okanagan Nation Fisheries Commission (ONFC) is working towards re-introducing sockeye into Skaha Lake, and part of the evaluation of this project includes looking at the possibility of exotic species moving into upstream waters and adversely affecting resident kokanee and rainbow trout populations. A compilation of articles is provided dealing with some North American Lakes where kokanee, rainbow trout or sockeye occur with the following non-salmonids: black bullhead, black crappie, bluegill, smallmouth bass, largemouth bass, tench, carp, yellow perch, pumpkinseed and walleye. The above listed non-salmonids are considered exotic species of concern where they might negatively affect some part of the life cycle of either kokanee, sockeye or rainbow trout. This list will be useful in examining how exotic species interact with salmonids in other systems and in helping to predict what could occur in the Okanagan.

2.0 SOURCES

Literature in the following places was searched for information:

- Okanagan Nation Fisheries Commission
- Okanagan University College
- University of British Columbia
- National Research Council
- Great Lakes Fishery Commission
- Fisheries Information Summary System (FISS)

The information on species within lakes was mostly gathered from FISS and corresponding reports were then sought.

3.0 RESULTS

A partial list of lakes having one or more of sockeye, kokanee or rainbow trout plus one or more exotic species of concern.

Lake	Kokanee	Rainbow Trout	Sockeye	Black Bullhead	Black Crappie	Bluegill	Smallmouth Bass	Largemouth Bass	Tench	Carp	Yellow Perch	Pumpkinseed	Walleye	Lake Description
Lake Ozette, WA	x		x					x	x					Mesotrophic, warm, low elevation
Lake Washington, WA		x	x				x	x	x					Mesotrophic
Christina Lake, BC	x	X		x			x	x	x	x		x		Oligototrophic, warm water
Lower Arrow Lake, BC	x	X		x			x	x	x	x		x		Ultra-oligotrophic
Kootenay Lake, BC	x	X						x			x	x		Oligotrophic
Duck Lake, (Kootenay), BC		X		x				x			x	x		Oligotrophic
Mara Lake, BC	x	X	x							x				Oligotrophic
Pitt Lake, BC		X	x		x					x				Oligotrophic
Osoyoos Lake, BC	x	X	x	x	x		x	x	x	x	x	x		Mesotrophic
Flathead Lake, MO	x							x			x			Oligomesotrophic
Lake Tahoe, CA	x	X					x	x			x			High elevation, Ultra-oligotrophic
Western Lake Erie, Ont		X		x	x	x	x	x			x	x	X	Mesotrophic

The lakes that would be most useful when looking at predation and interaction of exotic species with salmonids would be those that are physically and chemically similar to Osoyoos Lake. The mesotrophic lakes listed with Osoyoos Lake are: Lake Ozette, Lake Washington and Lake Erie.

Studies of the interaction of sockeye and kokanee with predators like yellow perch and largemouth bass in Lake Ozette showed that predation rather than food supply or competition from other fish was the limiting factor in *O. nerka* production (1). In Lake Washington, studies have shown that considerable predation occurs during smolt out-migration (3). The lake has smallmouth bass and juvenile salmonids present; therefore, it is possible that the sockeye population is affected.

From 1969 to 1988, the dominant predator, walleye, shaped the fish community structure of Lake Erie. During this period, walleye greatly influenced the fish community structure as their abundance increased. Lake Erie walleye selectively prey on soft-rayed fishes and during this time records indicate that there was a decline in the abundance of soft-rayed fishes but not of spiny rayed-fishes. It was found that other changes in the nutrient load, loss of spawning habitat, exploitation and introduction of more exotic species changed the structure of the fish community (10).

4.0 REFERENCES

1. Beauchamp, David A. 1995. Riverine Predation on Sockeye Salmon Fry Migrating to Lake Washington. N. Am. J. Fish. Manage. 15: 358-365.

2. Daily, Kin, Terry Shrader, Ray Temple, and Bob Hooton. Introduced Fishes Management Strategies. Oregon Department of Fish and Wildlife.

3. Fayram, Andrew H., and Thomas H. Sibley. 2000. Impact of Predation by Smallmouth Bass on Sockeye Salmon in Lake Washington, Washington. N. Am. J. Fish. Manage. 20: 81-89.

4. Fielder, David G. 1992. Evaluation of Stocking Walleye Fry and Fingerlings and Factors Affecting Their Success in Lower Lake Oahe, South Dakota. N. Am. J. Fish. Manage.12: 336-345.

5. Hatch, Richard W., Stephen J Nepszy, Kenneth M. Muth, and Carl T. Baker. 1987. Dynamics of the Recovery of the Western Lake Erie Walleye (*Stizostedion Vitreum vitreum)* Stock. Can. J. Fish. Aquat. Sci. 44: 15-22.

6. Kershner, Mark W., Denis M. Schael, Roger L. Knight, Roy A. Stein, and Elizabeth A. Marschall. 1998. Modeling sources of variation for growth and predatory demand of Lake Erie walleye (*Stizostedion vitreum)*, 1986-1995. Can. J. Fish. Aquat. Sci. 56: 527-538.

7. Knight, Roger L., and Bruce Vondracek. 1993. Changes in Prey Fish Populations in Western Lake Erie, 1969-88, as Related to Walleye, *Stizostedion vitreum*, Predation. Can. J. Fish. Aquat. Sci. 50: 1289-1298.

8. Mason, Doran M., Timothy B. Johnson, and James F. Kitchell. 1988. Consequences of prey fish community dynamics on lake trout (*Salvelinus namaycush)* foraging efficiency in Lake Superior. Can. J. Fish. Aquat. Sci. 55: 1273-1284.

9. McPhail, J.D. and R. Carveth. 1993. Field Key To The Freshwater Fishes of British Columbia. Province of British Columbia, Victoria.

10. Northcote, T.G. 1973. Some Impacts of Man on Kootenay Lake and its Salmonoids. Technical Report No. 25, Great Lakes Fishery Commission.

11. Peterson, James H., and James F. Kitchell. 2001. Climate regimes and water temperature changes in the Columbia River: bioenergetic implications for predators of juvenile salmon. Can. J. Fish. Aquat. Sci. 58: 1831-1841.

12. Scott, W.B., and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publications Ltd., Oakville, Ont.

13. Tabor, Roger A., Rip S. Shively, and Thomas P. Poe. 1993. Predation on Juvenile Salmonids By Smallmouth Bass and Northern Squawfish in the Columbia River near Richland, Washington.N. Am. J. Fish. Manage. 13: 831-838.

14. Tonn, William M., and John J. Magnuson. 1982. Patterns in the species composition and richness of fish assemblages in northern Wisconsin lakes. Ecology 63: 1149-1166.

15. http://www.britishcolumbia.com/Fishing.bcr/kooteanys.html

16. http://www.state.sd.us/gfp/fishing/LakeOahe/OaheIndex.html

17. http://www.tahoevacationguide.com/Activities/fishing.html

FINAL

OBJECTIVE 2 Task C
Leaping Abilities of Exotic Species of Concern

Contribution No. *9* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Author: Adrienne Vedan

Reviewed by: Chris Bull, R.P. Bio

Edited by: Howard Smith

1.0 INTRODUCTION

The Okanagan Nation Fisheries Commission (ONFC) is carrying out a feasibility study on the re-introduction of sockeye salmon (*Oncorhynchus nerka*) into Skaha Lake. In objective 2 of this study we examine the interaction and impact of exotic species of concern with sockeye. One effective means of managing the impact of exotic species is to restrict their access. This literature review looks at the swimming and leaping abilities of exotic species of concern as an aid to developing and or refining fish passage ladders for sockeye salmon at McIntyre Dam.

2.0 SOURCES

The following sources were utilized:

- Okanagan Nation Fisheries Commission
- Okanagan University College
- University of British Columbia
- National Research Council
- Department of Fisheries and Oceans WAVES library
- Internet

Information on the leaping abilities of the exotic species of concern was extremely limited. There was some information regarding their swimming ability but this information was also sparse.

3.0 MOVEMENT

Anadromous and other migratory fish species often need to travel long distances and cross areas of high water velocity in order to reach spawning grounds or other critical habitat. These ordeals are often intensified by dams or other man made obstacles. Therefore, the swimming ability of a fish affects its life history (6.)

Species, smaller than adult salmonids, often cannot swim as fast and usually have a difficult time negotiating obstacles under high flows. Not only do salmonids have great swimming ability but they also have the ability to jump. Depending on the salmonid species the ability to jump makes many falls on streams or rivers passable rather than an impediment depending on the height (12).

Swimming performance may include: burst speed, highest speed attainable and maintainable for less than 15 seconds; prolonged speed, a moderate speed that can be maintained for up to 200 minutes; and sustained speed, a speed that can be maintained indefinitely. Sustained and prolonged speeds are generally used when fish are migrating upstream and burst speeds are used to overcome high velocity areas like rapids (7).

4.0 RESULTS

The following table outlines the swimming and jumping capabilities of various fish species.

Table 1 Swimming and jumping capabilities of some Salmonids and Exotic Species

Species	Lifestage	Maximum Swimming Speed (m/s)			Swimming (m/s)	Maximum Jump Height (m)	Comments	Reference
		Sustained	Prolonged	Burst				
Coho/chinook	Adult	2.7	3.2	6.6		2.4		13
Sockeye	Adult	1.0	3.1	6.3		2.1		13
Chum/Pink	Adult	1.0	2.3	4.6		1.5		13
Steelhead	Adult	1.4	4.2	8.1		3.4		13
Cutthroat/rainbow	Adult	.9	1.8	4.3		1.5		13
Common carp	Adult	.590		1.638				5
Walleye	Adult		0.0-1.1					7
Largemouth Bass	Adult				.340 - .589		Sample size test of 15, swimming with an increasing velocity (can maintain speed for 3 minutes)	7
Yellow Perch	Adult				.313 - .537		Swimming with an increasing velocity (can maintain speed for 3 minutes)	7
Pumpkinseed	Adult	.27						2

5.0 SUMMARY

Information regarding the characteristics of how a particular fish can swim in a specific velocity of water either is limited or not available for most fish species (7.) Nevertheless, the information in Table 1 illustrates the poor swimming abilities of several non-salmonid species. It is unlikely that if a fish is a member of a species with a poor swimming ability it will have much jumping capability.

Efforts to prevent exotic species from populating upstream areas of the Okanagan River may best be expended in setting barriers high or swift enough to only allow passage of salmonids, thereby excluding smaller, usually less capable swimmers.

6.0 REFERENCES

1. Beamish, F.W.H. 1974. Apparent Specific Dynamic Action of Largemouth Bass, *Micropterus salmoides*. J. Fish. Res. Board Can. 31: 1763-1769.

2. Brett, J.R. and D.B. Sutherland. 1965. Respiratory Metabolism of Pumpkinseed (*Lepomis gibbosus*) In Relation to Swimming Speed. Fish. Res. Bd. Can. 22:405-409.

3. Farrell, A.P., A.K. Gamperl, and I.K. Birtwell. 1998. Prolonged Swimming, Recovery and Repeat Swimming Performance of Mature Sockeye Salmon *Oncorhynchus nerka* exposed to Moderate Hypoxia and Pentachlorophenol. The Journal of Experimental Biology 210: 2183-2193.

4. Jain, K.E., I.K. Birtwell and A.P. Farrell. 1998. Repeat swimming performance of mature sockeye salmon following a brief recovery period: a proposed measure of fish health and water quality. Can. J. Zool. 76: 1488-1496.

5. http://www.fishbase.org/search.html

6. http://www-heb.pac.dfo-mpo.gc.ca/congress/2000/Papers/migrationpdf/castro-santos.pdf

7. Katopodis, Chris and Rick Gervais. 1991. Ichthyomechanics. Freshwater Institute, Winnipeg, Manitoba.

8. Kolok, A.S. 1999. Interindividual variation in the prolonged locomotor performance of ectothermic vertebrates: a comparison of fish and herpetofaunal methodologies and a brief review of the recent Fish literature. Can. J. Fish. Aquat. Sci. 56: 700-710.

9. Peake, S., R.S. McKinley, and D.A. Scruton. 2000. Swimming performance of walleye (*Stozostedion Vitreum).* Can. J. Zool. 78: 1686-1690.

10. Peake, S., F.W.H. Beamish, R.S. McKinley, D.A. Scruton, and C. Katopodis. 1997. Relating swimming Performance of lake sturgeon, *Acipenser fulvescenc,* to fishway design. Can. J. Fish. Aquat. Sci. 54: 1361-1366.

11. Rome, Lawrence, C., Paul T. Loughna, and Geoffrey Goldspink. 1985. Temperature Acclimation: Improved Sustained Swimming Performance in Carp at Low Temperatures. Science 228: 194-196.

12. Symonds, Brian. 2003. Personal Communication.

13. Webb, Paul W. 1995. Locomotion. *In* Groot, C, L. Margolis and W.C. Clarke (ed's.) Physiological Ecology of Pacific Salmon. UBC Press, Vancouver BC.

14. Whyte, I., S. Babakaiff, M. Adams, and P. Giroux. 1997. Restoring fish access. *In* Slaney, P.A. and D. Zaldokas (ed's.) Watershed Restoration Technical Circular No. 9, W.R.P. Min. of the Environment, Victoria BC.

FINAL

OBJECTIVE 2 Task C
Movement and Colonization of Walleye

Contribution No. *10* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Author: Adrienne Vedan

Reviewed by: Chris Bull, R.P. Bio

Edited by: Howard Smith

1.0 INTRODUCTION

The Okanagan Nation Fisheries Commission (ONFC) is completing a feasibility study of the re-introduction of sockeye salmon *Oncorhychus nerka*, into Skaha Lake, which is within the species historic range. Objective 2 of this study includes an assessment of possible unwanted introductions of exotic fish. Walleye are a possible threat to the upper Okanagan River and this literature review will examine walleye habitat, reproduction and movement in order to see how these characteristics may determine where walleye colonize.

Walleye are not native to Washington State and the circumstances of their introduction are unknown. The first verification of a walleye in Washington State was in 1962, from Banks Lake in eastern Washington. Soon afterwards, they appeared in Franklin Roosevelt Lake (connected to Banks Lake through a huge pipe.). Since then they have spread from these original sites to the remainder of the mainstem Columbia River, from near the mouth to the Canadian border. This species is known to be a predator and to colonize quickly (8).

2.0 SOURCES

The research methods consisted of reviewing literature. The following search areas were utilized:

- Okanagan Nation Fisheries Commission
- Okanagan University College
- University of British Columbia
- National Research Council

Information available on walleye movement, reproduction, and habitat preference was extensive but information was limited in regards to methods of stopping walleye range extensions.

3.0 WALLEYE HABITAT

Walleye can withstand a wide variety of environmental conditions: however, they prefer moderate to large lacustrine or riverine systems characterized by: cool temperatures, shallow to moderate depths, extensive littoral areas, moderate turbidities, extensive areas of clean rocky substrate and mesotrophic lakes. The littoral and sublittoral areas that walleye occupy in lakes are comparable to extensions of suitable riverine habitat into the lacustrine environment.

Demersal fry, juveniles and adults are very photosensitive. During the day they seek shelter that has dim light and are usually found in deep or turbid water or in contact with the substrate under the cover of boulders, log piles, brush, or dense beds of submerged vegetation.

Adult walleye prefer temperatures between 20 degrees Celsius and 24 degrees Celsius. Growth in adults stops when temperatures are less than 12 degrees Celsius and temperatures above 29 degrees Celsius are considered lethal (13).

4.0 REPRODUCTION

Walleye reproductive success is dependant on water temperature and quality. They spawn during the spring when there is sudden warming and spawning usually occurs when temperatures are between 6-11 degrees Celsius. Spawning habitat consists of: shallow shoreline areas, shoals and riffles, and having good water circulation from wave action or currents to provide well oxygenated water.

They are nocturnal spawners and eggs are distributed freely over the substrate and fall into cracks. Walleye do not provide any parental care. Current velocities in spawning areas must be sufficient to carry fry downstream to lakes within a period of 3-5 days, after yolk-sac absorption or they will die from a lack of food. Fry will not begin to feed when water temperatures are below 15 degrees Celsius. Juvenile walleye have similar habitat requirements to those of adults.

The heavy Columbia River flows draw most sexually mature walleye to tailrace areas "and away from the Okanogan River when conditions (maximum turbidity and discharge) are most accommodating" (17). "The absence of suitable rearing habitat and food (in the Okanagan River)" is a limiting factor in walleye colonization of the Okanagan system (17).

5.0 MOVEMENT

Studies regarding the swimming performance (15) of walleye have shown that they have a narrow scope for activity compared to species like the sockeye salmon. Walleye are generally considered not to be strong swimmers or to occupy fast water areas which could explain why walleye have a poor performance record when it comes to passing fishways (15, 17). Nevertheless, walleye are well known for expanding into new systems and becoming a dominant species because they are effective predators. Although walleye are nocturnal, they are not restricted to particular areas and often travel long distances. One factor, which limits the movement and behaviour of walleye, is light, since their eyes are extremely sensitive.

The aversion to light probably explains why walleye have been unable to reach Osoyoos Lake through the Okanagan River although the lower Okanagan River supports walleye (17).

6.0 SUMMARY OF RESULTS

If walleye made their way in to the Canadian portion of the Okanagan River they could cause great damage to salmonid populations. Walleye are great predators and colonize quickly. The most important environmental factor which influences walleye movement is light since they are extremely photosensitive and it appears that the Canadian portion of the river is too bright for walleye to enter or remain in. Another limiting factor in walleye movement is that the Okanagan River does not provide walleye with suitable spawning conditions.

7.0 REFERENCES

1. Brown, A.L., M.S. Busby, and K.L. Mier. 2001. Biotic influences on habitat selection by Young-of-year walleye (*Stisostedion vitreum)* in the demersal stage. Can. J. Fish. Aquat. Sci. 58: 1058-1069.

2. Czesny, S., K. Dabrowski, and P. Frankiewicz. 2001. Foraging patterns of juvenile walleye(Stizostedion vitrreum) in a system consisting of a single predator and two prey species: testing model predictions. Can. J. Zool. 79: 1394-1400.C

3. Einfalt, Lisa M., and David H. Wahl. 1997. Prey selection by juvenile walleye as Influenced by prey morphology and behaviour. Can. J. Fish. Aquat. Sci.54: 2618-2626.

4. Eldridge, William H., Marc D. Bacigalupi, Ira R. Adelman, Loren M. Miller, and Anne R. Kapuscinski. 2002. Determination of relative survival of two stocked Walleye populations and resident natural origin fish by microsatellite DNA Parentage assignment. Can. J. Fish. Aquat. Sci. 59: 282-290.

5. Fielder, David G. 1992. Evaluation of Stocking Walleye Fry and Fingerlings and Factors Affecting Their Success in Lower Lake Oahe, South Dakota. N. Am. J. Fish. Manag. 12: 336-345.

6. Hatch, Richard W., Stephen J. Nepszy, M. Muth Kenneth, and Carl T. Baker. Dynamics of the Recovery of the Western Lake Erie Walleye (*Stizostedion vitreum vitreum)* Stock. Can. J. Fish. Aquat. Sci. 50: 1289-1298.

7. Henderson, Bryan A., and Stephen J. Nepszy. 1994. Reproductive Tactics of Walleye (*Stizostedion vitreum)* in Lake Erie. Can. J. Fish. Aquat. Sci. 44: 15-22.

8. http://www.wa.gov/wdtw/outreach/fishing/walleye/walleye1.htm

9. Johnson, Barry L., David L. Smith, and Robert F. Carline. 1988. Habitat Preferences, Survival, Growth, Foods, and Harvests of Walleyes and Walleyes X Sauger Hybrids. N. Am. J. Fish. Manage. 8: 292-304.

10. Kershner, Mark W., Denise M. Schael, Roger L. Knight, Roy A. Stein, and Elizabeth A. Marschall.1999. Modeling sources of variation for growth and predatory Demand of Lake Erie walleye (*Stizostedion vitreum*), 1986-1995. Can. J. Fish. Aquat. Sci. 56: 527-538.

11. Knight, Roger L., and Bruce Vondracek. 1993. Changes in Prey Fish Populations in Western Lake Erie, 1969-88, as related to Walleye, *Stizostedion vitreum,* Predation. Can. J. Fish. Aquat. Sci. 50: 1289-1298.

12. Kocovsky, Patrick M., and Robert F. Carline. 2001. Influences of Extreme Temperatures On Consumption and Condition of Walleyes in Pymatuning Sanctuary, Pennsylvania. N. Am. J. Fish. Manage. 21: 198-207.

13. McMahon, Thomas E., James W. Terrell, and Patrick C. Nelson. 1984. Habitat Suitability Information: Walleye. Washington DC: US Fish and Wildlife Service.

14. Nate, Nancy A., Michael A. Bozek, Michael J. Hansen, and Steven W. Hewett. 2000. Variation in Walleye Abundance with Lake Size and Recruitment Source. N. Am. J. Fish. Manage. 20: 119-126.

15. Peake, S., R.S. McKinley, and D.A. Scruton. 2000. Swimming performance of walleye (*Stizostedion vitreum*). Can. J. Fish. Aquat. Sci. 58: 1058-1069.

16. Sugisaki, H., K.M. Bailey, and R.D. Brodeur, 2001. Development of the escape response in larval walleye pollock (*Theragra chalcogramma*). Marine Biology 139: 19-24.

17. Williams, Ken, and Larry Brown. 1982. Mid-Columbia Walleye: Fisheries Life History Management.

FINAL

OBJECTIVE 2 Task C
Consumption of incubating salmon eggs by black bullheads (*Ameriurus melas*)

Contribution No. *11* to an *Evalutation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Author: Adrienne Vedan

Reviewed by: Chris Bull, R.P. Bio

Edited by: Howard Smith

1.0 INTRODUCTION

Species from external ecosystems have invaded the Okanagan basin via the Columbia and Okanogan Rivers. One of the species that is now present in the Okanagan basin is the black bullhead, *Ameiurus melas,* which was first recorded in 1941 as an invasion from the United States. Currently, it is found south of Okanagan Lake Dam (12).

As part of Objective 2, of the sockeye re-introduction to Skaha Lake project, the Okanagan Nation Fisheries Commission (ONFC) completed a literature review of the impacts of black bullheads on incubating salmonid eggs.

2.0 SOURCES

The following sources were searched:

- Okanagan Nation Fisheries Commission
- Okanagan University College
- University of British Columbia
- Pacific Regional Information Services for Education
- National Research Council Canada
- Internet

3.0 SUMMARY OF RESULTS

The information on food habits of the species was extensive, but not much was found on fish eggs in the diet.

The black bullhead is omnivorous, feeding on whatever it can find, including dead things. Midge and mayfly make up a considerable portion of the diet but bullheads also feed on other insects and their larvae, small crayfish, worms, small molluscs, crustaceans and plant material. Adults sometimes eat small fish, including other bullheads but fish play a very small part in their diet. Bullheads have also been known to eat the eggs of other fishes (13,9,3,6,4,11,8,5,10).

Black bullheads inhabit pools, backwaters, and slow-moving sections of creeks and both small and large rivers. They can also be found in impoundments, oxbows and ponds. They prefer turbid water and soft mud bottoms and can tolerate a pH as low as 3.4. The species is usually found in regions of pools having vegetative cover but will move into riffle areas to feed (13, 4,101,8,11,7).

During the day, bullheads remain inactive and stay within the vegetative beds until night falls. Adults feed primarily at night while the young are most active at dawn and dusk. They often destroy vegetation while stirring up the bottom in search of food (8, 9, 6).

Black bullheads are omnivorous and have been reported to eat fish eggs so there is a possibility that they may eat incubating salmon eggs also. However, an estimate of such losses is not possible on the basis of the literature reviewed.

4.0 REFERENCES

1. Crisp, D.T. and R.H.K. Mann. 1991. Effects of impoundment on populations of Bullhead *Cottus gobio L.* and minnow, *Phoxinus phoxinus (L.)*, in the basin of Cow Green Reservoir. Journal of Fish Biology 38: 731-740.

2. Fisher, Shannon J., and David W. Willis. 2000. Seasonal Dynamics of Aquatic Fauna and Habitat Parameters in a Perched upper Missouri River Wetland. Wetlands 20: 470

3. http://elib.cs.berkeley.edu/kopec/tr9/html/sp-black-bullhead.html

4. http://members.tripod.com/~huntingfishing/blackbullhead.htm

5. http://phartattack.tripod.com/catfish.html

6. http://www.calntisa.com/fish/bul.htm

7. http://www.dfg.ca.gov/fishing/catfish.pdf.

8. http://www.fieldandstream.com/fieldstream/fishing/article/0,13199,338718,00.html

9. http://fwie.fw.vt.edu/TN/TN00173.htm

10. http://www.gen.umn.edu/faculty_staff/hatch/fishes/black_bullhead.html

11. http://www.rook.org/earl/bwca/nature/fish/ictalurusmel.html

12. Long, Karilyn. 2001. Objective 2; Exotic Fish Species Risk Assessment *in* Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake. Prepared by Okanagan Nation Fisheries Commission, Westbank, BC. for the Colville Confederated Tribes, Nespelem, Washington.

13. Stuber, R.J. 1982. Habitat suitability index models: Black Bullhead. US Dept. Int. Fish. Wildl. Serv. FWS/OBS-82/10.14. 25pp.

14. Weaver, Melissa J., John J. Magnuson and Murray K. Clayton. 1997. Distribution of littoral fishes in Structurally complex macrophytes. Can. J. Fish. Aquat. Sci. 54: 2277-2289.

FINAL

OBJECTIVE 4
OkSockeye: A Simple Life-cycle Model of Okanagan Basin Sockeye Salmon
Version 2.2
Design Document

Contribution No. *12* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Authors: Calvin N. Peters
David R. Marmorek

OkSockeye:
A Simple Life-cycle Model of Okanagan Basin Sockeye Salmon

Version 2.2

Design Document

OkSockeye:
A Simple Life-cycle Model of Okanagan Basin Sockeye Salmon
Version 2.2

Design Document

Prepared for:

Okanagan Nation Fisheries Commission
3255 C Shannon Lake Road
Westbank, BC V4T 1V4

Prepared by:

Calvin N. Peters
ESSA Technologies Ltd.
3004 11th St. Vernon BC V1T 7H6
(250) 542-2973
cpeters@essa.com

and

David R. Marmorek
ESSA Technologies Ltd.
300-1765 W. 8th Ave. Vancouver B.C. V6J 5C6
(604) 733-2996
dmarmorek@essa.com

January 30, 2003

Citation: **Peters, C.N. and D.R. Marmorek.** 2003. OkSockeye: A Simple Life-cycle Model of Okanagan Basin Sockeye Salmon, Version 2.2, Design Document. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for the Okanagan Nation Fisheries Commission, Westbank, BC. 95 pp.

© 2003 ESSA Technologies Ltd.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the Okanagan Nation Fisheries Commission, Westbank, BC.

Table of Contents

List of Figures iii

List of Tables iv

Summary v

1.0 Introduction and Project Overview 1
- 1.1 Background 1
- 1.2 Model Objectives 2
- 1.3 Model Complexity 3
- 1.4 Relationship to the Fish / Water Management Tool (FWMT) 4

2.0 Model Scope and Overall Structure 5
- 2.1 Spatial and Temporal Scope 5
- 2.2 Management Actions 6
- 2.3 Overall Model Structure 7

3.0 Hydrology / Temperature Submodel 9
- 3.1 Selection of Inputs to Hydrology / Temperature Model 9
- 3.2 Flow in the Okanagan River (above Osoyoos Lake) 10
- 3.3 Temperature in the Okanagan River (at Okanagan Falls) 14
- 3.4 Flow and Temperature in the Okanagan River (below Osoyoos Lake) 14
- 3.5 Flow and Temperature in the Similkameen River 15
- 3.6 Temperature in the lower Okanagan River (at confluence with Columbia River) 16
- 3.7 Phosphorus concentration in Osoyoos and Skaha Lake 17
- 3.8 Secchi Depths in Osoyoos and Skaha Lake 19

4.0 Sockeye Submodel 21
- 4.1 Spawner - Egg 22
  - 4.1.1 Maturity Schedule 22
  - 4.1.2 Age-specific Fecundity 22
  - 4.1.3 Female Proportion 23
  - 4.1.4 Optimal female density 23
  - 4.1.5 Spawner capacity 23
  - 4.1.6 Annual egg abundance 27
- 4.2 Egg – Fry 28
  - 4.2.1 Egg Stranding 28
  - 4.2.2 Flushing mortality 29
  - 4.2.3 Natural Survival Rate 30
  - 4.2.4 Annual Fry Abundance 31
  - 4.2.5 Effect of flow on spawner-fry production functions 31
  - 4.2.6 Fry Supplementation 32
  - 4.2.7 Fry Production 33
- 4.3 Fry - Smolt 34
  - 4.3.1 Predation 34
  - 4.3.2 Smolt capacity 36
  - 4.3.3 Smolt Production 39
  - 4.3.4 Smolt Supplementation 40
- 4.4 Smolt – Adult 40
  - 4.4.1 Rearing lakes – Wells Dam 40

4.4.2 Smolts at Wells Dam – Adults at Wells Dam ... 41
4.5 Returning Adults (Columbia River mouth to Wells Dam) ... 44
4.5.1 Lower River harvest ... 44
4.5.2 Survival rate during upstream migration (Mouth of Columbia to Wells Dam) ... 47
4.5.3 Run Timing at Wells Dam ... 49
4.6 Prespawning Survival and Distribution (Wells Dam to Spawning Grounds) ... 49
4.6.1 Migration up the Okanagan River ... 50
4.6.2 Prespawning Survival Rate ... 52
4.6.3 Distribution of Spawners between Skaha and Osoyoos spawning grounds ... 53
4.6.4 Adult Supplementation ... 54

5.0 Kokanee Submodel ... 55
5.1 Growth ... 56
5.1.1 Von Bertalanffy growth equation ... 56
5.1.2 Computation of age 2 kokanee equivalents ... 57
5.1.3 Length-Weight relationship ... 61
5.2 Predation losses ... 61
5.3 Survival from Age 0 to Adult ... 64
5.4 Maturation and age 0 production ... 64
5.4.1 Spawner abundance ... 64
5.4.2 Spawner capacity ... 65
5.4.3 Spawner-egg (fecundity) ... 66
5.4.4 Egg - Emergent Fry ... 67
5.4.5 Emergent Fry – Rearing Fry (Age 0) ... 68
5.5 Total production ... 69

6.0 Mysis Submodel ... 71
6.1 Survival, harvest, and predation ... 71
6.2 Total production ... 75
6.3 Immature mysis-nerkid equivalence factor ... 76

7.0 Predator submodel ... 79
7.1 Egg deposition ... 79
7.2 Emerging fry ... 80
7.3 Rearing fry ... 80
7.4 Adults ... 80
7.5 Predation ... 80

8.0 Summary of Parameters and Preliminary Parameter Values ... 83

9.0 References ... 89

Appendix A. Project participants ... 93

Appendix B. OkSockeye Version History ... 95

List of Figures

Figure 0.1. Overall structure of model showing linkages between submodels. vi
Figure 0.2. Schematic of life-cycle of Okanagan sockeye, showing mortality factors included in the model vi
Figure 1.1. Iterative approach to model development. 4
Figure 2.1. Map of Columbia and Okanagan Rivers. Inset: Map of Okanagan Basin showing major lakes and dams 5
Figure 2.2. Overall structure of model showing linkages between submodels. 8
Figure 3.1. Net inflows to Okanagan Lake, 1944-1997. 11
Figure 3.2. Reconstructed spawning, incubation, and upstream migration flows at Oliver for years 1944-1974 based on mapping to post-1973 years. 13
Figure 3.3. Reconstructed upstream migration below Osoyoos Lake for years 1944-1974 based on mapping to post-1973 years. 15
Figure 3.5. Predicted vs. observed water temperature in lower Okanagan River. Observed water temperatures from Stockwell et al. 2001. 16
Figure 3.6. Observed (top) and reconstructed (bottom) Phosphorus concentrations in Skaha and Osoyoos Lakes. Reconstruction was based on maximum flows in the Okanagan River at Oliver. 18
Figure 4.1. Schematic of life-cycle of Okanagan sockeye, showing mortality factors included in the model 21
Figure 4.2. Area of good habitat in Osoyoos spawning index reach at various flows. 24
Figure 4.3. Area of high (top) and medium (bottom) quality spawning habitat for Skaha sockeye. 25
Figure 4.4. Relationship between number of eggs deposited and numbers of spawners at various flows. 28
Figure 4.5. Average spawning flows, minimum incubation flows, and the ratio of these flows in the Okanagan River, 1980-1999. Data source: Stockwell et al. 2001. 29
Figure 4.6. Relationship between # of pre-emergent flushed and maximum incubation (Nov-Feb) flow 30
Figure 4.7. Implied fry production curves for 1973, 1974, 1997, and 1998. 32
Figure 4.8. Density-dependent adjustment of biomass consumed by predators. 35
Figure 4.9. Relationship between sockeye smolt body weight and fry density. Based on Hyatt and Rankin 1999. 38
Figure 4.10. Smolt production curves with density effects (diamonds) and both predation and density effects (circles). The shape of this curve will depend on the density of predators. 39
Figure 4.11. Year effects applied to average Okanagan sockeye SARs. Developed from SAR data for Robertson Creek coho (Hyatt et al. 2000). 43
Figure 4.12. Okanagan and Wenatchee escapement 45
Figure 4.13. Top: Potential and actual harvest 1971–2001. Bottom: Fraction of potential harvest actually harvested as function of the number of consecutive years in which a commercial harvest was opened. Data sources: Hyatt et al. (2002). 46
Figure 4.14. Survival rate per dam 1980-2001, based on comparison of dam counts 48
Figure 4.15. Proportion of sockeye arriving at Wells Dam, based on daily adult dam counts. Source: Fish Passage Center. 49
Figure 4.16. Top: Number of fish arriving at Wells Dam (example only; assumes 30,000 fish and 1992 arrival timing), and daily water temperature in lower Okanagan River. Bottom: Computed number of fish entering Okanagan River, assuming fish hold in Columbia as long as Okanagan River temperature is greater than 21 degrees 51

Figure 4.17. Relationship between prespawning mortality rate and entry into Okanagan River. Entry days are counted from June 1. 52
Figure 5.1. General structure of kokanee submodel. 55
Figure 5.2. Annual estimates of Skaha Lake kokanee spawning abundance, 1991-2000. Source: WLAP 2001. 56
Figure 5.3. Example length-at-age curve produced by equation 5-1. 57
Figure 5.4. Age 3 length as a function of age 2 equivalent density and Secchi Depth. 58
Figure 5.5. Conversion efficiency as a function of average body size. 59
Figure 5.6. Density-dependent adjustment of biomass consumed by predators. 62
Figure 5.7. Size-dependent relative vulnerability to predation. 63
Figure 5.8. Maturation function in LLKM. 65
Figure 5.9. Relationship between # of surviving fry and # of emerging fry (example only). 68
Figure 6.1. Mysis survival rate as a function of density. 72
Figure 6.2. Example relationship between mysis contribution to kokanee diet and mysid density. 74
Figure 6.3. Mysis-nerkid equivalence factor as a function of lake productivity (represented by total P concentrations). 77
Figure 6.4. Mysid Production:Biomass ratios in lakes of different trophic status (from Cooper et al. 1992). 78

List of Tables

Table 2.1. Management actions implemented in the model, their mechanism (Direct via user-defined parameter value; Indirect via parameterisation of functional relationship), and relevant equation in this report. 6
Table 3.1. Hydrologic data sets. 9
Table 4.1. Age composition estimates from Hyatt et al. (2002). Age notation indicates # of winters spent in freshwater. # of winters spent in ocean. 22
Table 4.2. Age-specific fecundities (Major and Craddock 1965, as reported by Fryer 1995). 22
Table 4.3. Okanagan sockeye supplementation. Source: FPC Annual Reports 1996-2001. 40
Table 4.4. Preliminary set of SARs (Wells Dam to return to mouth of Columbia) 42
Table 4.5. Sockeye harvest schedule as proposed by the 2001-2003 Interim Management Agreement. 44
Table 5.1. LLKM default (provincial standard) values for length-weight coefficients 61
Table 7.1. LLKM default parameter values for rainbow trout. 82
Table 8.1. Preliminary parameter values. 83
Table 8.2. Initial conditions required to initialise the model (values are preliminary hypotheses). 87

Summary

The purpose of this model is to support exploration of an adaptive management experiment to introduce sockeye salmon into Skaha Lake, so as to better understand the possible effects of introducing sockeye into Okanagan Lake. The model allows users to explore the biological benefits and risks, and learning value of different candidate strategies for reintroducing sockeye into Skaha Lake. The model operates on an annual time step and provides annual relative abundance estimates of sockeye salmon in Osoyoos and Skaha Lakes, Skaha Lake kokanee, and Skaha and Osoyoos Lake *Mysis* populations. Other fish and mysis populations can be added to the model as required.

The model consists of five submodels (Figure 0.1):

1. Hydrology / Temperature submodel – calculates flows and temperatures in the Okanagan River between Okanagan Lake and the confluence with the Columbia River.
2. Sockeye submodel – calculates survival rates between life stages (Figure 0.2), based on various physical and biological mortality factors.
3. Kokanee submodel – calculates growth, maturation, and survival rates
4. Mysis submodel – calculates annual densities and biomass of mysis in Skaha Lake.
5. Predator submodel – calculates annual production and biomass consumed by lake-resident predators (rainbow trout used as an example predator).

The submodels are connected as shown in Figure 0.1. The hydrology submodel provides flows and temperatures that drive key biological processes in the sockeye, kokanee, and mysis submodels. The sockeye, kokanee, and mysis submodels exchange production information for determining density-dependent growth and survival rates in food-limited rearing habitat in Skaha Lake. The model also includes potential predation on mysis by kokanee. The predator submodel calculates the biomass of sockeye fry and kokanee required to support production of rainbow trout populations.

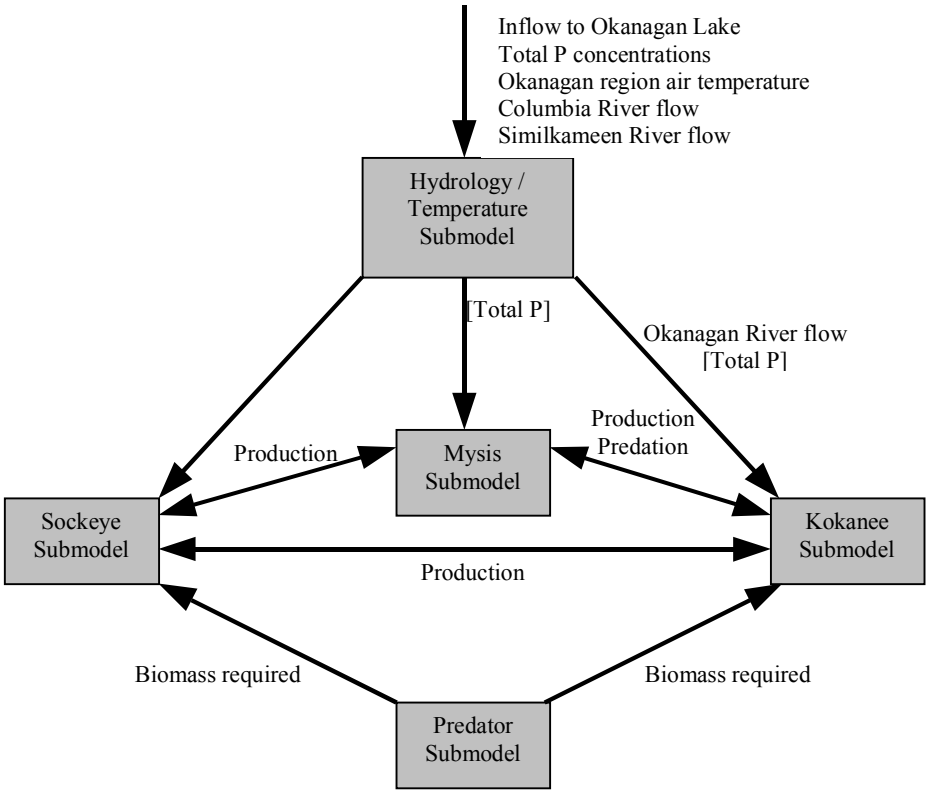


Figure 0.1. Overall structure of model showing linkages between submodels.

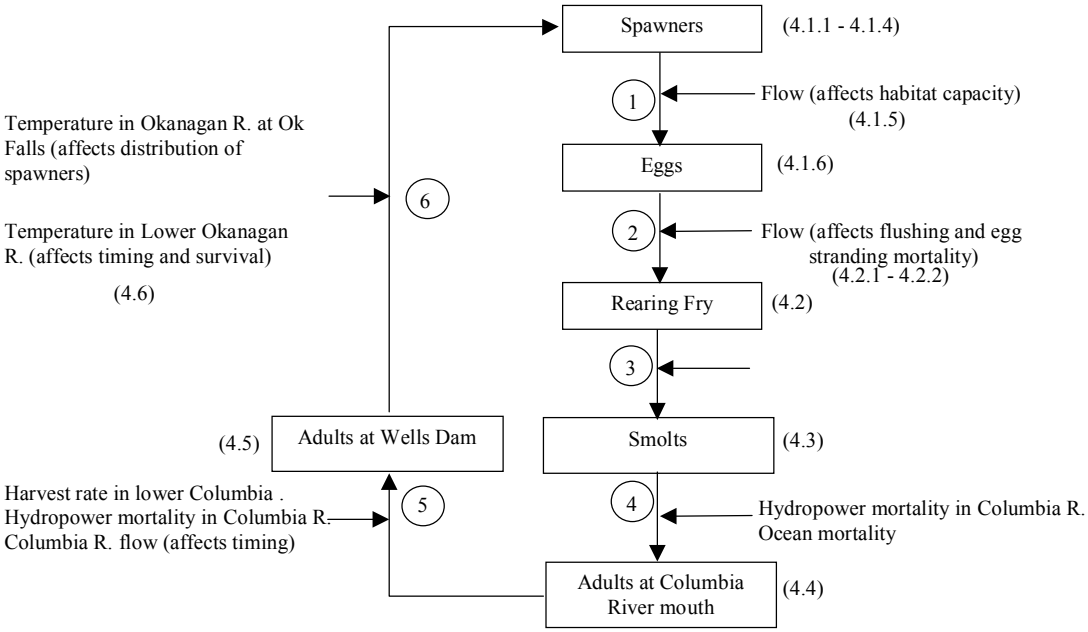


Figure 0.2. Schematic of life-cycle of Okanagan sockeye, showing mortality factors included in the model. Numbers in brackets correspond to sections in which each component is described.

1.0 Introduction and Project Overview

1.1 Background

Historical records indicate that sockeye salmon were once found in most of the lakes in the Okanagan Basin.[1] Currently, the only sockeye population within the Okanagan Basin is found in Osoyoos Lake. Abundance of this stock has declined significantly in the last fifty years. Tribes and First Nations in the U.S. and Canada have proposed re-introducing the species into Okanagan Lake, which has a large rearing capacity. However, assessing the potential benefits and risks associated with a re-introduction of sockeye salmon into Okanagan Lake is difficult because of uncertainties about factors that determine production of Okanagan sockeye,[2] and potential interactions with other species in Okanagan Lake.

A 1997 workshop to discuss these issues recommended that sockeye be re-introduced to Skaha Lake as an experimental management strategy to resolve some of these uncertainties (Peters et al. 1998). In preparation for such an experiment, the Okanagan Nations Fisheries Commission, the Colville Confederated Tribes, and other fisheries agencies have undertaken a research project to identify and assess the risks and benefits of an experimental re-introduction of sockeye salmon into Skaha Lake[3]. Specific risks due to disease transmission and introduction of exotic species are being addressed through ongoing field assessments. Restoration and learning benefits of reintroducing sockeye to Skaha Lake, and potential risks to resident kokanee stocks, will be addressed through the development of a life-cycle model of Skaha Lake sockeye and kokanee populations, together with targeted field work on such topics as disease, exotic species, and habitat inventories.

This document describes the objectives, scope, and design of the life-cycle model of Okanagan sockeye (OkSockeye). The design is based primarily on available data on Okanagan basin sockeye, kokanee, and mysid populations. Development of the OkSockeye model has been an iterative, multi-agency process. The first draft of this design document was reviewed and discussed at a 1-day workshop held in Westbank on February 27, 2002. Comments and suggestions by participants at this workshop have been incorporated into version 1.0 of the document, which was distributed to project participants June 19, 2002. Subsequent to the release of that draft, a model review meeting was held October 15, 2002, followed by a model review and training session on January 15-16, 2003. This version of the model and design document (version 2.2) incorporates comments and improvements coming out of those meetings (major changes from the June 19 2002 (version 1.0) Design Document are noted throughout the text). Appendix B of this document provides a version history of the Okanagan Sockeye model.

[1] We use Canadian spelling of Okanagan throughout this document.

[2] We refer to all sockeye salmon originating from Okanagan Basin lakes as Okanagan sockeye. Currently the only population of Okanagan sockeye rears in Osoyoos Lake, but populations could also potentially rear in Skaha, Okanagan, and other lakes if passage to those lakes was restored.

[3] Funded by contributions of the Bonneville Power Administration to the Northwest Power Planning Council's Fish and Wildlife Program.

1.2 Model Objectives

The overall role of the model within the overall Skaha Lake project is to explore the relative benefits and risks of possible reintroduction strategies and alternative monitoring approaches to assess the impacts of reintroduction. Consequently, the key function of the model is to provide a framework for capturing key hypotheses about sockeye and kokanee and the stressors that act on them throughout their entire life-cycles (including interactions among sockeye/kokanee/mysis in Skaha Lake), and produce a range of possible relative outcomes from various management and environmental scenarios.

The life-cycle model has three primary objectives.

1. **Explore stock rebuilding benefits**

   Restoring access to Skaha Lake for the Okanagan sockeye population (which is currently confined to Osoyoos Lake) has potential population-level benefits in terms of providing additional, higher quality rearing habitat for sockeye juveniles. However, increased juvenile output may not translate to increased abundance of returning adult sockeye because of various mortality factors throughout the rest of the life-cycle of the stock. Some of these factors include passage through 9 mainstem dams and many smaller vertical drop structures on the Okanagan and Columbia Rivers, commercial and sport harvests, and numerous physical and thermal barriers during upstream migration.

   The life-cycle model will use historical data and (where necessary) expert judgement to quantify these and other mortality factors and project ranges of future adult population abundance of Okanagan sockeye after reintroduction to Skaha Lake. This will provide a tool for addressing questions such as:

   - What are the overall benefits of reintroduction to Skaha Lake (in terms of numbers of returning adults)?
   - What are some of the potential bottlenecks in overall survival that constrain the benefits of reintroduction to Skaha Lake?
   - How would reducing these bottlenecks through various mitigation measures affect overall production of Okanagan sockeye?

2. **Explore risks to resident kokanee**

   Some agencies have expressed concern over the potential effects of the reintroduction of sockeye salmon on resident kokanee stocks. Potential risks include transmission of disease (which is being assessed through field sampling and assays), and increased competition between kokanee and sockeye juveniles for food resources, particularly in light of an established population of introduced mysid shrimp.

   To assess these risks, the life-cycle model will include a population model of resident kokanee in Skaha Lake, and will model competitive interactions between sockeye, kokanee, and mysis populations. This will allow us to use the model to explore questions such as:

   - What are the possible effects of reintroducing sockeye to Skaha Lake on the abundance of resident kokanee adults?
   - What are potential hypotheses about the mechanism by which kokanee, sockeye, and mysis interact (e.g. effects on lake carrying capacity)?

- What are the implications of these hypotheses in terms of projected effects of sockeye reintroduction on kokanee and sockeye production?
- What are the implications of these results for designing both the re-introduction of sockeye and before / after monitoring?

3. **Explore learning benefits**

   The ultimate purpose of an experimental reintroduction of sockeye into Skaha Lake is to provide a test case for reducing uncertainties surrounding the effects of reintroducing sockeye to Okanagan Lake. The reintroduction of sockeye to Skaha Lake, and the requisite monitoring of key variables both before and after the reintroduction, provides an opportunity to learn something about key uncertainties (e.g. potential impacts of sockeye on resident kokanee populations; mechanisms for sockeye-kokanee-Mysid interactions; shore/river spawning plasticity in sockeye; overall sockeye population responses to increased rearing habitat for juveniles).

1.3 Model Complexity

Our general approach to how much detail to include in a simulation model is to *keep it as simple as possible, but not too simple*. Put differently, we feel that the appropriate level of complexity is that which provides a reasonable representation of alternative hypotheses about the links between management actions (in this model, different reintroduction strategies and other mitigative actions) and performance measures (adult abundance of sockeye and kokanee). The mechanisms that we include in the model are thus best viewed as hypotheses that can in theory be tested using empirical data, either now using existing data or in the future if certain data are collected. Data do not necessarily need to be collected for all of the relationships included within the model. Rather it is important that a few critical inputs are provided, and the major model components are monitored as experiments are undertaken. Ultimately, the level of complexity is determined by the objectives of the model and the availability of the data upon which to base alternative hypotheses.

It is important to point out that **we are not attempting to build a model that will make precise predictions of system behaviour or outcomes**. Instead, the model will provide a tool for exploring the relative benefits and risks of possible reintroduction strategies and alternative monitoring approaches. The model should be thought of as a tool to explore the range of possible futures, and the key factors which determine them. The entire process of developing a model is an effort to discover how much detail must be included to adequately describe the behaviour of the system (i.e. to meet the model's objectives).The modelling process should therefore be viewed as iterative, with more components being incorporated only as they are needed and as components previously incorporated are understood (Figure 1.1). The current version of the OkSockeye model is an improvement over earlier versions, but can still be improved by incorporating information gathered through experiments and monitoring.

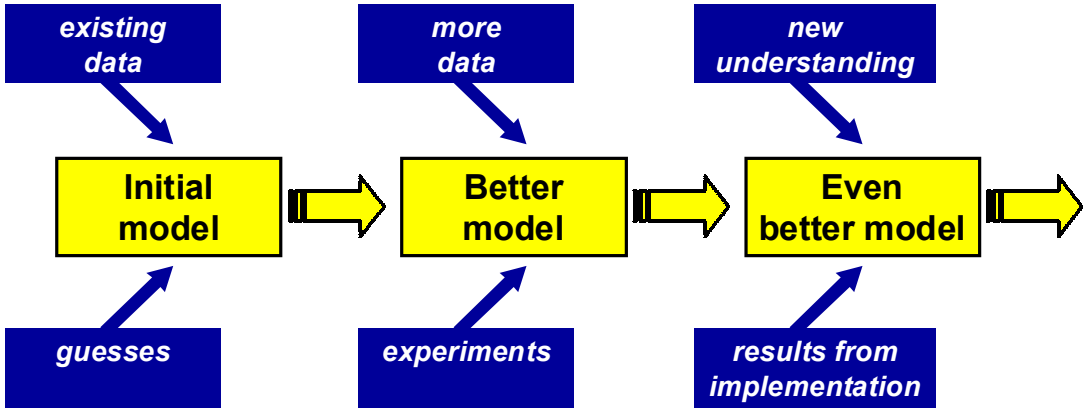


Figure 1.1. Iterative approach to model development.

Given the objectives of this model, and the limitations in available data, we have adopted the following simplifying principles in the model design:

1. While in reality there are many potential mortality factors at each life stage, we have chosen to model only the one or two that we perceive to be the most important or the most amenable to management control.
2. Where possible, we rely on simple empirical relationships rather than detailed mechanistic processes. Where more detailed mechanistic approaches are necessary, we have focussed on those mechanisms that appear to be most important in determining survival and growth rates.
3. We have chosen to represent some model components with single input values that may be derived from a more complicated model external to this one (see section 1.4 for an example).
4. We will attempt to make the model design sufficiently flexible to accommodate updates/improvements as more information becomes available or more detailed modules are developed. This modular structure has already proved to be useful in implementing some of the major changes since version 1.0 of the model was released.

We believe that these principles will result in a model that is detailed enough to meet the project objectives, while remaining consistent with the amount of data available.

1.4 Relationship to the Fish / Water Management Tool (FWMT)

The Okanagan Basin Technical Working Group, ESSA Technologies Ltd., and Summit Environmental, with funding provided by Douglas Country Public Utility District, have recently developed a Fish / Water Management Tool (FWMT) to explore the effects of flow management at Penticton Dam on downstream sockeye and Okanagan shore-spawning kokanee populations (ESSA Technologies and Summit Environmental 2002). The FWMT model goes into considerably more detail on sockeye early life history stages and its interactions with river flows and temperatures than the OkSockeye model, but considerably less detail on the migrating smolt, ocean residence, and adult return life stages. The two models are therefore complementary, and it will be useful to run the two models simultaneously (i.e., using outputs from FWMT as inputs to OkSockeye and vice-versa) to explore a wider range of suites of management actions (across all life history stages) than can be explored by either of the models on their own.

2.0 Model Scope and Overall Structure

2.1 Spatial and Temporal Scope

The spatial scope of the model is shown in Figure 2.1. Given the purpose of the model, the model will focus on the following populations:

- sockeye salmon in Osoyoos Lake;
- sockeye salmon in Skaha Lake (this population doesn't currently exist, but could be formed by a northward extension of the Osoyoos Lake population if fish passage around McIntyre Dam is provided);
- kokanee in Skaha Lake; and
- mysis in Skaha Lake.

The model will also include hydrography (flows, air and water temperatures) of Okanagan Lake and the Upper Columbia River to the extent that these physical factors affect downstream fish populations.

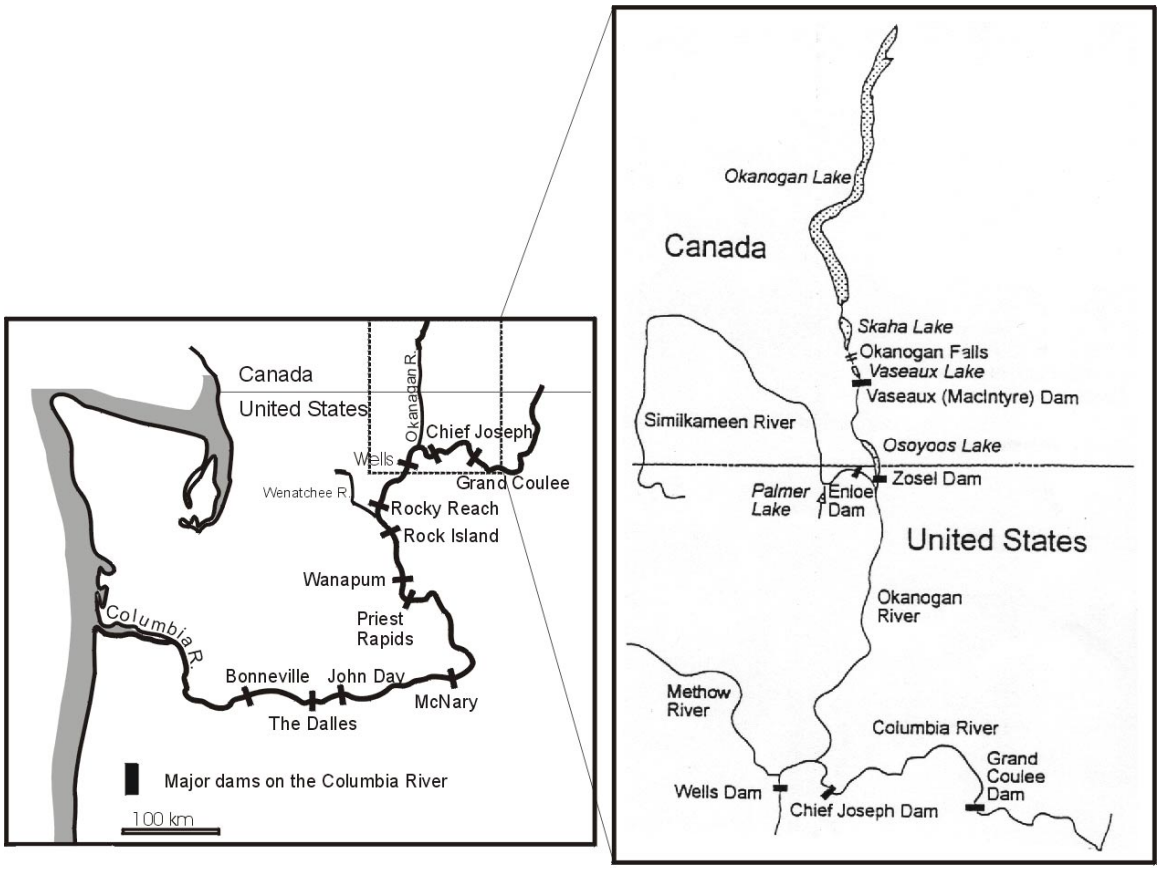


Figure 2.1. Map of Columbia and Okanagan Rivers. Inset: Map of Okanagan Basin showing major lakes and dams (inset source: Fryer 1995).

The model will operate at an annual time step, although certain processes will require a finer temporal resolution to capture the dynamics of physical and biological interactions. For example, simulation of sockeye spawning will require a seasonal or monthly time step to account for the effects of seasonal flows on spawning habitat. Similarly, upstream migration of sockeye through the Okanagan River from the confluence with the Columbia River to Osoyoos Lake will be modelled on a daily time step to account for the effects of water temperature on migration timing. Characteristics of fish and mysis populations will be accumulated on an annual basis. Given the pre-dominant 4-year life cycle of Okanagan sockeye, a 20 to 30-year (5–8 generations) time horizon for forward simulations will probably be sufficient.

2.2 Management Actions

One of the benefits of models is that it allows users try out different policies and combinations of policies and assess their relative effectiveness. For example, users of the model might wish to explore a scenario that includes harvest of mysis in Skaha Lake, reduction of harvest rates in the lower Columbia River, and flow management to reduce summer water temperatures in the Okanagan River. The model will allow users to implement the management actions shown in Table 2.1. In most cases, management actions are assumed to be constant from year to year.

Table 2.1. Management actions implemented in the model, their mechanism (Direct via user-defined parameter value; Indirect via parameterisation of functional relationship), and relevant equation in this report.

Action	Mechanism	Equation
Sockeye		
Changes in phosphorus concentrations of Osoyoos and Skaha Lakes	Direct	
Improvement in habitat quality	Indirect via parameterisation of spawning capacity vs. flow	4-2
Creation of new habitat	Direct	4-3
Hatchery fry supplementation	Direct	4-12
Smolt supplementation	Direct	4-24
Predator control in Okanagan Lakes (esp. Vaseaux)	Indirect via survival rate from rearing lakes – Wells Dam	4-25
Operation of mainstem dams	Indirect via mean SAR, upstream survival rate	4-26, 4-32
Control of northern pikeminnow in Columbia R. reservoirs	Indirect via mean SAR	4-26
Harvest in the Lower Columbia River.	Direct	4-30, 4-31
Harvest rate on Okanagan River.	Direct	4-35
Adult supplementation	Direct	4-37
Kokanee		
Changes in phosphorus concentrations of Osoyoos and Skaha Lakes	Direct	
Improvement in habitat quality	Indirect via parameterisation of spawning capacity vs. flow	4-2
Creation of new habitat	Direct	5-21
Recreational harvest	Direct	5-17

Action	Mechanism	Equation
Mysis		
Annual harvest	Direct	6-9
Lake Predators		
Annual harvest	Direct	7-4

2.3 Overall Model Structure

The model will consist of five submodels (described in detail in the next sections):

1. Hydrology / Temperature submodel;
2. Sockeye submodel;
3. Kokanee submodel;
4. Mysis submodel; and
5. Lake Predator submodel.

The submodels are connected as shown in Figure 2.2. The hydrology submodel provides flows and temperatures that drive key biological processes in the sockeye, kokanee, and mysis submodels. The sockeye, kokanee, and mysis submodels exchange production information for determining density-dependent growth and survival rates in food-limited rearing habitat in Skaha Lake. The model also includes potential predation on mysis by kokanee. The predator submodel calculates the biomass of sockeye fry and kokanee required to support production of predator populations.

Sections 3–7 describe in detail the proposed design of the submodels. Section 8 summarises the user-defined parameters and preliminary parameter values.

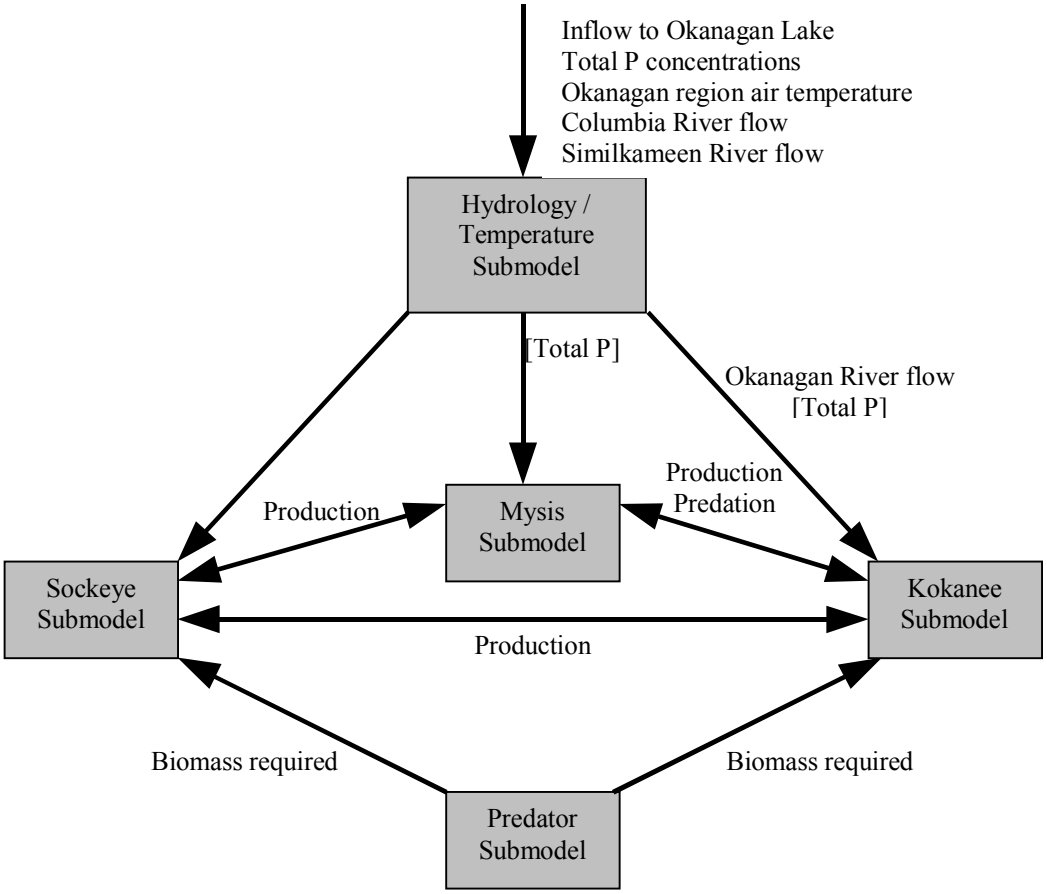


Figure 2.2. Overall structure of model showing linkages between submodels.

3.0 Hydrology / Temperature Submodel

The Hydrology / Temperature submodel is important for determining sockeye habitat spawning capacity, egg to fry survival and the survival of returning adults (see Figure 4.1).

3.1 Selection of Inputs to Hydrology / Temperature Model

Major inputs and outputs of the hydrology / temperature submodel are shown in Figure 2.2. Inputs to the hydrology submodel are assumed to be due to natural precipitation and weather processes (e.g. inflow to Okanagan Lake is governed by precipitation in the Upper Okanagan watershed and/or to management actions that are beyond the scope of this model; Similkameen River flows are determined by precipitation in the Upper Similkameen watershed and by management of Enloe Dam). To capture the variation in these inputs, the hydrology submodel will simply select a series of sequential water years from historical datasets to represent future flow and temperature scenarios (Table 3.1). It is preferable to select from a long a time series as possible to capture a broad range of environmental conditions.

For example, a 20-year simulation may use the daily flow and temperature data from years 1956-1975 to drive the model. Daily flow and temperature data will be aggregated up to annual, monthly, or seasonal values (averages, maxima, minima) as needed to fit the temporal requirements of the sockeye, kokanee, and mysis submodels. Starting water years can be selected randomly (to represent uncertainty in future climate conditions), or one could specify a particularly wet or dry series of water years to represent alternative hypotheses about future climate regimes.

Table 3.1. Hydrologic data sets.

Data	Years Available	Source
Okanagan Lake inflows	1922 to 1997	Bull 1999, citing Ward and Associates 1998
Okanagan River flow (at Oliver)	1944-1999	Stockwell et al. 2001
Similkameen River flow (at Nighthawk)	1928 to 2001	WA Dept of Ecology (www.ecy.wa.gov/programs/ewp)
Okanagan Region air temperature (at Oliver)	1939 to 1999	Environment Canada; Stockwell et al. 2001
Phosphorus concentrations in Skaha and Osoyoos Lakes	1968 to 2001	Geri Huggins, WLAP (email dated March 25 2002)

Historical flow and temperatures will be used to calculate various physical attributes in the Upper Okanagan River (between Okanagan Lake and Osoyoos Lake) and Lower Okanagan River (from Osoyoos Lake to the confluence with the Columbia River). Phosphorus concentrations are used to determine the productive capacity and Secchi Depths of rearing lakes. The following sections provide more details on how physical attributes are used in the other submodels to drive biological processes, the spatial and temporal elements of these attributes, and the proposed approaches for calculating them.

3.2 Flow in the Okanagan River (above Osoyoos Lake)

Flows in the Okanagan River (between Okanagan Lake and Osoyoos Lake) during spawning (September-October) will be used to determine the capacity of spawning habitat for Skaha Lake and Osoyoos Lake sockeye spawners. Flows during incubation (November–February) will be used to determine the flushing and stranding mortality of emergent sockeye fry. Daily flows during the summer (June – September)are used to determine daily temperatures, which determine the spatial distribution of sockeye spawners in the Okanagan River.

Flows out of Okanagan Lake are regulated to balance biological requirements of downstream sockeye, and regulation of lake levels for recreation, flood control, and biological requirements of shore-spawning kokanee. A detailed management model of Okanagan River flow management is beyond the scope of this project and is currently a task in an Okanagan Basin Technical Working Group project funded by the Douglas County PUD. The earlier draft of the design document proposed a simple approach to capture possible management effects on Okanagan River flows, but participants at the February 27th workshop suggested that the proposed approach was too simplistic and that it was too difficult to model this complex management situation in a simple way.

Therefore, in this model we assume that management of Okanagan River flows will continue into the future as they have since the Canada-BC Okanagan Basin Implementation Agreement was developed in the early 1970s. This agreement prescribes minimum and maximum flows during spawning, incubation, and upstream migration periods. Flows are managed to remain within these bounds, within the constraints imposed by drought and high flow conditions. This approach will produce flows within the prescribed minima and maxima in average water years, but will also produce flows outside of the prescribed constraints during the relatively rare water years when flows are excessively high or low.

This approach will be implemented in the model by using actual spawning, incubation, and upstream migration flows (as measured at Oliver, B.C.) for water years 1974 through 1999 (i.e., the years in which the current set of management rules have been implemented). Water years prior to 1974 will be “mapped” to post-1974 years according to the similarity of net inflows to Okanagan Lake (an indicator of natural runoff conditions). For example, comparison of net Okanagan Lake inflows for 1944 to net inflows for the 1974–1999 (current management years) suggests that runoff conditions in 1944 were most similar to those in 1985 (Figure 3.1). Therefore, if water year 1944 is selected for a given simulation year, then actual Oliver flows from the year 1985 will be used to drive physical and biological processes in the model. The result of this mapping approach is a simulated time series of spawning, incubation, and upstream migration flows from 1944–1999 (Figure 3.2). Simulated flows from 1944–1973 approximate what managed flows would have been in those years, given the post-1973 management regime and the natural runoff conditions in those years. In general, simulated flows during the 1944–1973 period are less variable than the actual flows.

Future development of a more detailed management model of Okanagan River flow control can feed into this model by providing revised historical time series of spawning, incubation, and upstream migration flows for sets of alternative management regimes.

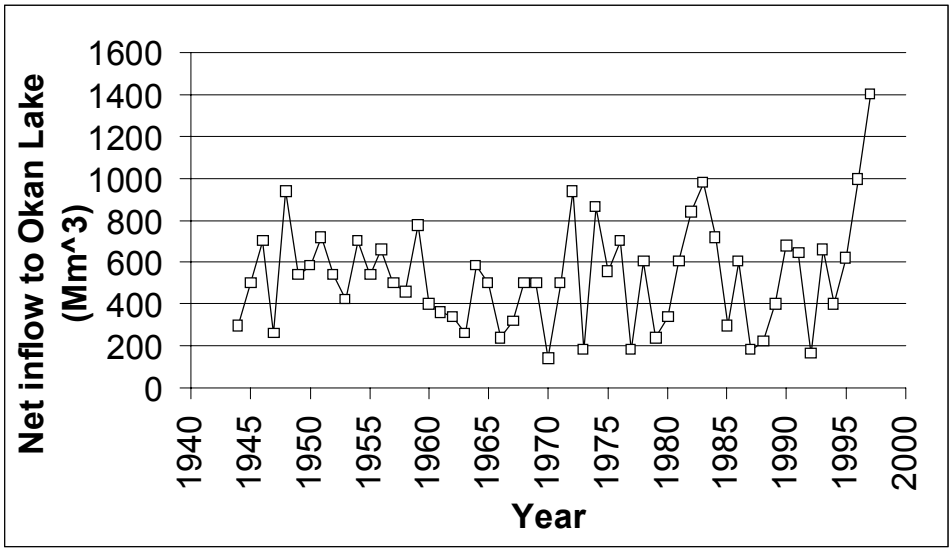
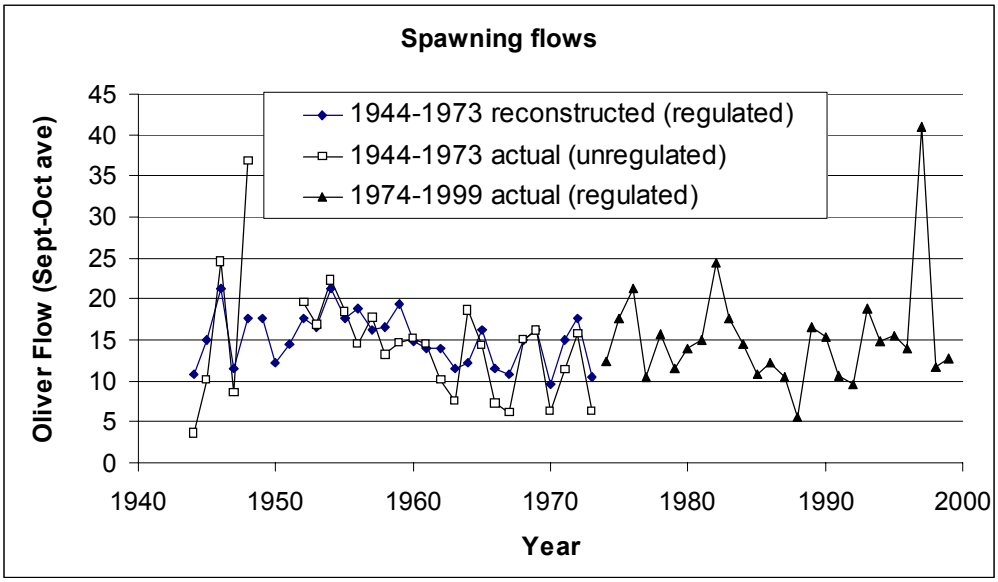
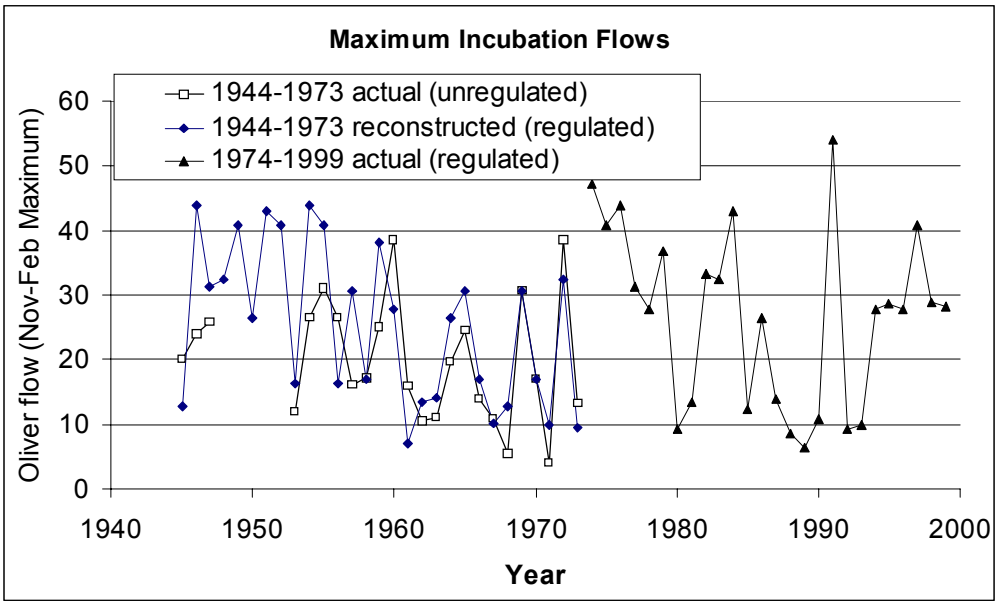


Figure 3.1. Net inflows to Okanagan Lake, 1944-1997.

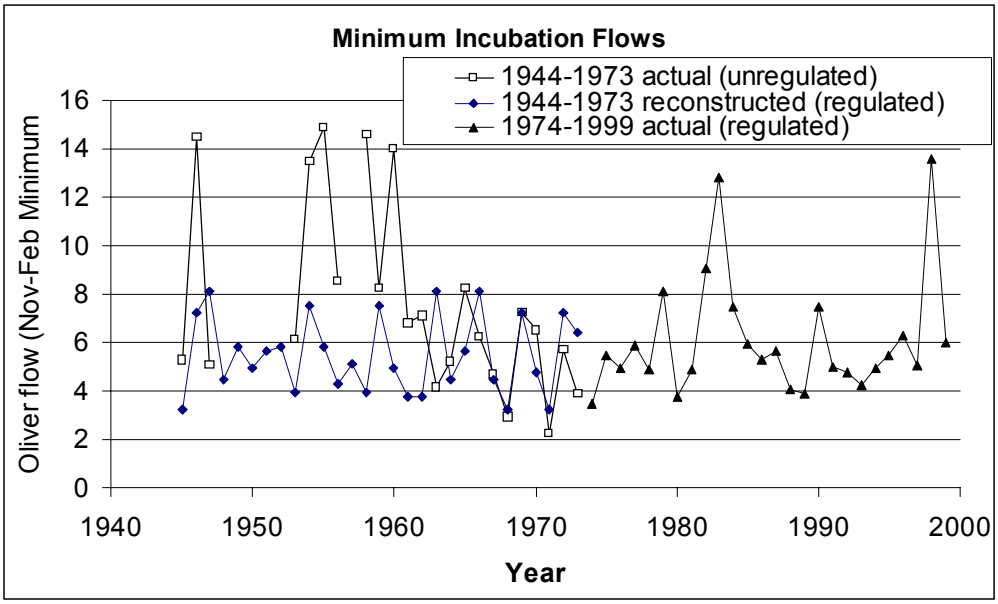




(Graphs continued on next page)

Figure 3.2. Reconstructed spawning, incubation, and upstream migration flows at Oliver for years 1944-1974 based on mapping to post-1973 years.

(Graphs continued from previous page)



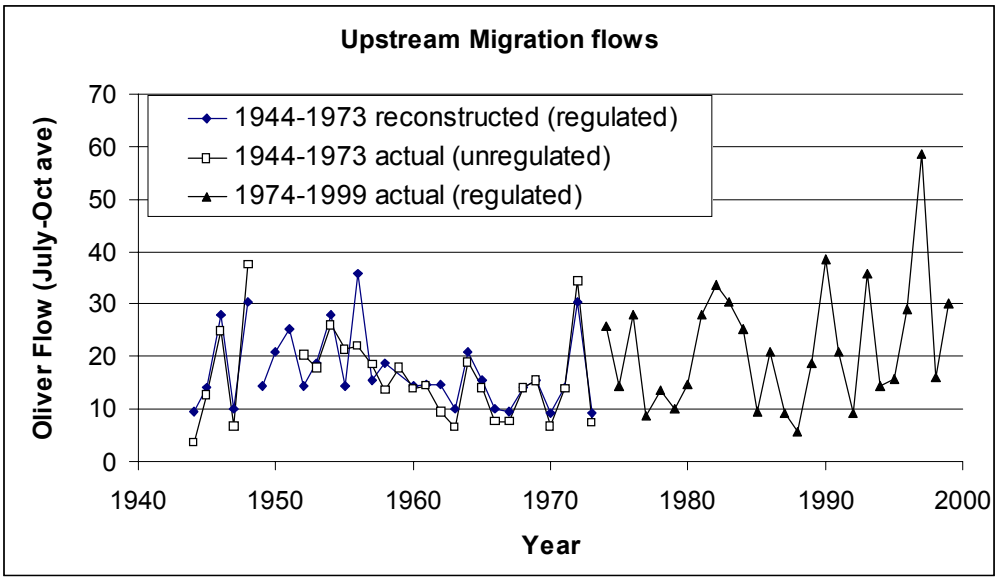


Figure 3.2. Reconstructed spawning, incubation, and upstream migration flows at Oliver for years 1944-1974 based on mapping to post-1973 years.

3.3 Temperature in the Okanagan River (at Okanagan Falls)

Note: The empirical relationship between water temperatures and 5-day average air temperatures developed for version 1.0 of the model has been replaced with the seasonal relationships developed by Hyatt and Stockwell (2002) for the FWMT project.

Water temperatures between Osoyoos and Skaha Lakes during the adult migration period (June–October) are required to determine the distribution of returning sockeye spawners between the two lakes. Lower temperatures in the Okanagan River will permit sockeye spawners to migrate further up the river (see section 4.6.3). Water temperatures are derived from a relationship between water temperatures and air temperatures developed by Hyatt and Stockwell (2002). The relationship is:

$$WaterTemp_{OkFalls} = Slope_{OkFallsTemp}\,(AirTemp_{Oliver,10\text{-}dayAve}) + Int_{OkFallsTemp} \qquad \text{[eq. 3-1]}$$

where: $AirTemp_{Oliver,10\text{-}dayAve}$ = air temperature measured at Oliver, average of 10 days preceding day on which water temperature recorded

Slope and $Int_{OkFallsTemp}$ = user-defined parameters, based on empirical relationship

We will use this relationship to construct a daily time series of water temperatures for water years 1944-1999. The time series used in a particular simulation year will be selected according to water year as discussed above.

3.4 Flow and Temperature in the Okanagan River (below Osoyoos Lake)

Note: The empirical relationship between water temperatures and 5-day average air temperatures developed for version 1.0 of the model has been replaced with the seasonal relationships developed by Hyatt and Stockwell (2002) for the FWMT project.

Daily flow and water temperatures in the Okanagan River below Osoyoos Lake are used (in conjunction with flows and temperatures in the Similkameen River, which joins the Okanagan River south of Osoyoos Lake) to determine water temperatures in the Lower Okanagan River (at the confluence with the Columbia River) between June and September. Summer temperatures in the lower river are used in the sockeye submodel to determine when returning adults enter the Okanagan River (see Section 4.6). This timing affects both the distribution and survival of returning adult spawners.

Flows below Osoyoos Lake will be selected according to water year using the same mapping approach described above for flows at Oliver. Only post-1973 actual flows will be used, to represent the assumption that future management rules will be the same as those in place since 1974. The reconstructed time series of average upstream migration flows is shown in Figure 3.3.

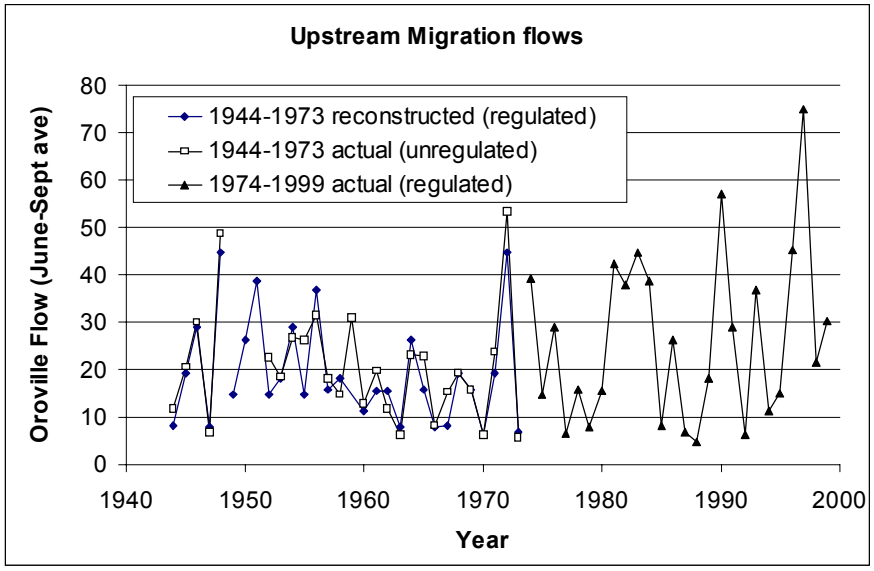


Figure 3.3. Reconstructed upstream migration below Osoyoos Lake for years 1944-1974 based on mapping to post-1973 years.

Because water temperature data in the Okanagan River are intermittent, we reconstructed a continuous time series of daily water temperatures based on an empirical relationship between water temperature at Zosel Dam (Oroville, WA) and air temperatures at Oliver (Hyatt and Stockwell 2002).

$$WaterTemp_{Oroville} = Slope_{OrovilleTemp}\ (AirTemp_{Oliver,10\text{-}dayAve}) + Int_{OrovilleTemp} \qquad \text{[eq. 3-2]}$$

where: $AirTemp_{Oliver,5\text{-}dayAve}$ = air temperature measured at Oliver, average of 10 days preceding day on which water temperature recorded

Slope and Int = user-defined parameters, based on empirical relationship

3.5 Flow and Temperature in the Similkameen River

Daily flows and temperatures in the Similkameen River, the largest tributary to the Okanagan River south of Osoyoos Lake, are needed to calculate temperatures in the lower Okanagan River. Flow data from the Similkameen River (measured at Nighthawk, located about 8 miles from the confluence with the Okanagan River) is available from 1928, and will be selected according to water year as described in section 3.1. Water temperature data for the Similkameen River is also intermittent, so we developed a relationship between summer (June-September) water temperatures, air temperatures (measured at Oliver) and Similkameen River (at Nighthawk) flows ($p << 0.001$; R-squared = 0.85):

$$WaterTemp_{Sim} = Const_{SimTemp} + TempCoef_{SimTemp} * AirTemp_{Oliver} + FlowCoef_{SimTemp} * Flow_{Sim} \qquad \text{[eq. 3-3]}$$

where: $WaterTemp_{Sim}$ = daily water temperature in Similkameen River;

$Const_{SimTemp}$, $TempCoef_{SimTemp}$, $FlowCoef_{SimTemp}$ = user-defined parameters, based on empirical relationship between water temperature, air temperature, and flow (parameter values are 6.22692, 0.58611, and –0.0005, respectively)

$AirTemp_{Oliver}$ = daily air temperatures, selected according to water year

$Flow_{Sim}$ = daily flow of Similkameen River at Nighthawk, selected according to water year

3.6 Temperature in the lower Okanagan River (at confluence with Columbia River)

Summer daily water temperatures (June-September) in the lower Okanagan River are important in determining the migration timing of returning adults. Water temperatures greater than 21 degrees constitute a thermal block to upstream migration, and fish will hold in the Columbia River until water temperatures in the Okanagan River fall to below that threshold. Delays in migration may be associated with lower prespawning survival and egg viability (Alexander et al. 1998).

There is no long-term continuous record of daily water temperatures in the lower Okanagan River. Therefore, in the model, daily temperatures in the lower Okanagan River will be approximated as the flow-weighted average of water temperatures in the Okanagan River at Zosel Dam and in the Similkameen River:

$$WaterTemp_{OkLower} = \frac{Flow_{Oroville,Summer} * WaterTemp_{Oroville} + Flow_{Sim} * WaterTemp_{Sim}}{AdjFlow_{Oroville} + Flow_{Sim}} \quad \text{[eq. 3-4]}$$

where: $Flow_{OkOroville}$ = selected according to water year (see Figure 3.3)
$WaterTemp_{OkOroville}$ = derived from equation 3-2
$Flow_{Sim}$ = daily flow of Similkameen River at Nighthawk, selected according to water year
$WaterTemp_{Sim}$ = derived from equation 3-3

The weighted average as calculated in equation 3-4 closely approximates the limited observations of water temperatures at Malott, WA about 11 miles from the confluence with the Columbia River (Figure 3.5; correl. coeff. = 0.96).

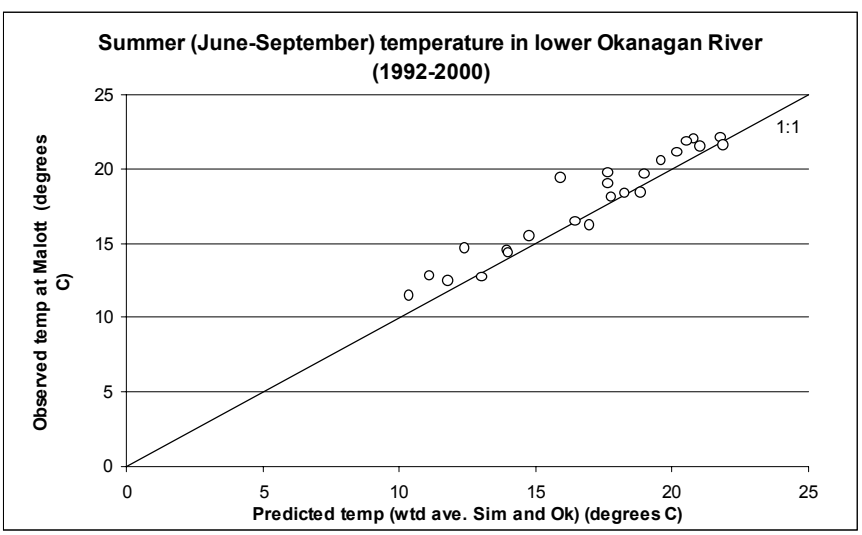
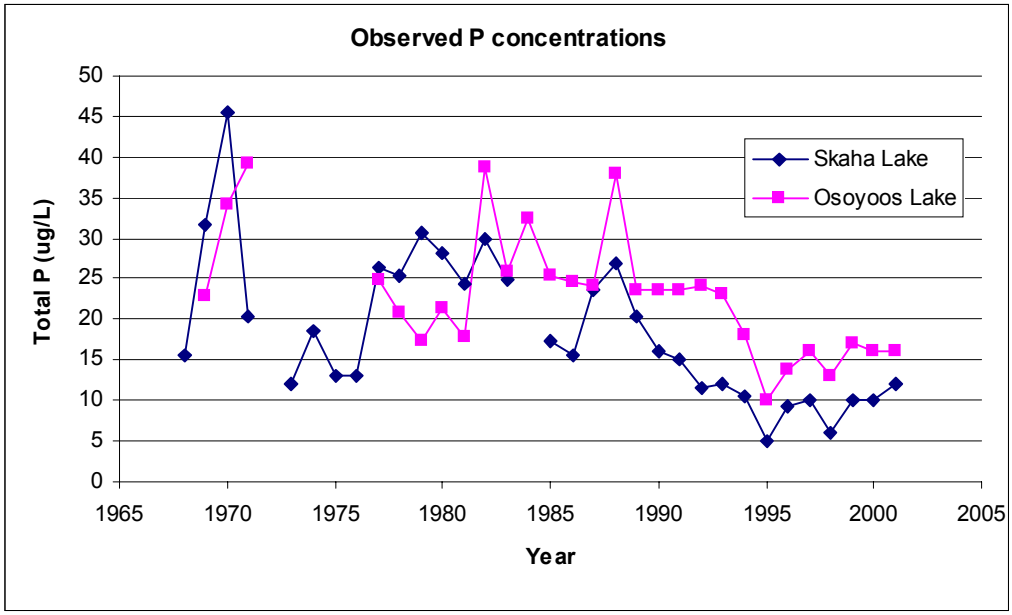


Figure 3.5. Predicted vs. observed water temperature in lower Okanagan River. Observed water temperatures from Stockwell et al. 2001.

3.7 Phosphorus concentration in Osoyoos and Skaha Lake

Total phosphorus concentrations have been found to be a reasonable predictor of a lake's ability to produce fish biomass (Hyatt and Rankin 1999). Total phosphorus concentrations for Osoyoos and Skaha Lakes are shown in Figure 3.6 (top panel). P concentrations have declined since the earliest records around 1970, likely as a result of installation of more efficient sewage treatment plants in the 1970s and 1980s. We assume that post-1985 values represent current conditions, and use these values to reconstruct a continuous time series of P concentrations from 1944 to 1984 (Figure 3.6, bottom panel). Reconstruction of the pre-1985 years is based on similarity in the maximum flows in the Okanagan River at Oliver (see Figure 3.2). The reconstructed time series thus represents an approximation of the P concentrations that might have been observed in years prior to 1985, given the current efficiency of Okanagan waste treatment plants and the hydrological conditions that existed in the earlier years.



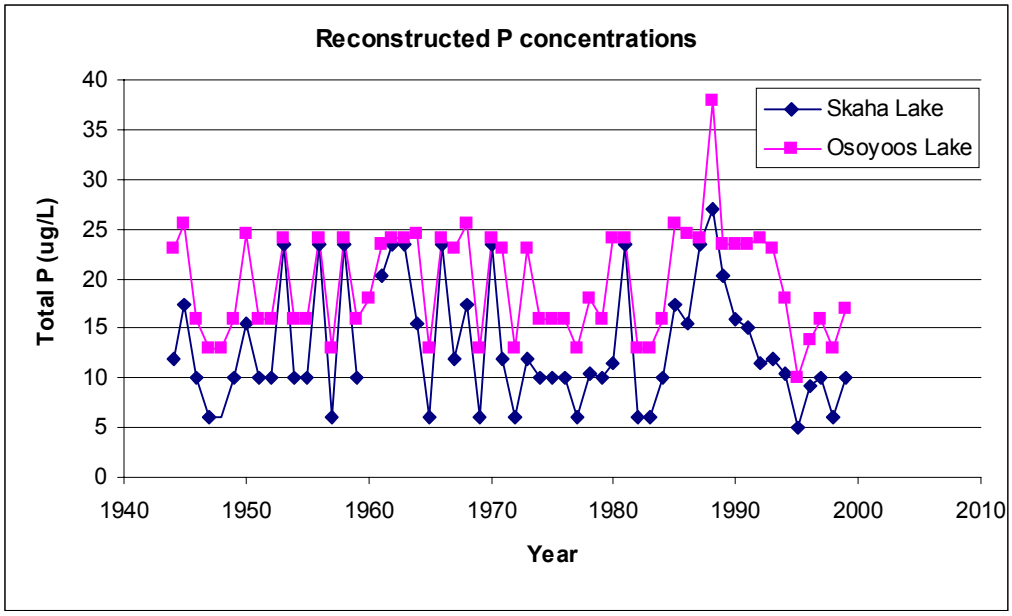


Figure 3.6. Observed (top) and reconstructed (bottom) Phosphorus concentrations in Skaha and Osoyoos Lakes. Reconstruction was based on maximum flows in the Okanagan River at Oliver.

3.8 Secchi Depths in Osoyoos and Skaha Lake

Lake Secchi Depths are required by the Kokanee submodel for determining growth rates of adult fish. We calculate Secchi Depths (in meters) based on Total Phosphorus concentrations using Phosphorus and Secchi Depth data from Okanagan Lake (1997–2000; Andrusak et al. 2001). The relationship is:

$$\log(SecchiDepth) = Int_{SecchiDepth} + Slope_{SecchiDepth} * \log(TotalPhosphorus) \qquad \text{[eq. 3-5]}$$

where: $Int_{SecchiDepth}$ = user-defined parameter
$Slope_{SecchiDepth}$ = user-defined parameter
TotalPhosphorus = total P concentration (ug/L); reconstructed as shown in Figure 3.6.

4.0 Sockeye Submodel

The sockeye submodel is based on survival from one life-stage to the next. Figure 4.1 shows a general schematic of these life stages and the mortality factors included in the model. Each of the linkages is described in the following sections. Participants at the February 27th workshop suggested a simpler approach in which the number of emerging fry is a density-dependent function of spawner abundance. This function would represent the aggregated response of fry production to changes in spawning and incubation flows, assumptions about the capacity of spawning habitat, and other biological parameters such as fecundity and survival rates, and optimal female densities. The function would change from year to year in response to variation in spawning and incubation flows.

We have chosen to retain the less aggregated approach (in which spawner-egg and egg-fry life stages are modelled separately) for two reasons. First, this approach allows more direct control over the capacity of spawning habitat, which workshop participants indicated was a potentially important management action. Second, the less aggregated approach requires assumptions about potentially important biological parameters (e.g. optimal female densities) to be explicit, and allows users to explore the implications of these parameters for model results.

Note that one can reconstruct spawner-fry production relationships using the outputs of the model's aggregated approach, then compare the implied relationships across a set of flow conditions to determine the effects of flows on the shape of the production curves. Some of these comparisons are shown in Section 4.2 below for illustration.

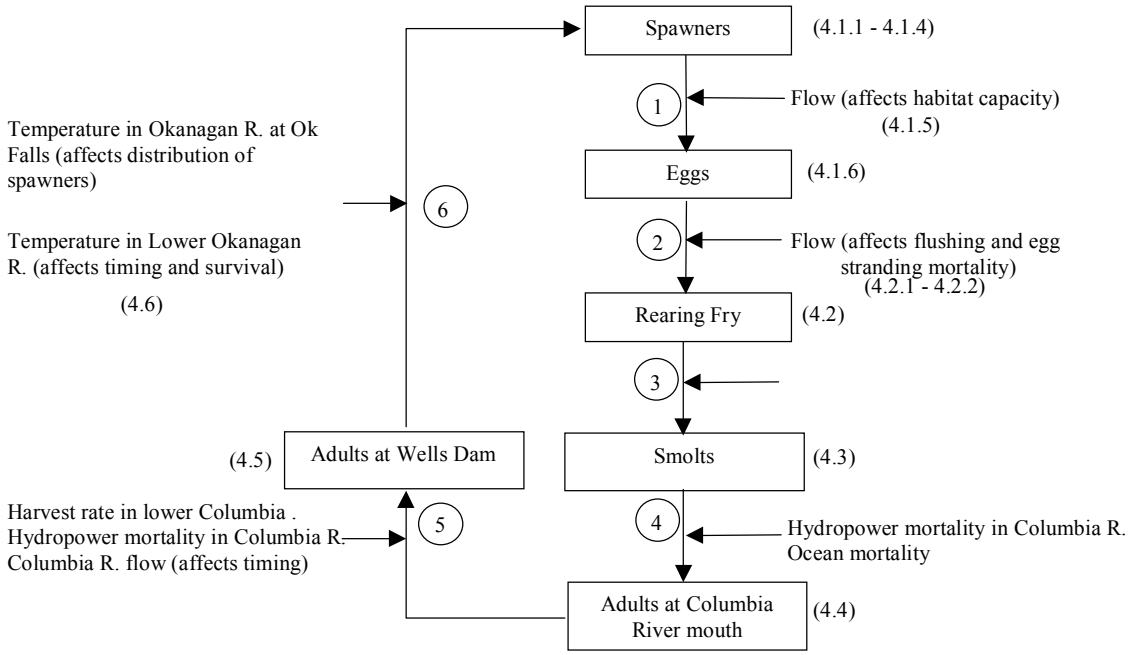


Figure 4.1. Schematic of life-cycle of Okanagan sockeye, showing mortality factors included in the model. Numbers in brackets correspond to sections in which each component is described.

4.1 Spawner - Egg

Egg production is a function of maturity schedule, age-specific fecundity, sex ratio, optimal female density, and spawner capacity of the spawning grounds.

4.1.1 Maturity Schedule

Note: Maturity schedules have been updated using the Core Numbers and Traits (CNAT) estimates from Hyatt et al. (2002), adjusted for fish of unknown age.

Hyatt et al. (2002) estimated the age composition of Okanagan sockeye for 1988-1992 and 2000-2001. Because the vast majority of Okanagan sockeye spend only 1 winter in freshwater (average 96% over the seven years of CNAT estimates), the model assumes that all Okanagan sockeye are age 1.x. The simplified maturation schedule is shown in Table 4.1. The proportions of ages 1.1, 1.2, and 1.3 in Table 4.1 are based on Hyatt et al.'s estimated age composition.

While the maturation schedule is likely a result of interactions between genetic and environmental factors, such complexity is beyond the scope of this model. Instead, we propose to simply select randomly from these seven maturity schedules (and other years if such data are available) for each brood year of sockeye.

Table 4.1. Age composition estimates from Hyatt et al. (2002). Age notation indicates # of winters spent in freshwater. # of winters spent in ocean.

	Age (%)		
Return Year	**1.1**	**1.2**	**1.3**
1988	0.2	98.0	1.8
1989	4.4	92.1	3.5
1990	62.0	26.8	11.2
1991	13.9	84.7	1.4
1992	2.2	97.8	0.0
2000	8.9	90.3	0.8
2001	3.3	94.4	2.3

4.1.2 Age-specific Fecundity

Fryer (1995) reports age-specific fecundity rates (eggs per female) estimated from spawning ground surveys (Table 4.2).

Table 4.2. Age-specific fecundities (Major and Craddock 1965, as reported by Fryer 1995).

Age	Fecundity (eggs per female)
1.1	2014
1.2	2879
1.3	3609

The age-weighted average fecundity in a given brood year is:

$$AveFecundity = \Sigma_t (\#Spawners_t * Fec_a) / \Sigma_a \#Spawners_a \quad \text{[eq. 4-1]}$$

where: $\#Spawners_a$ = # of spawners of age a
Fec_a = fecundity at age a (from Table 4.2)

4.1.3 Female Proportion

Note: Sex composition has been updated using the Core Numbers and Traits (CNAT) estimates from Hyatt et al. (2002).

Hyatt et al. (2002) estimate an average female proportion of 0.52 from 21 years of data between 1971 to 2001. For the Osoyoos population. this value is adjusted to account for removal of females for broodstock for hatchery fry supplementation into Skaha Lake (see section 4.2.6).

4.1.4 Optimal female density

Hyatt and Rankin (1999) report optimal female densities for a number of sockeye stocks. These range from 0.56 to 2.0 females/m^2 (mean 1.48).

4.1.5 Spawner capacity

Existing spawning habitat for Osoyoos Lake sockeye is in the Okanagan River between McIntyre Dam and Osoyoos Lake, with the majority of spawning taking place in the 2.4 km index section immediately downstream of McIntyre Dam (Hyatt and Rankin 1999). Surveys conducted in the early seventies generated estimates of the amount of "good" spawning habitat in this section at various flows (Figure 4.2; Fisheries Service Environment Canada 1973). Potential spawning habitat for Skaha Lake sockeye is available in the channelled portion of the Okanagan River between Okanagan Lake and Skaha Lake. A recent survey of spawning habitat conducted as part of the overall Skaha Lake project estimated that there was 63 m^2 of high quality habitat and 6,955 m^2 of medium quality spawning habitat in this reach (ONFC 2002). Workshop participants noted that this area was not likely to be flow-dependent because the reach is channelled with uniform geometry. Based on this information, we can develop a relationship between flows and spawning habitat to reflect the estimated capacity of both high and medium quality spawning habitat (Figure 4.3; note different scales from Figure 4.2). Note that the relationships shown in Figure 4.3 can be reparameterised to represent potential improvement of existing medium quality spawning habitat to good quality habitat.

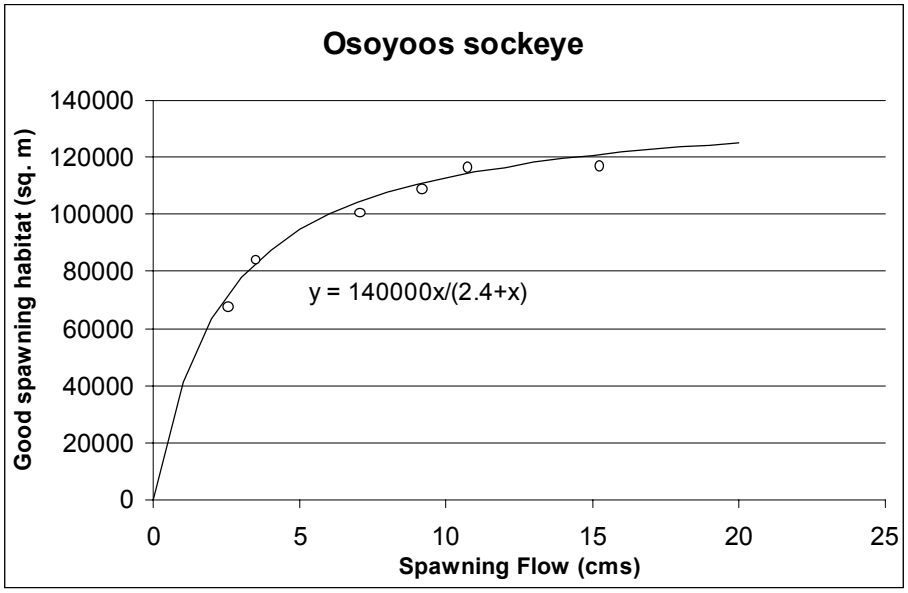
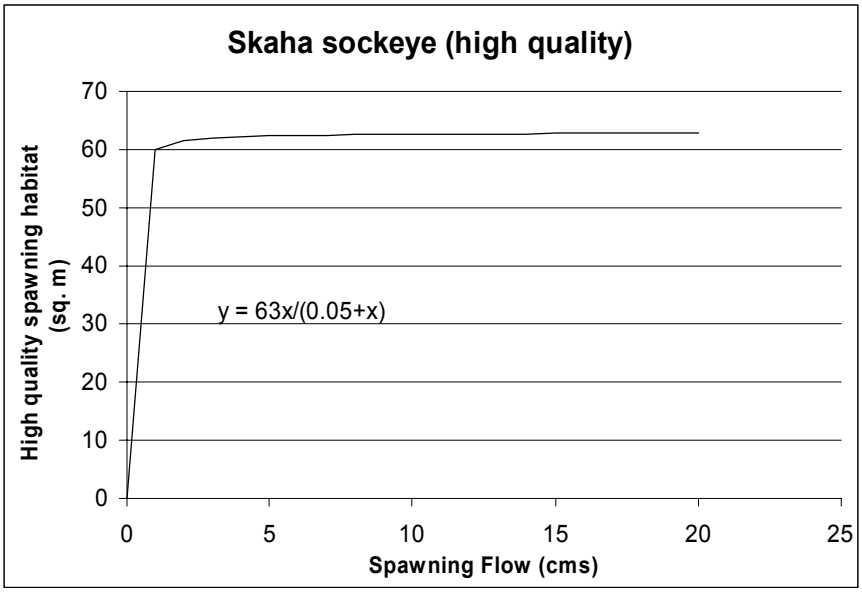


Figure 4.2. Area of good habitat in Osoyoos spawning index reach at various flows.



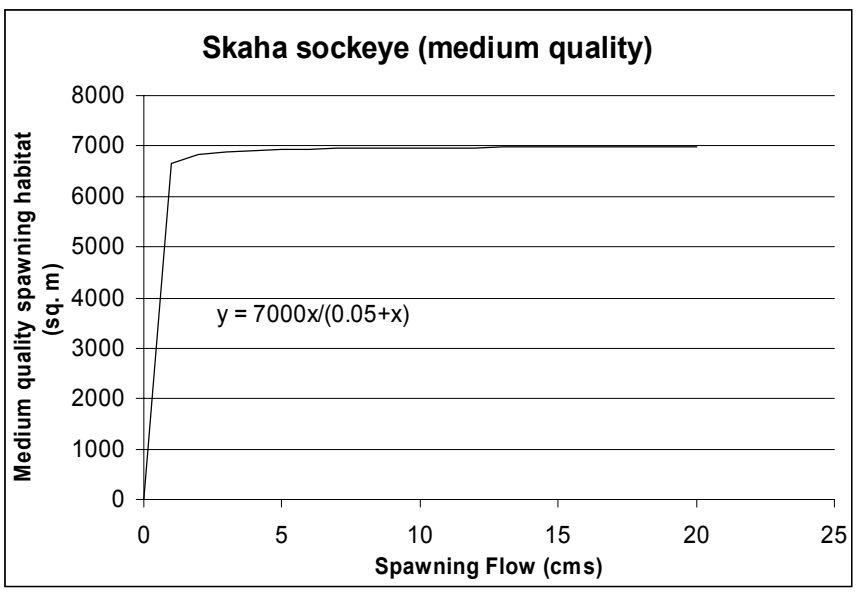


Figure 4.3. Area of high (top) and medium (bottom) quality spawning habitat for Skaha sockeye.

The relationship between spawning habitat and average spawning flows for both Osoyoos and Skaha spawning populations is:

$SpawnHab_{Current} = MaxHabitat * Flow_{Oliver,AveSpawn} / (FHalfMaxHabitat + Flow_{Oliver,AveSpawn})$ [eq. 4-2]

where: MaxHabitat = the maximum amount of habitat at high flows (user-defined population-specific parameter; m^2)

$Flow_{Oliver,AveSpawn}$ = average spawning flow (equation 3-1; cms)

FHalfMaxHabitat = flow producing half of MaxHabitat (user-defined population-specific parameter)

Workshop participants suggested that the model should allow the user to increase the habitat area by a fixed, flow-invariant amount. For Osoyoos sockeye, this could represent potential spawning habitat in the channelled portion of the Okanagan River immediately upstream from Osoyoos Lake. Although most spawning currently takes place in the natural river portion, the channelled portion could become important if spawning densities increase dramatically. The inclusion of a fixed additional habitat area could also be used to represent additional spawning habitat for Osoyoos sockeye between Vaseaux and Skaha Lakes (which would become accessible to Osoyoos spawners if passage around McIntyre and Okanagan Falls dams were restored), or restoration of spawning habitat for Skaha spawners between Skaha and Okanagan Lakes.

Total spawning habitat is therefore given by:

$$SpawnHab_{Total} = SpawnHab_{Current} + SpawnHab_{New} \quad \text{[eq. 4-3]}$$

where: $SpawnHab_{Current}$ = the current amount of habitat derived from equation 4-2 (m^2)
$SpawnHab_{New}$ = additional spawning habitat created or restored (user-defined population-specific parameter; m^2)

An additional complication in determining spawning capacity for Skaha sockeye spawners is the degree of overlap (competition for spawning habitat) with kokanee spawners. Overlap arises because of similarities in the timing, location, and habitat preferences of spawning kokanee and sockeye. Workshop participants suggested that the overlap was likely to occur mainly in the "medium quality" spawning areas, because substrate size in those areas were closer to the range utilised by kokanee (gravel size in the high quality areas is generally larger than the range preferred by kokanee).

To model these interactions, the model will include a user-defined overlap parameter ranging from 0 to 1. This parameter represents the fraction of the total medium-quality spawning habitat (as determined from equation 4-3) that is shared by sockeye and kokanee. A value of 0 indicates that there is no spatial or temporal overlap between the two populations; all spawning habitat is equally available to both populations at the time that they spawn. This represents an hypothesis where the two spawning populations are distinct in time and space. A value of 1 indicates that the two populations overlap completely in time and space; all of the available spawning habitat is competed for by the two populations. Since there is some spatial and temporal overlap between the two spawning populations, one would expect the overlap parameter to have a value close to 1, and a value of 0 for the overlap parameter is probably not justified.

Partitioning of shared habitat is based on the relative abundance of spawners.

The spawning overlap parameter is used to calculate the fraction of medium quality spawning habitat available to sockeye using equation 4-4:

$$SpawnHabFrac_{sockeye} = \#Spawners_{sockeye} / (\#Spawners_{sockeye} + \#Spawners_{kokanee}) * (SpawnOverlap) + (1 - SpawnOverlap) \quad \text{[eq. 4-4]}$$

where: $\#Spawners_{sockeye}$ = obtained from equation 4-37
$\#Spawners_{kokanee}$ = obtained from the kokanee submodel

SpawnOverlap = fraction of habitat competed over by kokanee and sockeye (user-defined parameter)

The total habitat available for use by Skaha Lake sockeye is calculated using equation 4-5):

$$SpawnHab_{Total} = SpawnHab_{Total,Medium} * SpawnHabFrac_{sockeye} + SpawnHab_{Total,High} \quad \text{[eq. 4-5]}$$

where: $SpawnHab_{Total,Medium}$ = amount of medium quality habitat, obtained from equation 4-3 and parameter values given in Figure 4.3 (bottom panel).
$SpawnHabFrac_{sockeye}$ = obtained from equation 4-4
$SpawnHab_{Total,High}$ = amount of high quality habitat, obtained from equation 4-3 and parameter values given in Figure 4.3 (top panel).

Calculated values of spawning habitat for Osoyoos (equation 4-3) and Skaha (equation 4-5) are used to estimate the spawning capacity (maximum number of female spawners on the spawning grounds) based on an optimal female density of 1.48 females / m^2 (mean of other sockeye stocks; Hyatt and Rankin 1999). The equation is:

$$SpawnCapacity = SpawnHab_{Total} * FemaleDensity \quad \text{[eq. 4-6]}$$

where: $SpawnHab_{Total}$ = obtained from equation 4-3 or equation 4-5
FemaleDensity = # of females per sq. m of spawning habitat (user-defined parameter)

4.1.6 Annual egg abundance

The number of eggs laid in a brood year is a Beverton-Holt type of function based on the number of spawners. This function produces a density-dependent relationship between spawner abundance and egg abundance (Figure 4.4). The function is mediated by spawning flow through its effect on the capacity of spawning habitat (equation 4-2).

$$\#Eggs = \frac{\#Spawners_{total} * FemaleProp * AveFecundity}{[1+(AveFecundity/EggCap * (\#Spawners_{total} * FemaleProp)]} \quad \text{[eq. 4-7]}$$

where: #Eggs = total number of eggs deposited
$\#Spawners_{total}$ = number of spawners from equation 4-36 and 4-37
AveFecundity = age-weighted average fecundity (from equation 4-1)
EggCap = egg capacity of spawning habitat
= SpawnCapacity (equation 4-3) * AveFecundity (equation 4-1)
FemaleProp = average proportion of the population that are female (user-defined parameter)

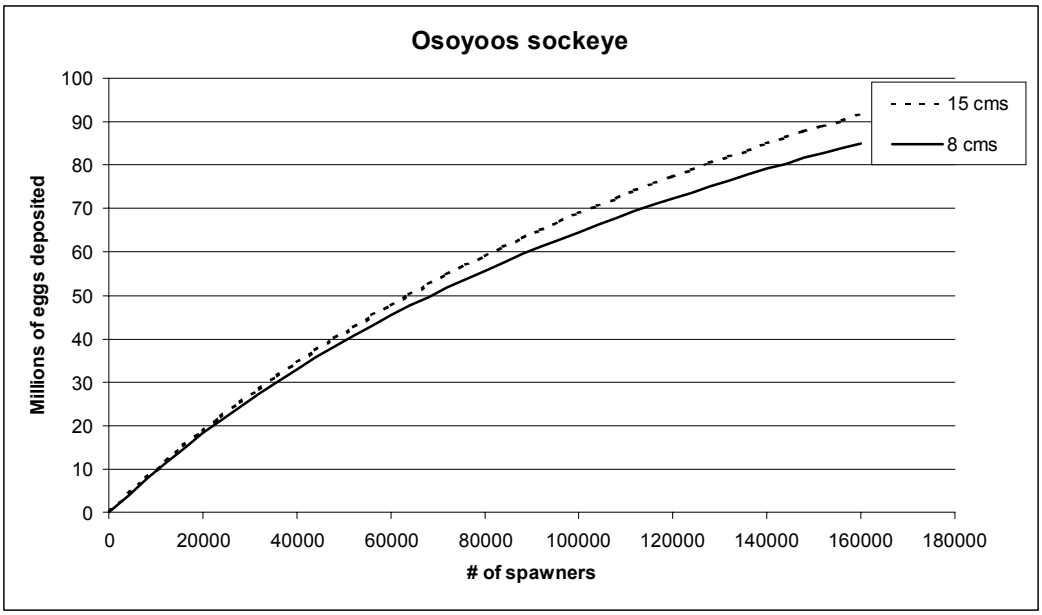


Figure 4.4. Relationship between number of eggs deposited and numbers of spawners at various flows.

4.2 Egg – Fry

Fry production for a given number of eggs is determined by three factors:

1. Egg stranding if incubation flows are too low.
2. Mortality associated with premature flushing of pre-emergent fry by excessive incubation flows.
3. Natural survival rate of eggs (survival in the absence of egg stranding or premature flushing of pre-emergent fry).

4.2.1 Egg Stranding

High flows during spawning followed by low flows during incubation can lead to stranding and desiccation or freezing of redds in the upper margin of the wetted spawning area. In the Okanagan River, minimum incubation flows have ranged from 27 to 69% of average spawning flows since 1981 (Figure 4.5).

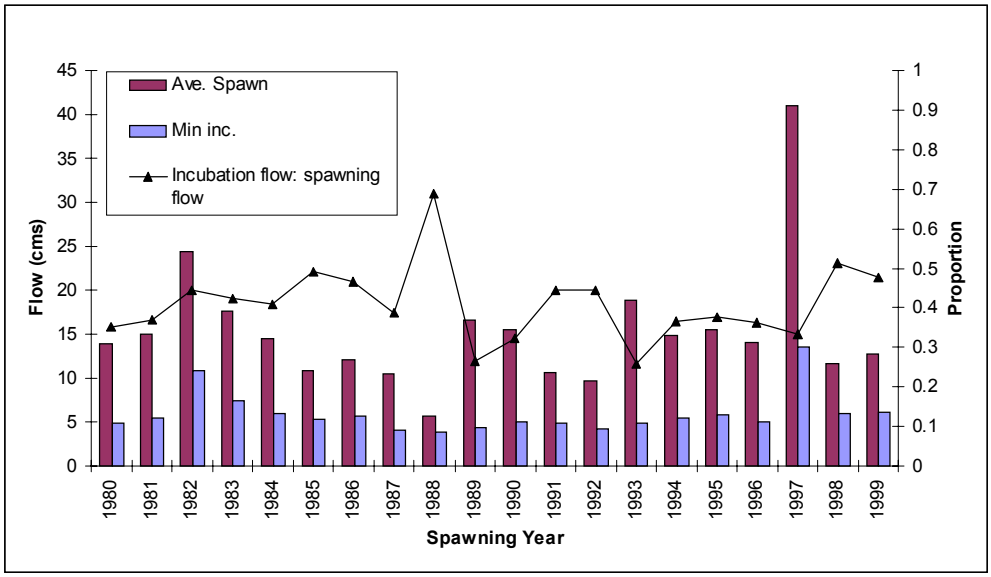


Figure 4.5. Average spawning flows, minimum incubation flows, and the ratio of these flows in the Okanagan River, 1980-1999. Data source: Stockwell et al. 2001.

Presumably, higher stranding mortality is associated with lower incubation flow: spawning flow ratios. Workshop participants indicated that there is no data on stranding mortality, and that eggs will continue to incubate as long as they are wet. We propose to include a simple approach based on the amount of stranding on the change in spawning habitat between spawning and incubation periods, using Figure 4.2 and 4.3:

$$EggSurvRate_{Strand} = 1 - \frac{StrandAdj * (SpawnHab_{AveSpawnFlow} - SpawnHab_{MinIncFlow})}{SpawnHab_{AveSpawnFlow}} \quad \text{[eq. 4-8]}$$

where: spawning habitats are estimated from equation 4-3 and 4-5; and
StrandAdj = adjustment to modify the strength of the stranding effect (user-defined parameter)

The StrandAdj factor reflects the combined effects of channel shape and sockeye depth spawning preferences. Setting StrandAdj >1 would increase stranding mortality; setting StrandAdj <1 would decrease it. Setting StrandAdj = 0 would represent the hypothesis that stranding is not a significant mortality factor for eggs.

4.2.2 Flushing mortality

Note: The scour relationship developed for version 1.0 of the model has been replaced with the scour-mortality relationships developed by Summit Environmental for the FWMT project (Summit 2002).

High incubation flows can lead to flushing of fry out of the gravel prematurely (prior to emergence). Data to characterise this relationship comes from the empirical and modelling work done by Summit Environmental in 2002, where they developed a series of equations to describe redd scour at various flow levels (Figure 4.6). Based on their work, we developed a single equation to compute egg mortality due to scour as a function of flows during incubation:

$$EggSurvRate_{Flush} = 1 - [Flow_{Oliver,MaxInc}^{FlushShape} / (FHalfFlush^{FlushShape} + Flow_{Oliver,MaxInc}^{FlushShape})] \quad \text{[eq. 4-9]}$$

where: $Flow_{MaxInc}$ = maximum daily flow Nov-Feb in Okanagan River, selected according to water year
FlushShape = shape parameter (user-defined parameter)
Fhalf = Flow that generates 50% survival rate (user-defined parameter)

This equation closely approximates the series of equations developed by Summit (2002).

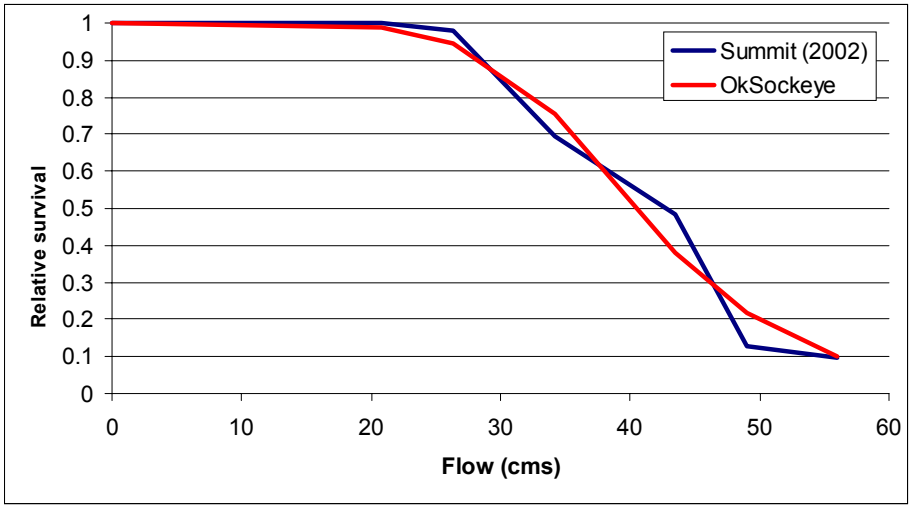


Figure 4.6. Relationship between # of pre-emergent flushed and maximum incubation (Nov-Feb) flow. Data source: Summit (2002).

4.2.3 Natural Survival Rate

Natural egg-fry survival rates in sockeye stocks range from 7 to 50% (17 to 20% in flow-controlled streams) (Bradford 1995). The biostandard for British Columbia is 15% (Shepherd and Inkster 1995). Because these rates can be highly variable, we propose to draw from a log-normal distribution of survival rates with mean and standard deviation set by the user:

$$\ln(EggSurvRate_{Nat}) = N(EggFrySurvMean, EggFrySurvStDev) \quad \text{[eq. 4-10]}$$

where: EggFrySurvMean = mean of the $\log_e$-transformed distribution of survival rates (user-defined parameter)
EggFrySurvStDev = standard deviation of the $\log_e$-transformed distribution of survival rates (user-defined parameter)

We could also use a smaller amount of natural variation in the egg survival rate, and apply the relationship in Equation 4-8 to reflect year to year changes in stranding mortality.

The model will allow different natural egg-fry survival rates (means and standard deviations) for Skaha sockeye eggs laid in medium and high quality spawning habitat to reflect alternative hypotheses about the effects of habitat quality on egg survival (see section 4.1.5). Survival rates may be reduced in medium quality gravel, for example, because of greater amounts of fine sediments and corresponding reductions in oxygen concentrations in redds.

4.2.4 Annual Fry Abundance

The number of fry produced in a year is:

$$\#Fry_{wild} = \#Eggs * EggSurvRate_{Strand} * EggSurvRate_{Flush} * EggSurvRate_{Nat} \qquad \text{[eq. 4-11]}$$

where: #Eggs = derived from equation 4-7
$EggSurvRateS_{trand}$ = derived from equation 4-8
$EggSurvRate_{Flush}$ = derived from equation 4-9
$EggSurvRate_{Nat}$ = derived from equation 4-10

4.2.5 Effect of flow on spawner-fry production functions

The spawner-egg and egg-fry survival relationships described in the preceding sections can be combined to develop implied spawner-fry production relationships. Spawner-fry relationships, while not used explicitly in the model, are useful for assessing the implied effects of flows on overall production of fry. We have developed implied relationships for Osoyoos Lake sockeye in four fry emergence years: 1973, 1974, 1997, and 1998 (brood years 1972, 1973, 1996, and 1997; Figure 4.7). These years were used because fry densities were estimated for those years (Hyatt and Rankin 1999), and because they represent a range of spawning and incubation flows.

For example, 1998 and 1973 both have average or above average spawning flows, and incubation flows that are within the range recommended in the Canada-B.C. Okanagan Basin Agreement. Fry production is highest in those years (the two curves are virtually indistinguishable) because spawning habitat is not flow-limited (Figure 4.2) and incubation flows are not high enough to cause significant flushing mortality (Figure 4.6). 1997 had average spawning flows but excessive incubation flows, leading to higher incidence of flushing mortality and a lower fry production curve. Lowest fry production is seen in 1974, which had both high incubation flows and low spawning flows. Fry production in that year was limited by flow-related reductions in both spawning capacity and in egg-fry survival rates.

The figure also shows the observed spawner and fry abundances for those years. Deviations between predicted and observed values reflect differences between actual natural egg-fry survival rates in those years and the constant natural egg-fry survival rate used to derive the implied relationships (which was around 9%, based on average sockeye values reported by Bradford 1995). For example, the deviation of the observed fry abundance in 1973 from the fry abundance predicted by the implied production function suggests that the natural egg-fry survival rate in that year was considerably lower than 9%.

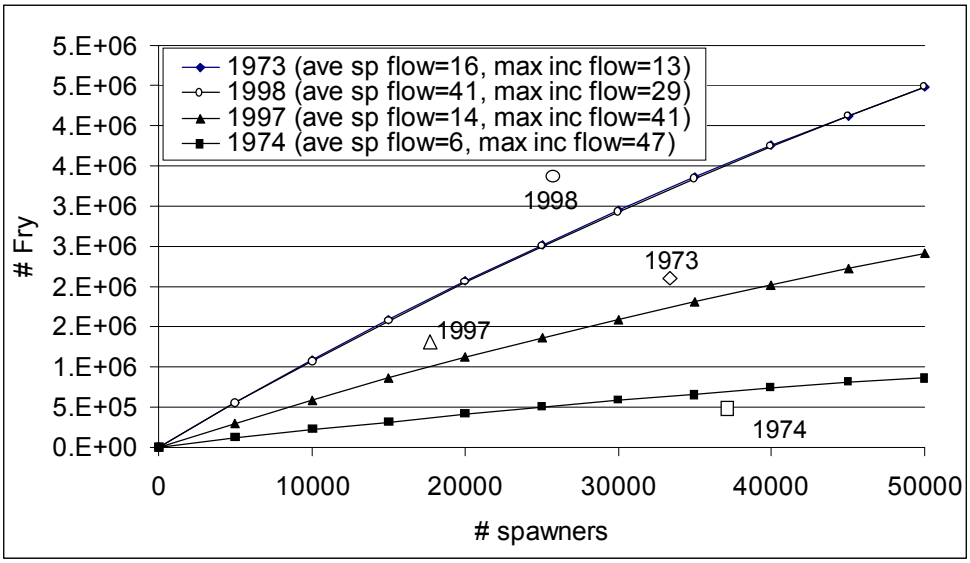


Figure 4.7. Implied fry production curves for 1973, 1974, 1997, and 1998.

4.2.6 Fry Supplementation

Note: This component is new to Version 2.2 of the model, added after the October 2002 review meeting to represent a potential mode of reintroduction to Skaha Lake.

A potential strategy for reintroducing sockeye to Skaha Lake is to extract eggs from female broodstock from the Osoyoos population, raise those eggs to fry stage in a hatchery, then release the fry into Skaha Lake. The OkSockeye model allows users to model this process by selecting a target number of fry to supplement into Skaha Lake for a given year, then computing how many Osoyoos females would have to be from the spawning population in the previous year to produce that number of fry given assumptions about average fecundity and egg-fry survival rates in hatcheries. The equation to compute the number of females required is:

$$\#FemaleBroodstock_{Os,t-1} = FrySupp_{Sk,t} / (AveFecundity * HatcheryEggFrySurv) \qquad \text{[eq. 4-12]}$$

where: $FrySupp_{Sk,t}$ = the target number of fry to release into Skaha Lake in year t (user-defined parameter)

AveFecundity = the age-weighted average fecundity, derived from equation 4-1 (assumes that the age proportions in the group of females extracted for broodstock is the same as in the population).

HatcheryEggFrySurv = survival rate of eggs to fry in hatcheries (user-defined parameter)

To address potential damage to the Osoyoos population by removing too many females, the model includes a hard minimum level of Osoyoos females that must be maintained ($MinFemale_{Os}$). If the number of females required (as computed in equation 4-12) would cause the female abundance of the Osoyoos stock to go below this level, then the model will extract as many females as possible given the minimum constraint and use equation 4-12 to compute the number of fry that can be produced by those females. This means that in years with low returns of Osoyoos sockeye, the target number of fry supplements into Skaha Lake may not be reached. In years when the Osoyoos female population is below the minimum level, no females are extracted.

4.2.7 Fry Production

The total production from sockeye fry (kg/ha) in year t is needed to a) partition lake carrying capacity for survival of sockeye fry, kokanee fry; and immature mysis; and b) compute growth rates of adult kokanee. Fry production values specific to each of these applications are computed by adjusting basic production rates by population and age-specific equivalence factors (described below).

Basic production is calculated from the biomass using Production:Biomass ratios specific to each species and age. Production rate (kg/ha) is calculated as:

$$P{:}B_{SxFry} = FeedingRate_{SxFry} * ConvEff_s \qquad \text{[eq. 4-13]}$$

where: $ConvEff_s$ = conversion efficiency of sockeye fry (kg/ha production per kg/ha consumed; assume same size-dependent function as kokanee; see equation 5-3)

$FeedingRate_{SxFry}$ = feeding rate of sockeye fry (kg/ha consumed per kg/ha biomass; user-defined parameter)

Production from sockeye fry is:

$$SxFryProd_{SxFry} = [\#Fry * (Weight_{SxFry}/1000)] / LakeArea * P{:}B_{SxFry} * SxEquiv \qquad \text{[eq. 4-14]}$$

where: #Fry = computed from equation 4-11 (plus any supplemented fry from equation 4-12)

$Weight_{SxFry}$ = user-defined parameter (g)

LakeArea = area of rearing lake (ha)

$P{:}B_{SxFry}$ = Production:Biomass ratio of sockeye fry (see equation 4-13)

SxEquiv = sockeye equivalence factor (user-defined parameter; depends on species)

The SxEquiv factor for determining the effects of sockeye fry on sockeye smolt capacity is obviously 1. However, for determining the effects of sockeye fry on kokanee and mysid survival and growth the equivalence factors represent differences in competitive ability and ecological niches beyond the differences represented by differences in P:B ratios. Examples of such differences that can be represented by the equivalence factors include differences in diet, spatial or temporal overlap, or the ability of populations to physically exclude other populations from food or space. Two equivalence factors are needed:

1. The equivalence factor $SxEquiv_{JuvSurv}$ is needed for partitioning lake carrying capacity for survival of kokanee and mysis juveniles. This equivalence factor, and the analogous equivalence factor for mysis, is expressed in terms of kokanee juveniles (i.e. $SxEquiv_{JuvSurv}$ =2 implies that sockeye fry are twice as successful as kokanee fry in utilising lake capacity). The use of kokanee juveniles as a "common currency" simplifies the definition of equivalence factors while still allowing for complex interactions among sockeye, kokanee, and mysis juveniles. For example, setting the sockeye equivalence factor to 1 and the mysis equivalence factor to 0.5 would imply that mysis are half as competitive as both sockeye and kokanee juveniles. Setting the sockeye equivalence factor to 5 and the mysis equivalence factor to 0.5 would imply that mysis are half as competitive as kokanee juveniles but are 1

tenth as competitive as sockeye fry. As a preliminary assumption, we assume that sockeye fry and kokanee fry are direct ecological analogs (i.e., $SxEquiv_{K,Fry} = 1$).

2. The equivalence factor $SxEquiv_{AdGrowth}$ is needed to account for the effects of sockeye production on growth rates of adult kokanee. As a preliminary assumption, we assume that sockeye fry are out-competed by kokanee adults and thus do not affect adult growth of kokanee (i.e., $SxEquiv_{K,Ad} = 0$).

4.3 Fry - Smolt

Fry rearing in Skaha and Osoyoos Lakes experience different rearing conditions and mortality factors. In Skaha Lake, kokanee and mysis potentially compete with juvenile sockeye for food resources. In Osoyoos Lake, epilimnial water temperature and hypolimnial oxygen concentrations are thought to be the major limiting factors on juvenile production. The proposed modelling approach is the same for both lakes, but different parameterisations can represent different rearing conditions. For example, density of mysis and kokanee can be set to low values in Osoyoos Lake to reflect reduced competition, but the lake area of Osoyoos Lake can be set to the area of the North Basin only to represent oxygen and temperature constraints on rearing habitat in the south basin.

4.3.1 Predation

The predator submodel (see section 7) calculates the maximum biomass of sockeye that was required during the previous year to produce the biomass at each predator age class in the current year. Unlike kokanee, only one age-class (fry) of sockeye is available to lake predators. The predation effects included in the model therefore include predation at the time of migration into the lake and predation throughout the year while fry are maturing into smolts. This section describes the process to compute the sockeye losses due to consumption that occurred between year t-1 (fry) and year t (smolts).

The maximum biomass required by the predator population is based solely on its consumptive requirements, and must be adjusted to account for the density of sockeye fry available and for size-dependent relative vulnerability of sockeye fry to predator age classes.

a) Density adjustment

At low prey densities, predators will presumably shift to an alternate prey source and realised predation rates will decline. This relationship is illustrated in Figure 4.8.

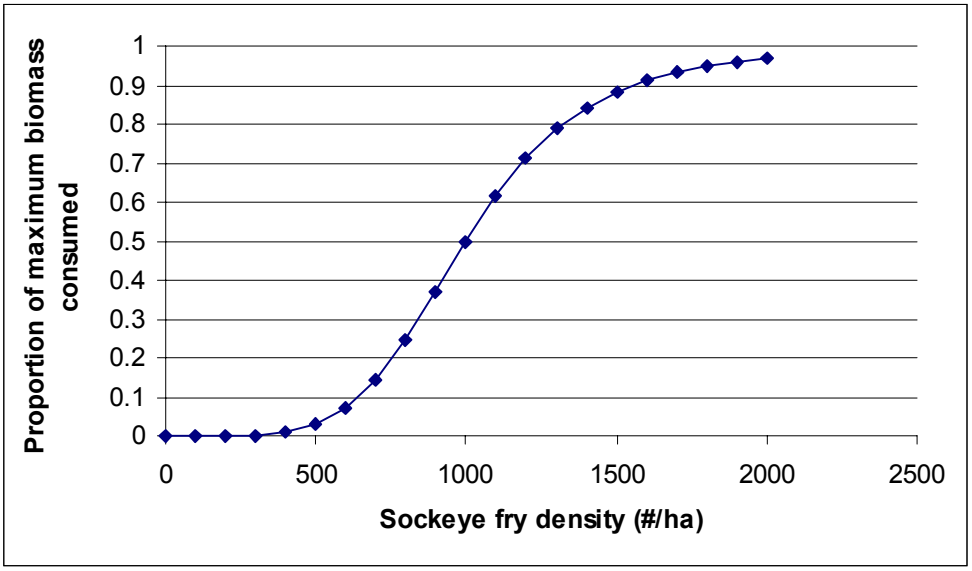


Figure 4.8. Density-dependent adjustment of biomass consumed by predators.

The relationship in Figure 4.8 (a Type III functional response) determines the actual proportion of sockeye fry biomass consumed during year t by a predator age class p and has the equation:

$$PropCons_{p,t} = SoxDensity_{t-1}^{SoxConsShape} / (SoxConsHalf^{SoxConsShape} + SoxDensity_{t-1}^{SoxConsShape}) \quad \text{[eq. 4-15]}$$

where: SoxConsShape = shape parameter (user-defined parameter)
SoxConsHalf = sockeye density where proportion consumed = 0.5 (user-defined parameter)
$SoxDensity_{t-1}$ = sockeye fry density in previous year (#/ha)
= $\Sigma\#Fry_{t-1}$ / LakeArea

b) Relative vulnerability adjustment

Relative vulnerability of sockeye fry to predation is assumed to be a function of the ratio of relative prey/predator fork lengths, which will vary among predator age classes (sockeye fry fork lengths are assumed to be constant). We assume that the relationship between relative vulnerability of sockeye fry and prey:predator fork length is the same as that derived for kokanee predation from rainbow trout stomach content data Korman et al. 1993). This relationship is shown in Figure 5.7 and described in equation 5-12.

The actual biomass of sockeye fry consumed by each predator age class during year t is determined from the biomass required by predators, the density-dependent proportion of the required biomass that is consumed, and the length-dependent relative vulnerability of sockeye fry to the predator age class:

$BiomassCons_{Sxfry,p,t} = PropCons_{p,t} * SoxBioCons_{p,t} * RelVuln_{Sxfry,p}$ [eq. 4-16]

where: $PropCons_{p,t}$ = proportion of biomass consumed (from equation 4-15)
$SoxBioCons_{p,t}$ = sockeye biomass required by predators (from equation 7-8)
$RelVuln_{Sxfry,p}$ = relative vulnerability of sockeye fry to predation, based on relative prey:predator fork lengths (see equation 5-12)

The total biomass of sockeye consumed is obtained by summing equation 4-16 over all predator age classes:

$BiomassCons_{Sxfry,t} = \Sigma_p BiomassCons_{Sxfry,p,t}$ [eq. 4-17]

where: $BiomassCons_{Sxfry,p,t}$ = biomass of sockeye fry consumed by age p predators (from equation 4-16)

Finally, the fraction of sockeye fry consumed by predators is calculated as:

$FractionCons_{Sxfry,t} = (BiomassCons_{Sxfry,t} / Weight_{Sxfry,t-1}) / \#Fry_{,t-1}$ [eq. 4-18]

where: $BiomassCons_{Sxfry,t}$ = biomass of sockeye fry consumed during year t (from equation 4-17)
$Weight_{Sxfry,t-1}$ = weight of sockeye fry in year t-1 (user-defined parameter)
$\#Fry_{t-1}$ = # of sockeye fry in year t-1 (from equation 4-11)

4.3.2 Smolt capacity

The total fish capacity (kg/ha) is a function of total phosphorus concentrations in many northern temperate lakes, including Osoyoos Lake (North Basin, where most rearing occurs) (Hyatt and Rankin 1999). Re-creation of a historical time series of Phosphorus concentrations in Osoyoos and Skaha Lakes was discussed in section 3.7 above. We will use the relationship between total P concentrations and productive capacity of lakes (described in Hyatt and Rankin 1999) to compute the rearing capacity of each lake (kg/ha) in each simulation year:

$\log(TotalCap) = Int_{TotalCap} + Slope_{TotalCap} * \log(TP)$ [eq. 4-19]

where: $Int_{TotalCap}$ = user-defined parameter
$Slope_{TotalCap}$ = user-defined parameter
TP = Total Phosphorus concentration (ug/L), recreated as in Figure 3.6.

Computation of smolt production in rearing lakes is complicated by competitive interactions with kokanee and mysis. In reality, such interactions are complex, and involve spatial/temporal differences in distributions, as well as possibly differences in zooplankton prey preferences. In this model, we propose to model these interactions by simply partitioning the capacity of each lake according to the relative production from the sockeye, kokanee and mysis biomass in the previous year. Because smolts migrate in the spring, we assume that their survival from fry in year t-1 to smolt in year t is a function of lake capacity during year t-1 (i.e., the year in which most of their survival and growth occurs). The capacity of the lake to produce sockeye smolts in year t is therefore given by:

$$TotalCap_{s,t-1} = \frac{SxFryProd_{t-1} * TotalCap_{t-1}}{(SxFryProd_{t-1}+KokFryProd_{t-1}+KokAdProd_{t-1}+ImmMysProd_{t-1}+MatMysProd_{t-1}} \quad \text{[eq. 4-20]}$$

where:

$TotalCap_{t-1}$	=	derived from equation 4-19 (kg/ha)
$SxFryProd_{t-1}$	=	sockeye fry production (kg/ha) in the previous year from equation 4-14, (SxEquiv = 1)
$KokFryProd_{t-1}$	=	production (kg/ha) of kokanee fry biomass in year t-1 from kokanee submodel equation 5-27 using the equivalence factor $KokFryEquiv_{JuvSurv}$ (which by definition = 1)
$KokAdProd_{t-1}$	=	production (kg/ha) of kokanee adult biomass in year t-1 from kokanee submodel equation 5-31 using the equivalence factor $KokAdEquiv_{JuvSurv}$
$ImmMysProd_{t-1}$	=	production (kg/ha) of immature mysis biomass in year t-1 from mysis submodel equation 6-11b using the equivalence factor $ImmMysEquiv_{JuvSurv}$
$ImmMysProd_{t-1}$	=	production (kg/ha) of mature mysis biomass in year t-1 from mysis submodel equation 6-11a using the equivalence factor $MatMysEquiv_{JuvSurv}$

We assume that the production from kokanee and mysis biomass in the fall of year t-1 provides a reasonable approximation of the average level of competition encountered by sockeye fry from the time they emerge in the spring of year t-1 to the time they emigrate as smolts in year t.

Equation 4-20 computes the portion of the total capacity of the lake (in kg/ha) to produce sockeye smolts. Converting this to fish numbers requires an assumption about body size of smolts; larger body sizes means that fewer fish are required to utilise capacity, while smaller body sizes require more fish to utilise capacity. An additional complication is that juvenile body sizes are also related to fry density. Hyatt and Rankin (1999) developed a power relationship between smolt size (in grams) and fry density in Osoyoos Lake (Figure 4.9). This relationship is applicable to the fry densities commonly observed in Osoyoos Lake, but may not be applicable at lower fry densities (the power function predicts smolt sizes in excess of 700g at low fry densities). A linear relationship, which is applied to Skaha Lake sockeye, provides a similar fit to the Osoyoos Lake data but predicts much lower smolt sizes at low fry densities (Figure 4.9). For the linear relationship, we assume that the minimum size achieved by smolts at very high densities (>4800 fry/ha) is 5 g.

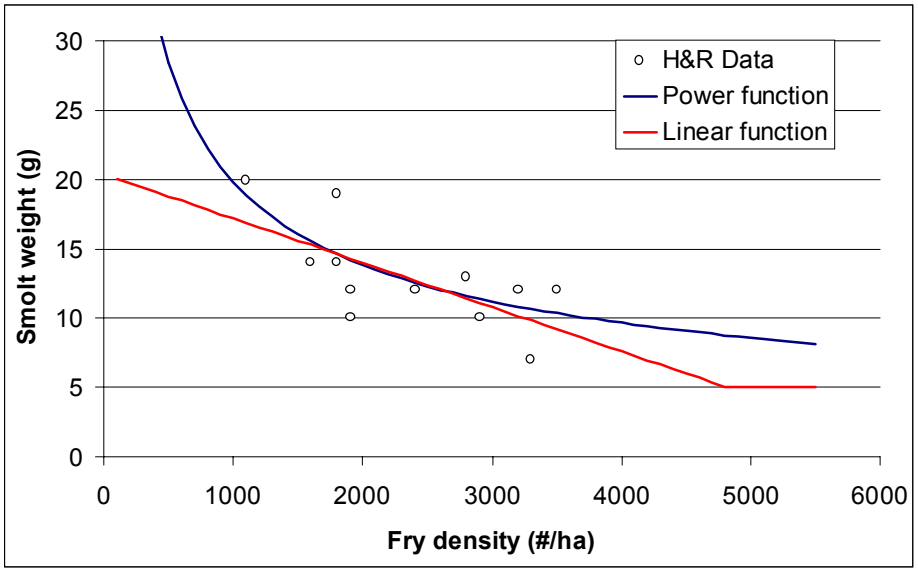


Figure 4.9. Relationship between sockeye smolt body weight and fry density. Based on Hyatt and Rankin 1999.

The model includes a generic smolt weight vs. fry density function that can be parameterised to represent either the power or linear relationship shown in Figure 4.9. The equation is:

$$SmoltSize_t = SmoltSizeInt + SmoltSizeSlope * (\#Fry_{t-1}/LakeArea)^{SmoltSizeShape} \quad \text{[eq. 4-21]}$$

where: SmoltSizeInt = hypothetical smolt weight at zero fry density; user-defined parameter
SmoltSizeSlope = coefficient relating smolt size to fry density; user-defined parameter
$\#Fry_{t-1}$ = number of fry in year t-1(from equation 4-11)
LakeArea = area of the rearing lake (ha)
SmoltSizeShape = rate of decline in smolt weight; user-defined parameter

A power relationship (used to represent Osoyoos sockeye) is represented by setting SmoltSizeInt = 0, SmoltSizeSlope = some large positive number, and SmoltSizeShape < 0. A linear relationship (used for Skaha sockeye) is represented by setting SmoltSizeInt > 0, SmoltSizeSlop < 0, and SmoltSizeShape = 1.

Given the total capacity of the lake to produce sockeye smolts in year t from fry in year t-1 ($TotalCap_{s,t-1}$) and the size of smolts produced ($SmoltSize_t$), the model will calculate the capacity of the lake for sockeye smolts from equation 4-22:

$$SmoltCap_t = TotalCap_{s,t-1} * LakeArea / (SmoltSize_t /1000) \quad \text{[eq. 4-22]}$$

where: $TotalCap_{s,t-1}$ = capacity of lake for sockeye smolts (kg/ha); derived from equation 4-20
LakeArea = area of the rearing lake (ha)
SmoltSize = derived from equation 4-21 (g)

4.3.3 Smolt Production

The smolt capacity and fraction of fry consumed by predators are then used to compute the number of smolts produced from the number of fry according to a density-dependent function (similar to Figure 4.4)

$$\#Smolts_{wild,t} = \frac{\#Fry_{t-1} * (1-FractionCons_{Sxfry,t}) * MaxFrySurv}{[1+(MaxFrySurv / SmoltCap_t) * \#Fry_{t-1} * (1-FractionCons_{Sxfry,t})]} \qquad \text{[eq. 4-23]}$$

where: $\#Smolts_{wild,t}$ = number of smolts in year t (assumes that all fry spend only one winter in freshwater)

$\#Fry_{t-1}$ = number of fry in year t-1 (from equation 4-11)

$FractionCons_{Sxfry,t}$ = fraction of fry consumed by predators (from equation 4-18)

MaxFrySurv = fry-smolt survival rate at very low fry densities (user-defined parameter)

$SmoltCap_t$ = smolt capacity in year t (from equation 4-22)

The combination of density-dependent predator effects and density-dependent capacity effects results in a fry to smolt relationship like the one shown in Figure 4.10. At low fry densities, predation is minimal (due to the relationship shown in Figure 4.8) and the production curve increases at a rate equal to the maximum fry-smolt survival. As fry abundance increases, the fraction consumed increases non-linearly until 100% of the biomass required by predators is consumed (see Figure 4.8). At this point, the # of fry consumed represents a significant fraction of the total number of smolts, resulting in a decline in the production curve. Beyond this point, predators are saturated and the number of fry consumed makes up an increasingly smaller fraction of the total number of fry. At high fry abundances, the slope of the production curve declines as the fry abundance approaches the carrying capacity.

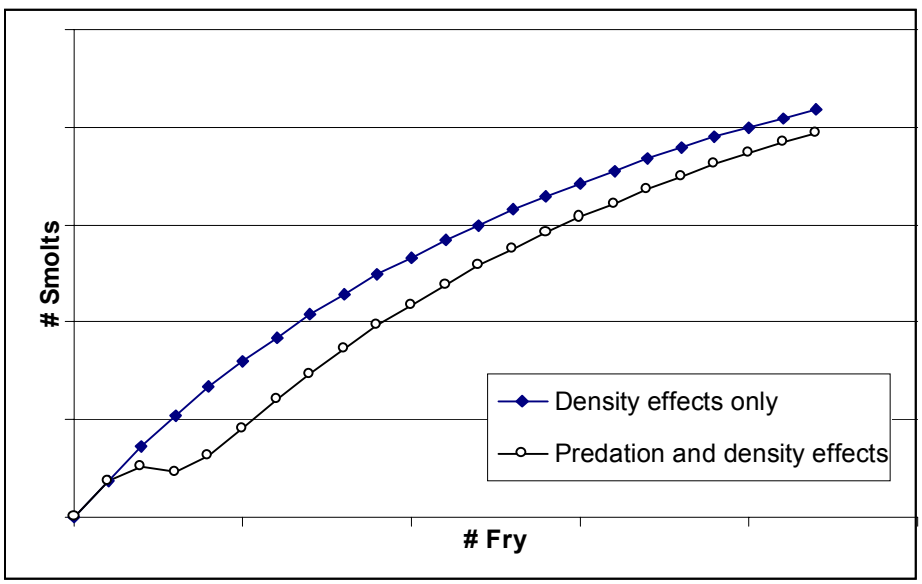


Figure 4.10. Smolt production curves with density effects (diamonds) and both predation and density effects (circles). The shape of this curve will depend on the density of predators.

4.3.4 Smolt Supplementation

The Colville Confederated Tribes have operated a supplementation program for Okanagan sockeye since 1995 (average 82,000 smolts released; Table 4.3).

Table 4.3. Okanagan sockeye supplementation. Source: FPC Annual Reports 1996-2001.

Year of Release	Number released	Location / time of release
1995	40963	Osoyoos stock reared at Cassimir Bar hatchery, then taken to net pens in Osoyoos Lake for acclimation
1996	150000	Osoyoos stock reared at Cassimir Bar hatchery, then taken to net pens in Osoyoos Lake for acclimation
1997	188350	Osoyoos stock reared at Cassimir Bar hatchery, then taken to net pens in Osoyoos Lake for acclimation
1998	80585	released near mouth of Okanagan River in April
1999	13396	released near mouth of Okanagan River in April
1999	21557	released into Osoyoos Lake in October

Supplementation of smolts into Skaha Lake is therefore a possible mechanism for establishing a Skaha Lake population. However, funding for the Cassimir Bar Hatchery facility by the Douglas Count Public Utility District has been discontinued. Smolt supplementation is therefore likely to be nil in the foreseeable future until an alternative facility is found. To allow for potential future supplementation of smolts, the model will allow the user to specify a constant number of smolts to be released in each year for each lake. The total number of smolts produced in a given outmigration year is:

$$\#Smolts_{total} = \#Smolts_{wild} + \#Smolts_{supp} \qquad \text{[eq. 4-24]}$$

where: $\#Smolts_{wild}$ = number of wild smolts produced (from equation 4-23)
$\#Smolts_{supp}$ = number of supplemented smolts (user-defined parameter)

4.4 Smolt – Adult

4.4.1 Rearing lakes – Wells Dam

Osoyoos lake sockeye smolts migrate through Osoyoos Lake and the lower Okanagan River before encountering Wells Dam. Skaha lake smolts must migrate through the Okanagan River between Skaha and Vaseaux lakes, Vaseaux Lake, the Okanagan River between Vaseaux and Osoyoos lakes, Osoyoos Lake, and the lower Okanagan River on their way to Wells Dam. Mortality factors through this portion of the downstream migration route include warm temperatures, passage over numerous vertical drop structures, and predation in lakes and rivers. Workshop participants were particularly concerned with predation on smolts migrating through Vaseaux Lake, which is a small and shallow lake with a high density of predaceous fish.

Modelling each of these mortality factors individually is beyond the scope of this model. A simpler approach is to allow the user to specify a survival rate for each sockeye population from their rearing lake

to Wells Dam. This survival rate would implicitly account for effects of predation and vertical drop structures, and would likely be higher for Skaha sockeye than Osoyoos sockeye.

$\#Smolts_{Wells} = \#Smolts_{Total} * SmoltSurvWells$ [eq. 4-25]

where: $\#Smolts_{Total}$ =# of smolts produced (from equation 4-24)
SmoltSurvWells = survival rate of smolts from their rearing lake (Skaha or Osoyoos) to Wells Dam

4.4.2 Smolts at Wells Dam – Adults at Wells Dam

Note: This version of OkSockeye has been revised to include annual variations in smolt-adult survival rates (SARs), using year effects developed from variations in SARs of other salmon stocks.

Mortality in this portion of the smolt-adult life stage is thought by many reviewers to be the primary cause of recent stock declines (e.g. Fryer 1995, 1996 Okanagan Sockeye Workshop). Passage through or around ten major mainstem dams during both upstream and downstream migration represents a significant source of mortality. Ocean conditions also vary significantly from year to year. Unfortunately, data to quantify smolt-adult survival rates are few, primarily because migrating smolts have not been systematically enumerated. Fish Passage Indices are monitored at several Columbia River dams, but expressing these indices in terms of absolute abundances is problematic because the efficiency with which smolts are bypassed into the counting systems is unknown and varies dramatically from year to year (Fryer 1995). A detailed model of sockeye passage through the mainstem Columbia River dams is beyond the scope of this model.

There are at least two potential approaches for modelling survival rates in this life stage. Each is discussed below along with their pros and cons.

1. **Fryer's SARs**

   Fryer (1995) estimated SARs from Priest Rapids Dam (PRD) to the mouth of the Columbia River. Smolt abundance at PRD was estimated using mark-recapture studies from 1984-1988; adult abundance was estimated from counts at Bonneville Dam and lower Columbia River harvest data. SARs ranged from 0.1 to 1.9% over the 5 years of the study (mean=1.1%, st.dev = 0.7%). The life-cycle model could simply draw from these estimates (or a distribution described by the mean and standard deviation of the estimates) in forward simulations.

   A problem with this approach is that the limited number of years encompasses a limited number of years of ocean conditions and river flow conditions. Fryer (1995) reports a significant relationship between absolute smolt abundance estimates at PRD and the smolt index estimated at McNary Dam (MCN). Theoretically, one could use this relationship to derive a longer time series of PRD absolute smolt estimates from the time series of MCN smolt indices. However, this would require a sequence of assumptions about stock and age composition of smolts and returning adults. Another problem is that the SAR estimates cover only 5 of the 9 dams of the Columbia River hydropower system. Some assumption would have to be made about survival rates through the four dams between the Okanagan River and PRD. Finally, dam counts and smolt estimates are problematic because of changes in sampling methods between years, changes in dam operations that affect sampling precision and accuracy, limitations of the counting systems, and other factors.

2. 1998-2000 Reach Survival Estimates

The Fish Passage Center (FPC) has estimated survival rates of PIT-tagged sockeye through three dams, from Rock Island Dam (RIS) to McNary Dam (MCN) since 1998 (FPC 1999, 2000, 2001). These survival rates have ranged from 46 to 68% (mean = 59%) over the three years of estimates. Extrapolating these results on a per-project basis to passage through all nine dams of the hydropower system leads to estimates of hydropower system survival rates of 10 to 31% (mean = 21%). One would then need to assume some magnitude (or distribution) of ocean survival rate to derive a true SAR (from Wells Dam to return to Columbia River mouth).

Problems with this approach include a lack of data on marine survival rates and the limited number of years in which reach survival rates were estimated. Bradford (1995) reviews SARs of other sockeye stocks but these rates include mortality during the freshwater portion of smolt migration as well as marine mortality.. An additional problem is that the reach survival estimates may not apply outside of the reach they were estimated over. For example, survival rates at Wells Dam may be higher than what is suggested by the RIS-MCN reach survival estimate because the Wells bypass system is more efficient.

Hyatt (pers. comm.) has indicated that a more reliable set of SAR estimates may be forthcoming based on improved estimates of smolt densities in Osoyoos Lake. In the meantime, we propose to combine Fryer's SARs with survival rates through the four dams upstream from Priest Rapids Dam (derived from per-project expansion of the 1998–2000 reach survival estimates) to yield overall Wells – Columbia River mouth SARs (Table 4.4).

Table 4.4. Preliminary set of SARs (Wells Dam to return to mouth of Columbia). Source: Fryer (1995); FPC Annual Reports 1998–2000. SARs represent averages over all age classes. See Table notes for explanation of how each column was calculated.

(1) Year	(2) Fryer's SAR PRD-Columbia at mouth	(3) Ave. RIS-MCN survival rate 1998-2000 (%) (3 projects)	(4) Ave. per-project RIS-MCN survival rate 1998-2000 (%)	(5) WEL-PRD survival rate	(6) Overall SAR Wells-Columbia at Mouth	(7) ln(Overall SAR)
1984	0.010	0.59	0.84	0.49	0.0050	-5.30
1985	0.017	0.59	0.84	0.49	0.0085	-4.77
1986	0.007	0.59	0.84	0.49	0.0035	-5.65
1987	0.001	0.59	0.84	0.49	0.0005	-7.60
1988	0.019	0.59	0.84	0.49	0.0095	-4.66

Table Notes:
Column2: From Fryer 1995
Column3: From FPC Annual Reports
Column4 = Column3$^{(1/3)}$
Column5 = Column4^4
Column6 = Column2 * Column5
Column7 = ln(Column6)

The mean of the ln(SARs) from Table 4.4 is –5.6. Based on suggestions by workshop participants, the model incorporates a time series of annual variations from the mean value (or year-effects) based on SAR data from Robertson Creek coho (Figure 4.11). Variations in marine survival of Barkley Sound coho appear to be correlated with deviations in adult returns of Barkley Sound sockeye (Hyatt et al. 2000). Barkley Sound sockeye have a minimal riverine migration period and thus variations in SAR represent

variations in marine survival rates. Year-effects will be selected according to water year to reflect the effects of large-scale climatic effects on marine survival rates. This approach assumes that Columbia River sockeye and Barkley Sound sockeye experience similar ocean conditions, an assumption that workshop participants felt was reasonable.

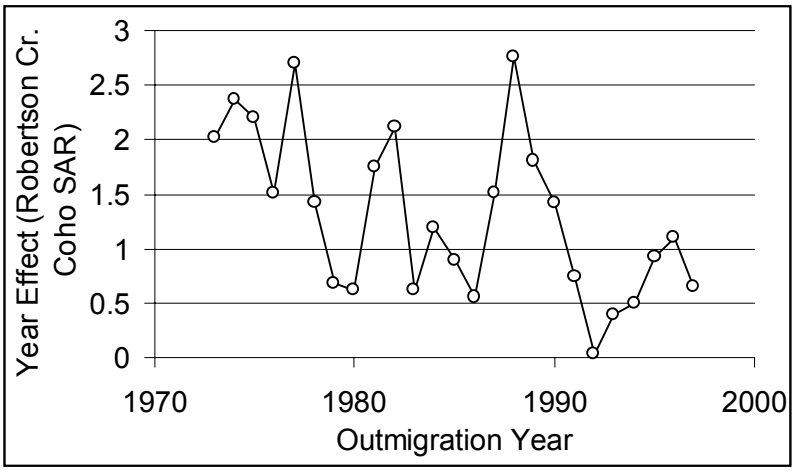


Figure 4.11. Year effects applied to average Okanagan sockeye SARs. Developed from SAR data for Robertson Creek coho (Hyatt et al. 2000).

Using this approach, the SAR for smolts entering the ocean in year t is:

$$SAR_t = e^{SARMean} * SARYearEffect \qquad \text{[eq. 4-26]}$$

where: SARMean = mean of the $\log_e$-transformed distribution of survival rates (user-defined parameter; use mean from Table 4.4 as preliminary value until better estimates are available)

SARYearEffect = variation in SAR from mean in year t, derived from SAR data for Barkley Sound coho

One could adjust the mean of this distribution to reflect potential future improvements in passage conditions and/or changes in ocean climate regimes. For example, the mean SAR could be increased to reflect potential reductions in reservoir mortality in lower Columbia dams from the northern pikeminnow control program. This program pays a bounty to fishermen who catch this predator of salmonid smolts. This program was initiated in the early 1990's and thus are not reflected in Fryer's SAR estimates.

SARs and maturity schedule (see Table 4.1) will be applied to a particular smolt migration to determine the number of Okanagan sockeye adults returning to the mouth of the Columbia River in a particular return year t:

$$\begin{aligned} \#AdultsColMouth_{Ok,\,t} = {} & \#Smolts_{Wells,t-1} * PropAge_{1.1,\,t-1} * SAR_{t-1} \\ & + \#Smolts_{Wells,t-2} * PropAge_{1.2,\,t-2} * SAR_{t-2} \\ & + \#Smolts_{Wells,t-3} * PropAge_{1.3,\,t-3} * SAR_{t-3} \end{aligned} \qquad \text{[eq. 4-27]}$$

where: $\#Smolts_{Wells}$ = obtained from equation 4-25
$PropAge_{1.x}$ = selected from Table 4.1
SAR = selected from Table 4.4

4.5 Returning Adults (Columbia River mouth to Wells Dam)

The number of adults returning to the Columbia River mouth in a particular return year is obtained from equation 4-27. Major processes affecting the survival of these fish to Wells Dam include Lower River harvest (between Columbia River mouth and The Dalles Dam), losses during upstream migration, and arrival timing at Wells Dam. We assume that none of these processes are age-selective (i.e., the age distribution of fish surviving to the spawning grounds is the same as the age distribution of fish arriving at the mouth of the Columbia River).

4.5.1 Lower River harvest

Note: In version 2.2, total sockeye returns to the mouth of the Columbia River (Okanagan + Wenatchee) is computed using Wenatchee abundance, rather than an estimate of Okanagan:Wenatchee proportion. In addition, parameters for equation 4-29 have been updated using adult return data from CNAT v. 1.0 (Hyatt et al. 2002).

The 2001–2003 Interim Management Agreement is based on a combined (Okanagan and Wenatchee) sockeye escapement of 75,000 fish at Bonneville Dam (ODFW and WDFW 2002). Below this level, only small Treaty ceremonial and subsistence (C&S) fisheries (which occur in Zone 6, between Bonneville and McNary Dams; most fishing occurs in Bonneville Reservoir ODFW and WDFW 2002) are permitted. For run sizes above the target, commercial fisheries above and below Bonneville Dam (Zones 1-5) are allowed on a sliding scale (Table 4.5).

Table 4.5. Sockeye harvest schedule as proposed by the 2001-2003 Interim Management Agreement. Source: ODFW and WDFW 2002.

Projected Run Size at Bonneville Dam	Non-Treaty Commercial Harvest (Zones 1-5)	Treaty C&S Harvest	Treaty Commercial Harvest (Zone 6, Bonneville reservoir)
< 50,000	0	5%	0
50,000 – 75,000	0	7%	0
> 75,000	surplus (negotiated)	> 7% (negotiated)	surplus (negotiated)

Several assumptions are required to model lower river harvest. First, we assume that the fisheries are not stock-selective (i.e., the fraction of Okanagan sockeye in the fisheries is the same as the fraction at the mouth of the Columbia River). Data to support this assumption are limited. Fryer (1995) found that lower river fisheries were significantly selective for Wenatchee fish in only one of the three years examined. More stock composition data is needed to test this assumption.

Second, because escapement targets are set for combined Wenatchee and Okanagan sockeye stocks, we must make some assumptions about the contribution of Wenatchee fish to the number of adult returns to the mouth of the Columbia. The relative escapement of Wenatchee and Okanagan sockeye is highly variable over time and shows no apparent temporal trend (Figure 4.12).

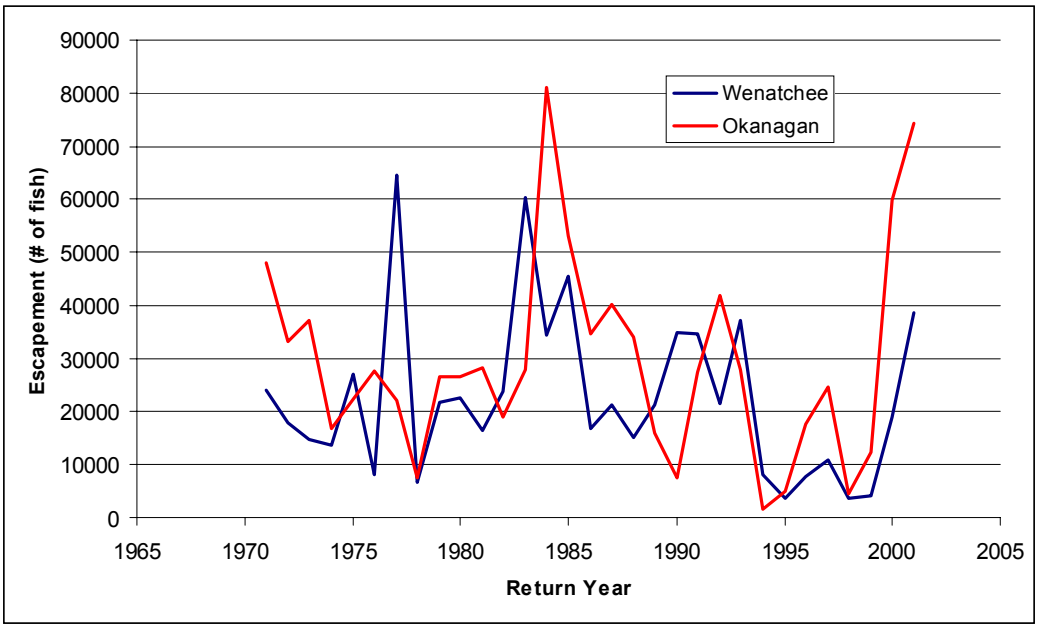


Figure 4.12. Okanagan and Wenatchee escapement (CNAT data from Hyatt et a. 2002). Okanagan escapement based on adult counts at Wells Dam; Wenatchee escapement based on adult counts at Rock Island and Rocky Reach dams.

We use Wenatchee escapement and CNAT data on lower Columbia River catch to compute the number of Wenatchee fish at the mouth of the Columbia for each water year for which there is data (1971-2001), then add this number to the number of returning Okanagan fish to obtain the total number of adult sockeye at Columbia River mouth (equation 4-28). For water years prior to 1971, we select a Wenatchee abundance randomly from 1971-2001 estimates.

$$\#AdultsColMouth_{Total} = \#AdultsColMouth_{Ok} + \#AdultsColMouth_{Wen} \qquad \text{[eq. 4-28]}$$

where: $\#AdultsColMouth_{Ok}$ = obtained from equation 4-27.
$\#AdultsColMouth_{Wen}$ = computed from Wenatchee escapement + Wenatchee contribution to lower Columbia River harvest.

Finally, the model must make some assumptions about the ability of the fisheries to catch their allowable limits. For Treaty C&S fisheries, harvest rates are relatively small and we will assume that the full allocation is caught in each year. Treaty and non-Treaty commercial fisheries are less efficient in catching available surpluses because commercial harvests are opened only sporadically, and because pre-season predictions of run sizes are imperfect. A comparison of maximum possible harvest and actual total (commercial and C&S) harvest since 1981 suggests that the fraction of the potential harvest that is actually harvested is usually small in the first year or two that a commercial fishery is allowed (this fraction is close to the C&S harvest rate), but increases with the number of consecutive years a commercial fishery is opened as commercial fishermen become accustomed to fishing (Figure 4.13).

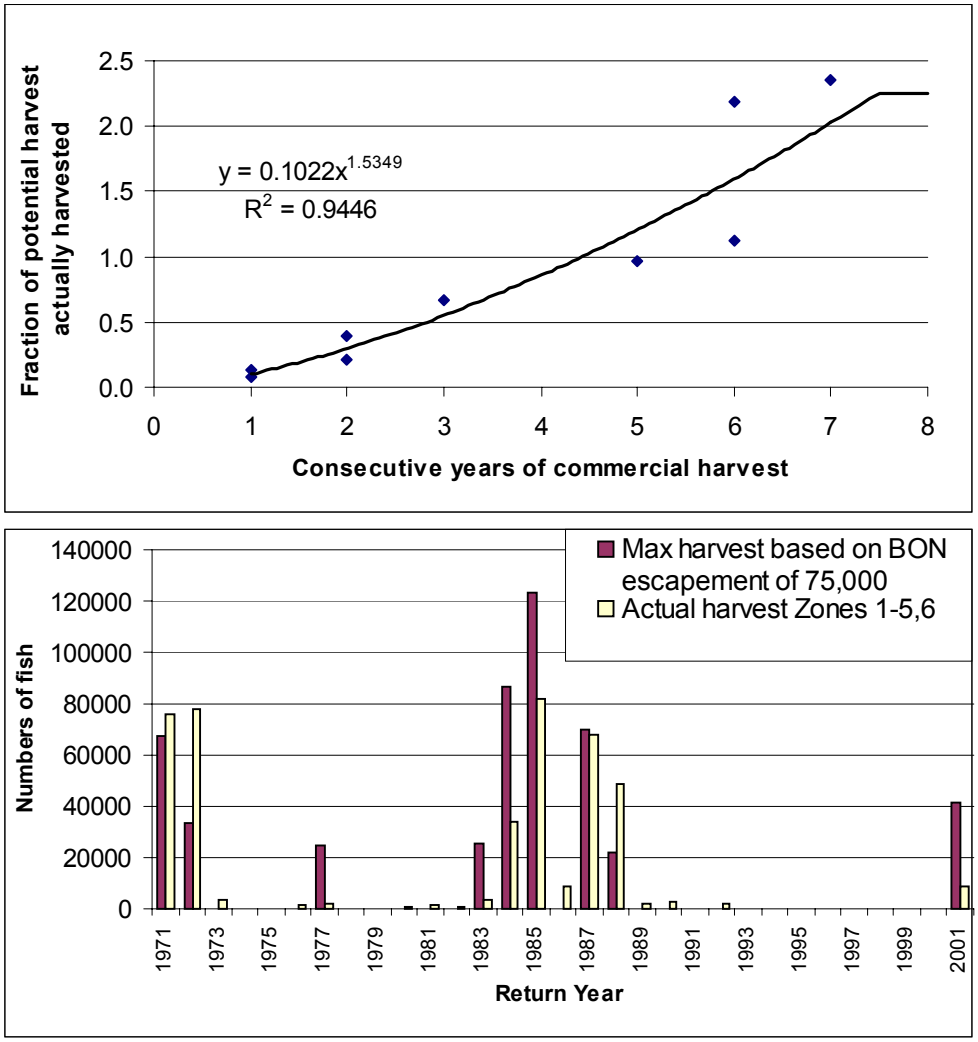


Figure 4.13. Top: Potential and actual harvest 1971–2001. Bottom: Fraction of potential harvest actually harvested as function of the number of consecutive years in which a commercial harvest was opened. Data sources: Hyatt et al. (2002).

We will use the relationship in the bottom pane of Figure 4.13 as a simplified representation of the dynamics of the commercial fishery in response to sporadic openings and the imprecision of run forecasts upon which openings are planned. The equation is:

$$\text{FractionCaught} = \text{Minimum}(\text{HarvRateFirstYear} * \#\text{ConsYear}^{\text{HarvShape}}, \text{MaxFraction}) \qquad \text{[eq. 4-29]}$$

where: HarvRateFirstYear = fraction of potential harvest actually caught in the first year of a commercial fishery (user-defined parameter)

Shape = parameter that determines how quickly the efficiency increases in consecutive years (user-defined parameter)

MaxFraction = upper limit on the efficiency of the commercial fishery (user-defined parameter; represents some maximum at which managers are likely to shut down a commercial fishery)

The number of Okanagan sockeye caught when the total run size exceeds the escapement target at Bonneville Dam is:

$$\#FishCaught_{Okanagan} = (\#AdultsColMouth_{Total}) - EscTarget_{Bon} * FractionCaught * (\#AdultsColMouth_{Ok}/\#AdultsColMouth_{Total}) * FracSurplusAvail \quad \text{[eq. 4-30]}$$

where: $\#AdultsColMouth_{Total}$ = derived from equation 4-28
$EscTarget_{Bon}$ = sockeye escapement target at Bonneville Dam (user-defined parameter)
FractionCaught = derived from equation 4-29
FracSurplusAvail = fraction of surplus available to lower River fisheries (user-defined parameter); this proportion is currently 1.0, but could conceivably be negotiated to allow larger harvests upriver.
$\#AdultsColMouth_{Ok}$ = obtained from equation 4-27

The number of Okanagan sockeye caught in years where the total run size does not exceed the escapement target is:

$$\#FishCaught_{Okanagan} = \#AdultsColMouth_{Ok} * TreatyC\&SHarvestRate \quad \text{[eq. 4-31]}$$

where: $\#AdultsColMouth_{Ok}$ = derived from equation 4-27
TreatyC&SHarvestRate = Treaty C&S harvest rate (user-defined parameter based on Table 4.5)

4.5.2 Survival rate during upstream migration (Mouth of Columbia to Wells Dam)

Past attempts to quantify upstream migration mortality have relied on adult dam counts (Fryer 1995). There are many problems with these data (e.g. changes in methods between dams and years) and survival estimates based on them are widely variable and are often unreliable (survival rate > 1) when one looks at the full data set from 1980-2001[4]. However, notwithstanding the significant problems with adult dam counts these data provide a convenient means of quantifying upstream survival rates and will be used in this model.

Fryer (1995) estimated an average survival rate of 0.76 from the Zone 6 fishery (Bonneville reservoir) to Wells Dam from 1985-1992. An alternative approach is to look at all relevant dam counts and calculate per-project survival estimates.[5] Relevant dam count comparisons include:

- The Dalles – John Day (JDA) (1 project)
- The Dalles – McNary (2 projects)
- The Dalles – Priest Rapids (3 projects)
- The Dalles – Rock Island (5 projects)
- Rocky Reach – Wells (1 project)

Not all comparisons produced useable estimates in all years (because the survival rates were > 1).

[4] Post-1979 conditions are though to be most representative of current hydrosystem operations.

[5] Relevant comparisons are those that do not include harvest in Bonneville reservoir (i.e. the lowest dam should be The Dalles or above), and do not compare Okanagan sockeye counts to mixed Okanagan/Wenatchee counts (i.e., counts from dams below the Wenatchee River should not be compared to counts from above the Wenatchee River).

Per-project survival rates from these dam count comparisons are shown in Figure 4.14. Average across dams varies from 0.81 to 1.0. The average is negatively correlated with Columbia River flows (measured at Wells Dam; R^2 = -0.64), suggesting that using Columbia River flows is a reasonable explanation for the observed variability. Therefore, our approach to modelling hydrosystem-related survival rates through this life-stage will be to select annual per-project survival rates according to the water year (selection of water years is discussed in section 3.1 above). Historical water years will have to be "mapped" to years where upstream survival data exist (i.e., historical water years without upstream survival data will be matched with a year with upstream survival data based on the similarity of the Columbia River flows). Such an approach reflects the association between Columbia River flows and per-project upstream survival rates. Therefore, the number of adult fish at Wells Dam is given by:

$$\#AdultsWells = (\#AdultsColMouth_{Ok} - \#FishCaught_{Okanagan}) * PerProjSurv^{9} \qquad \text{[eq. 4-32]}$$

where: $\#AdultsColMouth_{Ok}$ = derived from equation 4-27
$\#FishCaught_{Okanagan}$ = derived from equation 4-30 or 4-31
PerProjSurv = per-project upstream survival rate, selected according to water year

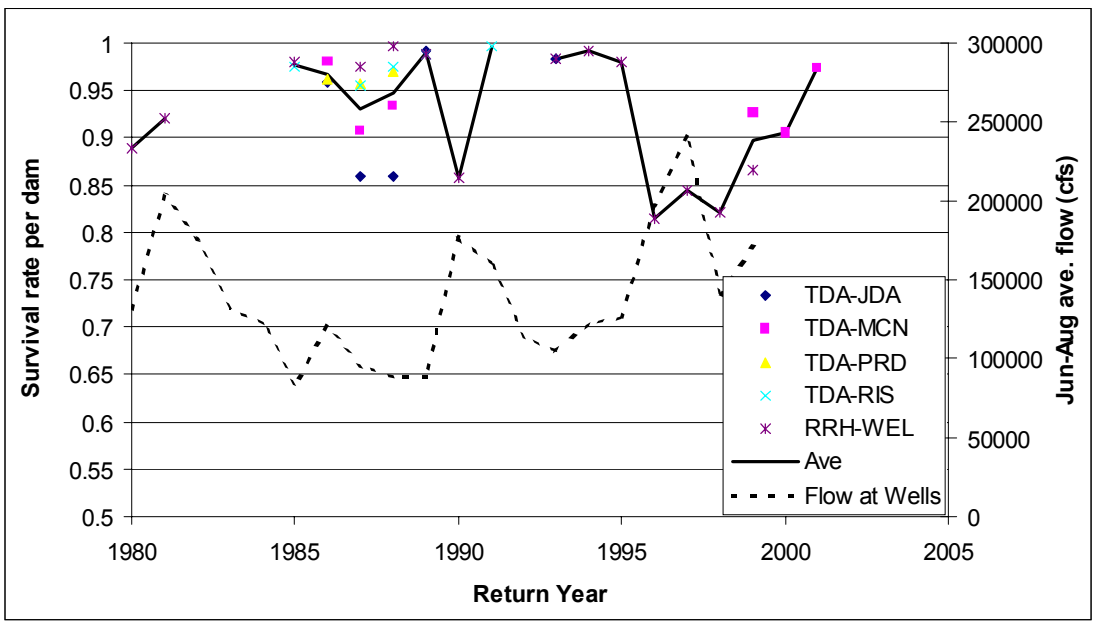


Figure 4.14. Survival rate per dam 1980-2001, based on comparison of dam counts. Average June-August flow at Wells Dam also shown. Dam count data from Fish Passage Center; flow data from Stockwell et al. 2001.

4.5.3 Run Timing at Wells Dam

We use daily adult dam counts at Wells Dam from 1977-2001 to model run timing of Okanagan sockeye (Figure 4.15). Quinn et al. (1997) found a statistically significant relationship ($p<0.001$) between sockeye arrival time at Rock Island Dam and Columbia River flows. The relationship between arrival time at Wells Dam and Columbia River flows is weaker but still significant ($p<0.05$). To represent this association, we will select a historical run time curve from those shown in Figure 4.15 according to the water year. The number of fish arriving at Wells Dam on a particular day d is:

$$\#ArriveWells_d = \#AdultsWells * ProportionArrivingWells_d \qquad \text{[eq. 4-33]}$$

where: #AdultsWells = computed using equation 4-32
$ProportionArrivingWells_d$ = derived from run timing curve selected according to water year

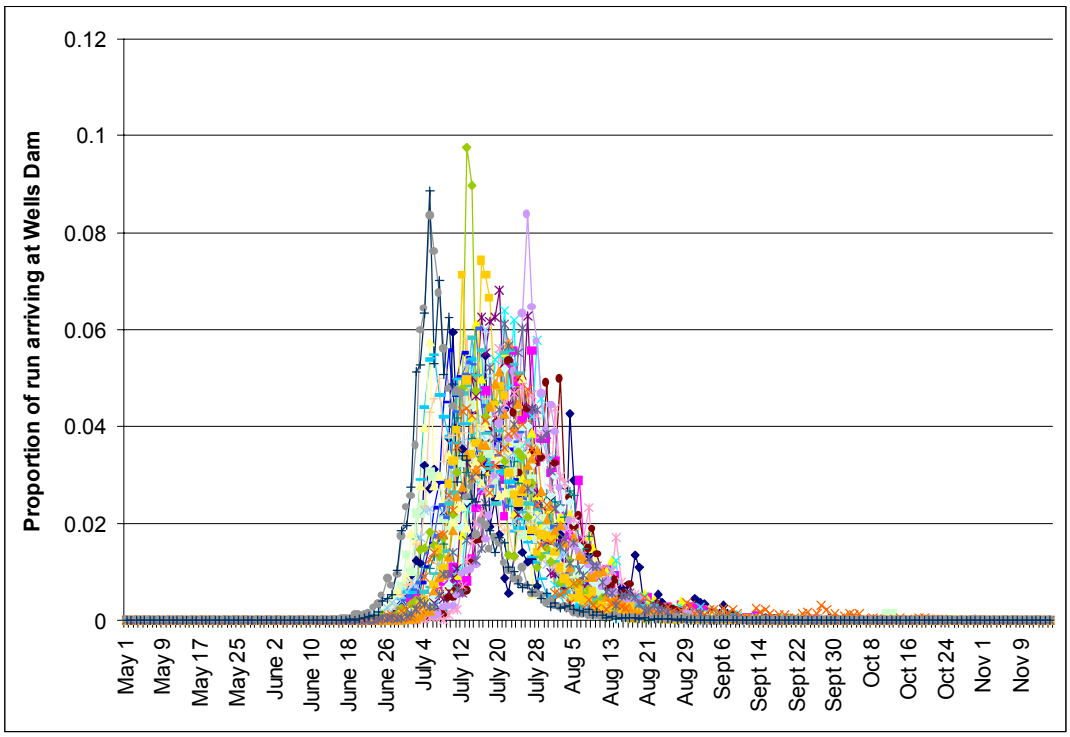


Figure 4.15. Proportion of sockeye arriving at Wells Dam, based on daily adult dam counts. Source: Fish Passage Center.

4.6 Prespawning Survival and Distribution (Wells Dam to Spawning Grounds)

This component of the model includes timing of migration up the Okanagan River, pre-spawning survival rate, supplementation, and distribution of spawners between Skaha spawning areas and Osoyoos spawning areas.

4.6.1 Migration up the Okanagan River

Returning sockeye frequently encounter a thermal barrier to upstream migration in the Okanagan River at its confluence with the Columbia (Fryer 1995, Hyatt and Rankin 1999, Alexander et al. 1998). Sockeye appear to hold in the Columbia River when water temperatures exceed 21°C, and migrate up the Okanagan River when temperatures fall below this threshold. The movement of fish up the Okanagan River is thus a function of arrival timing at Wells Dam (which was discussed in section 4.5.3) and water temperatures in the Okanagan River (discussed in section 3.5).

Overlapping the arrival timing distribution with water temperatures will determine how many fish migrate up the river each day ($\#MigrateOkan_d$). In each day during the summer migration period, the model will calculate the water temperature in the lower Okanagan River (equation 3-4). If the temperature is below 21 degrees, all of the fish arriving at Wells Dam in that day will enter the Okanagan River. If the daily temperature is above 21 degrees, the fish arriving at Wells Dam in that day will hold in the Columbia River. Fish will continue to hold until temperatures fall below 21 degrees, at which time all of the fish that are holding in the Columbia River will proceed up the Okanagan River. An example of this approach is shown in Figure 4.16 (assumes 30,000 fish arriving at Wells Dam and 1992 water temperatures and return timing). From July 6 – July 11, the water temperature is below 21 degrees and the number of fish entering the Okanagan River is equal to the number of fish arriving at Wells Dam. From July 12 to July 15, the temperature exceeds 21 degrees and fish do not enter the Okanagan River but accumulate in the Columbia. On July 16th, the temperature drops to below 21 degrees and all of the fish that have been accumulating in the Columbia since July 12, as well as the fish that arrive at Wells on the 16th, enter the Okanagan River. This explains the large peak of fish entering the Okanagan River on July 16th in the lower pane of Figure 4.15.

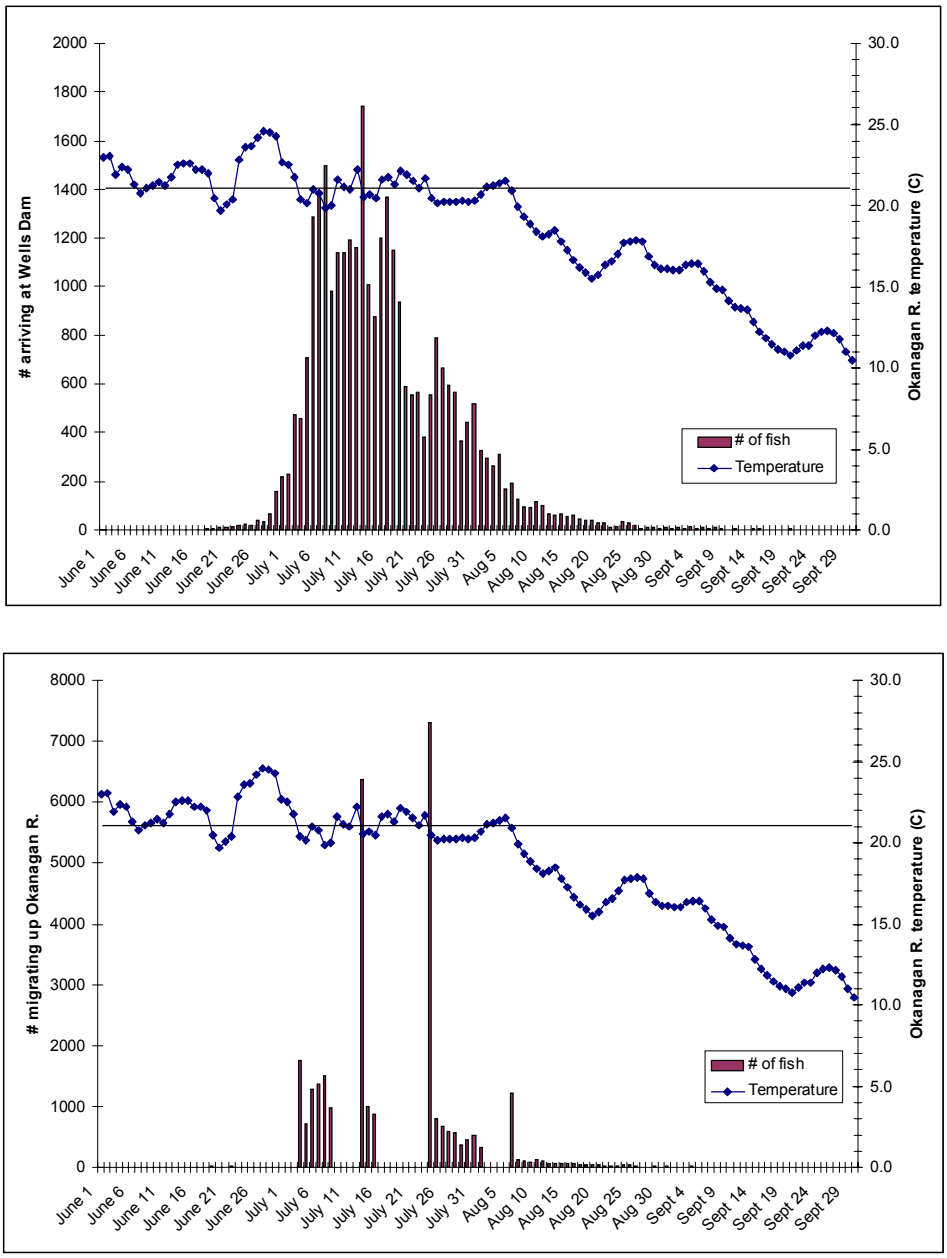


Figure 4.16. Top: Number of fish arriving at Wells Dam (example only; assumes 30,000 fish and 1992 arrival timing), and daily water temperature in lower Okanagan River. Bottom: Computed number of fish entering Okanagan River, assuming fish hold in Columbia as long as Okanagan River temperature is greater than 21 degrees. Temperature data from Stockwell et al. 2001.

Radio-tagging in 1997 suggested that a small number of Okanagan sockeye spawn in areas other than the main spawning grounds upstream from Osoyoos Lake (Alexander et al. 1998); because these numbers are small we will assume that all fish that spawn do so in the main spawning grounds.

4.6.2 Prespawning Survival Rate

Differences between Wells Dam counts and spawning ground surveys has been well-documented and discussed (Hyatt and Rankin 1999). On average, spawning ground counts are 43% of the Well Dam counts (Hyatt and Rankin 1999). Prespawning mortality is one contributor to this discrepancy, possible others include fallback and double-counting at Wells Dam, inadequate spatial or temporal coverage during spawning ground surveys, and small Indian and First Nations catches along the Okanagan River.

Other reviews (Chapman et al. 1995) have estimated prespawning mortality to be at least 25%; the 1997 radio-tag study by Alexander et al. (1998) estimated prespawning losses of 17%. Both of these studies suggested that prespawning mortality was probably higher when water temperatures in the Okanagan River were high and fish were forced to hold in the Columbia River. Data presented by Alexander et al. (1998) showed that radio-tagged fish that passed Wells Dam late in the spawning period had higher mortality than fish that passed early in the migration period. Given this information, it seems reasonable to hypothesise a relationship between survival rate from Wells Dam to the spawning grounds as a function of entry time into the Okanagan River (which would account for both late arrival at Wells Dam and holding in the Columbia River due to high Okanagan river temperatures) as shown in Figure 4.17.

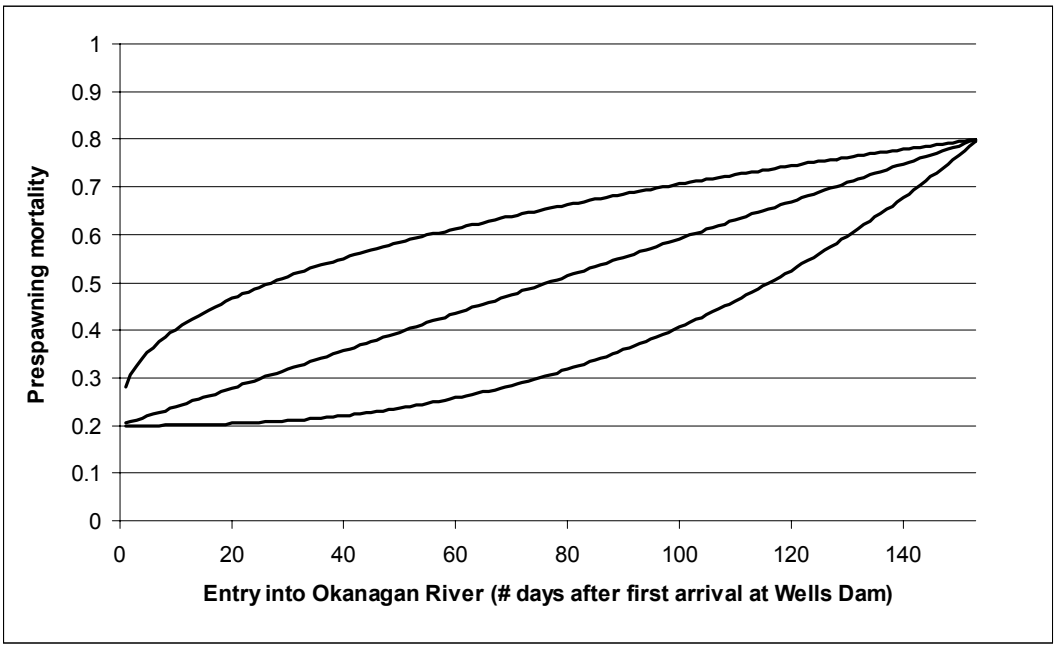


Figure 4.17. Relationship between prespawning mortality rate and entry into Okanagan River. Entry days are counted from June 1.

The relationship shown in Figure 4.17 has the equation:

$$\text{PrespawnMort} = [(\text{MaxPreMort}-\text{MinPreMort})*e^{(-5.3*\text{PreMortShape})}] * \text{EntryDay}^{\text{PreMortShape}} \qquad \text{[eq. 4-34]}$$

where: MaxPreMort = maximum mortality rate (user-defined parameter; mortality experienced by latest entrants into Okanagan River)

MinPreMort = minimum mortality rate (user-defined parameter; mortality experienced by earliest entrants into Okanagan River)

PreMortShape = shape parameter (user-defined parameter; function of the length of the upstream migration period)
EntryDay = # days after arrival at Wells Dam

The shape parameter determines whether mortality increases at an increasing rate with delayed entry into Okanagan Lake (bottom line in Figure 4.17), at a decreasing rate (top line), or a constant rate (middle line). This relationship is theoretical (although consistent with available information), but could in theory be tested with field data. For example, one could place thermographs along the river, then track radio-tagged fish to see how their mortality is affected by temperature. Model users can define a constant prespawning mortality rate by setting MinPreMort = MaxPremort = constant mortality fraction.

The model will also allow the user to set some constant Tribal and First Nations harvest rate. The total number of fish arriving on the spawning grounds is:

$$\#Spawners_{Total,wild} = [\Sigma_d \#MigrateOkan_d * (1\text{-}PrespawnMortality_d)] * (1\text{-}OkanHarvest) \quad \text{[eq. 4-35]}$$

where: $\#MigrateOkan_d$ = computed as in Figure 4.16
$PrespawnMort_d$ = computed as in equation 4-34
OkanHarvest = constant Tribal and First Nations harvest rate (user-defined parameter)

4.6.3 Distribution of Spawners between Skaha and Osoyoos spawning grounds

A key question to resolve is: once passage is restored to Skaha Lake, how should the model initially allocate spawners between Osoyoos spawning grounds and Skaha spawning grounds? Workshop participants suggested the following two hypotheses:

1. Assume that the earliest-returning fish (those that return to the upper Okanagan River in July) will continue to migrate upstream as long as water temperatures are below some critical temperature (15 degrees). If temperatures between Vaseaux and Skaha Lakes (at Okanagan Falls) are below this threshold, spawners will hold in Skaha Lake before spawning in spawning areas between Skaha and Okanagan Lakes. This hypothesis would be implemented as:

$$\#Spawners_{Skaha,wild} = \Sigma_d(\#Spawners_{Total,wild,d} \text{ if } WaterTemp_{OkFalls} < UpstreamCritTemp) \quad \text{[eq. 4-36]}$$
$$\#Spawners_{Osoyoos,wild} = \#Spawners_{Total,wild} - \#Spawners_{Skaha,wild}$$

where: $\#Spawners_{Total,wild,d}$ = total # of Okanagan sockeye on day d (in July), derived from equation 4-35
$WaterTemp_{OkFalls}$ = water temperature at Ok Falls, derived from equation 3-3.
UpstreamCritTemp = critical water temperature for upstream migration

2. Assume that Osoyoos-origin spawners will continue to spawn in current spawning habitat even if passage to Skaha Lake is restored. This may be a reasonable assumption if the straying rate is low and fidelity to spawning grounds is high. In this case, re-establishment of Skaha sockeye would require direct transplantation of Osoyoos smolts or spawners into Skaha rearing or spawning habitat (see Section 4.6.3). Transplanted smolts and progeny of transplanted spawners would then return to Skaha spawning areas. This hypothesis could be implemented using equation 4-36 by setting the upstream critical temperature for the Osoyoos population to a very low value (e.g. 0 degrees) to effectively prevent any naturally-returning spawners from making it upstream to Skaha Lake, and setting the upstream critical temperature for the Skaha population to a very high

value (e.g. 99 degrees) to ensure that all Skaha-origin spawners return to Skaha Lake spawning grounds.

4.6.4 Adult Supplementation

Note: The formulation of Adult supplementation has been revised in version 2.2. Adult supplements to Skaha Lake are now taken from the Osoyoos population, up to some conservation constraint.

The model will allow the user to specify a constant number of spawners each year taken from the Osoyoos population and transplanted to Skaha spawning grounds as a reintroduction strategy:

$$\#Spawners_{Skaha,Total} = \#Spawners_{Skaha,wild} + \#Spawners_{Skaha,supp} \quad \text{[eq. 4-37]}$$
$$\#Spawners_{Osoyoos,Total} = \#Spawners_{Osoyoos,wild} - \#Spawners_{Skaha,supp}$$

where: $\#\ Spawners_{Skaha,wild}$ = computed from equation 4-36, depending on the hypothesis about distribution of Okanagan sockeye spawners

$\#Spawners_{Skaha,supp}$ = number of Osoyoos spawners used to supplement the Skaha population (user-defined, year-specific parameter)

$\#\ Spawners_{Osoyoos,wild}$ = computed from equation 4-36, depending on the hypothesis about distribution of Okanagan sockeye spawners

The model includes a conservation constraint on the number of spawners that can be removed from the Osoyoos stock for supplementation purposes, similar to the constraint imposed on the removal of females for hatchery broodstock (section 4.2.6). Since with adult supplementation both males and females would be removed, the model computes a minimum level of total spawners (male and female) that must be maintained:

$$MinSpawners_{Os} = MinFemale_{Os} / FemaleProp \quad \text{[eq. 4-38]}$$

where: $MinFemale_{Os}$ = minimum level of Osoyoos females that must be maintained (user-defined parameter)

FemaleProp = average proportion of the population that are female (user-defined parameter)

If the user-specified number of spawners to supplement in a given year would cause the spawner abundance to go below this level, then the model will extract as many spawners as possible given the minimum constraint and use this value in equation 4-37 to obtain the total number of spawners in each population. In years when the Osoyoos spawner population is below the minimum level, no spawners are removed from supplementation. We assume that the spawners removed from the Osoyoos population have the same age and sex characteristics as the population at large.

5.0 Kokanee Submodel

The kokanee submodel is largely based on the Large Lakes Kokanee Model (LLKM), developed by ESSA with close cooperation of fisheries scientists from the (former) B.C. Ministry of Environment, Lands, and Parks[6] (Korman et al. 1993). The LLKM is an age-structured model designed to explore the effects of a wide range of kokanee management actions such as stocking, fishing regulations, and habitat enhancement. The LLKM therefore includes detailed modules for:

- kokanee population dynamics;
- fishing effort;
- competitor population dynamics; and
- predator population dynamics.

The scope of the Okanagan sockeye model we are building is much more limited than the LLKM, so we have incorporated only the kokanee and predator population dynamics modules (the predator population module is discussed in section 7).[7] The kokanee module includes four basic processes: Growth, predation losses, survival, and maturation (Figure 5.1). Each of these is discussed below. All computed quantities represent the state of the population in the fall.

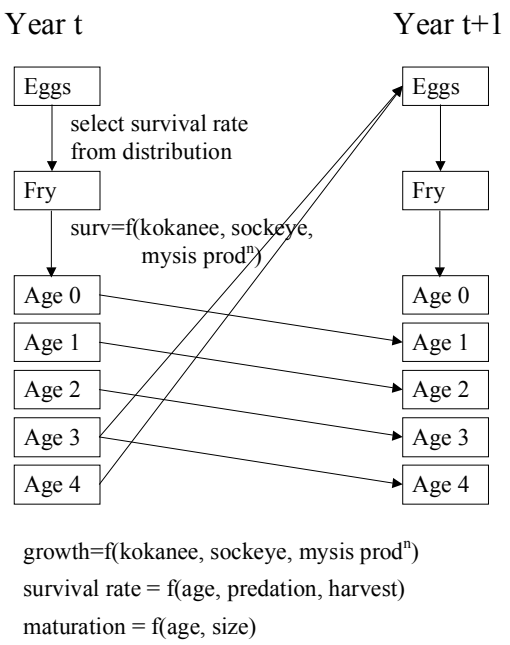


Figure 5.1. General structure of kokanee submodel.

[6] BC MELP scientists included Eric Parkinson, Jay Hammond, and Bruce Shepherd).

[7] Because of software incompatibilities, we are unable to directly incorporate the existing LLKM model into this model.

Skaha Lake has a relatively small kokanee population (Figure 5.2), compared to Okanagan Lake. The Okanagan Lake Action Plan (Andrusak et al. 2001) has generated some relatively good data for Okanagan Lake kokanee, but we have not been able to obtain significant data for Skaha Lake kokanee. In the absence of specific data, we have relied where possible on data for Okanagan Lake kokanee to generate preliminary parameter values. Where Okanagan Lake kokanee data were not available, we use the default parameter values supplied in the Large Lakes Kokanee Model. Many of these defaults are based on provincial standards supplied by BC MELP fisheries scientists involved in LLKM development.

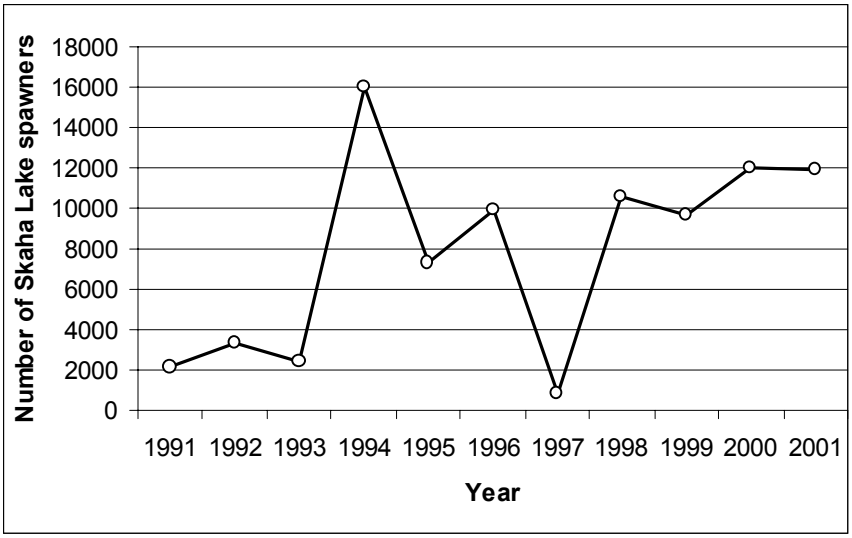


Figure 5.2. Annual estimates of Skaha Lake kokanee spawning abundance, 1991-2000. Source: WLAP 2001.

5.1 Growth

5.1.1 Von Bertalanffy growth equation

Kokanee size at age a is modelled using the difference formulation of the Von Bertalanffy growth equation (Ricker 1975):

$$Length_{a,t} = Length_{a-1,t-1} + K_{Brody}(Length_{Max} - Length_{a-1,t-1}) \quad \text{[eq. 5-1]}$$

where: $Length_{a-1}$ = average length of fish of age a-1 in previous year
K_{Brody} = Brody growth coefficient (a user-defined parameter; standard Provincial value = 0.55)
$Length_{Max}$ = mean asymptotic length (an estimated parameter)

This function produces age-dependent growth rates as shown in Figure 5.3. These growth rates are also density-dependent as explained in section 5.1.2. $Length_{Max}$ represents the maximum size reached by the oldest age classes. K_{Brody} represents the initial growth rate, or how quickly the maximum size is reached.

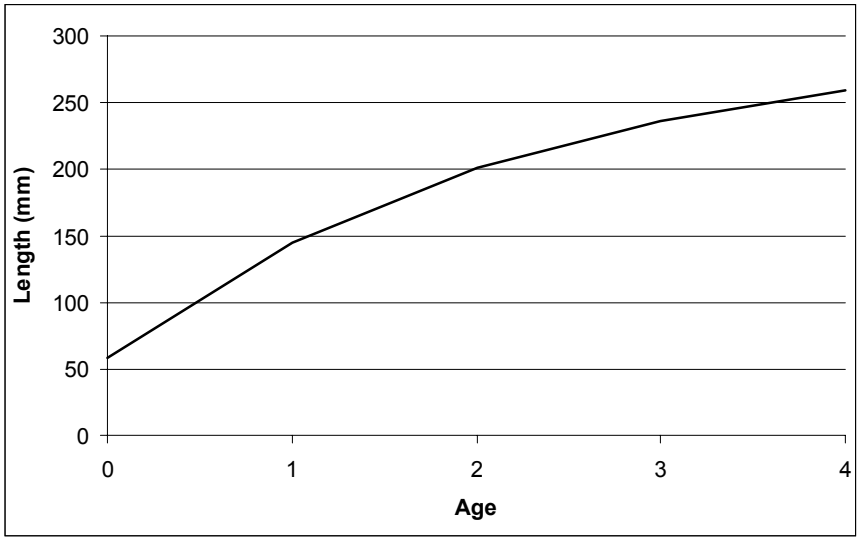


Figure 5.3. Example length-at-age curve produced by equation 5-1.

Equation 5-1 is parameterised using the following procedure. The parameter LengthMax in a particular simulation year can be calculated by assuming a constant value for K_{Brody} (the provincial standard for this value is 0.55) and deriving independent estimates of $Length_0$ and $Length_3$. Length at age 0 is assumed to be a user-defined constant value; mean lengths of age 0 Okanagan kokanee have generally been between 50 and 60mm (Andrusak et al. 2001). Length at age 3 is estimated from lake productivity and the biomass of competitors (explained in the next section). Having estimates of $Length_0$, $Length_3$, and K_{Brody}, equation 5-1 can be used to estimate $Length_{Max}$. Note that this will change from year to year as a result of changes in density of Age 2 equivalent kokanee. The estimated LengthMax can be used to calculate lengths of all ages of kokanee in that year using equation 5-1.

5.1.2 Computation of age 2 kokanee equivalents

Length at age 3 in year t is estimated as a function of the density of Age 2 kokanee equivalents in the previous year and lake productivity (Figure 5.4) based on Rieman and Myers (1992):

$$Length_{3,t} = MaxLength_3 - ProdCoeff * \log(ProdAge2Eq_{t-1}) - SecchiCoeff * SecchiDepth \quad \text{[eq. 5-2]}$$

where:

$MaxLength_3$	=	maximum length (mm) of age 3 fish at 0 density (user-defined parameter)
ProdCoeff	=	coefficient relating age 3 length to age 2 equivalent production (user-defined parameter)
$ProdAge2Eq_{t-1}$	=	production of Age 2 kokanee and equivalents (kg/ha) in year t-1 (computed value; explained below)
SecchiCoeff	=	coefficient relating age 3 length to Secchi Depth (user-defined parameter)
SecchiDepth	=	Secchi Depth of lake (m) (from equation 3-5)

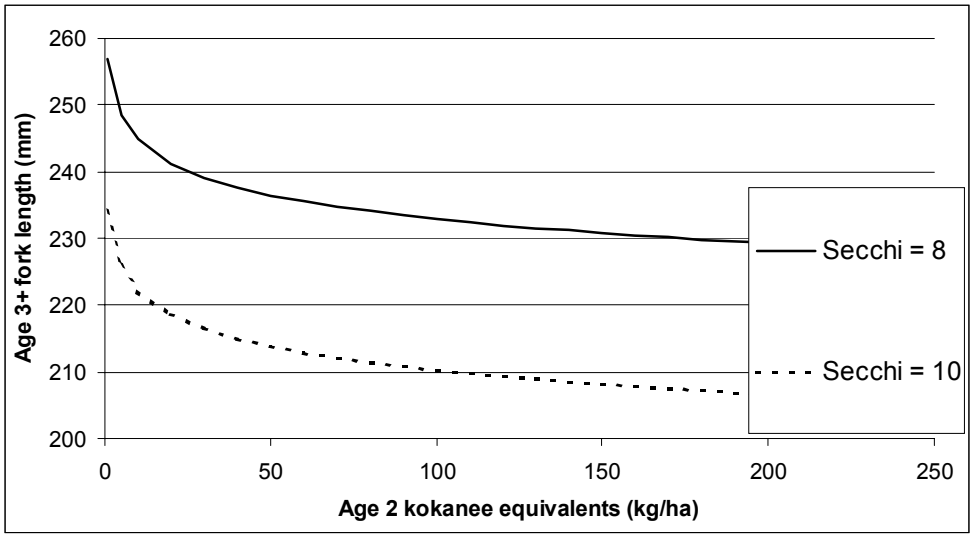


Figure 5.4. Age 3 length as a function of age 2 equivalent density and Secchi Depth.

Age 2 equivalent production includes all organisms that can compete with Age 2 kokanee for food, which in the Skaha Lake model includes kokanee of other ages, juvenile sockeye, and mysis.

Kokanee equivalents

Production of age 0, 1, 3, and 4 kokanee is converted to age 2 kokanee production based on the Production:Biomass ratios of each age relative to that of age 2 fish. Production:Biomass ratios are derived for each age class from conversion efficiency (kg production per kg consumed) and feeding rates (kg consumed per kg biomass) using equation 4-13. Conversion efficiency is based on average body size (Figure 5.5). Smaller kokanee with higher conversion efficiencies than age 2 fish thus place a smaller drain on total food resources

Conversion efficiency is predicted from body sizes at each age using equation 5-3:

$$ConvEff_{k,a} = ConvEffConst_k + ConvEffSlope_k * \log(Weight_a) \qquad \text{[eq. 5-3]}$$

where: $ConvEffConst_k$ = constant (user-defined parameter)
$ConvEffSlope_k$ = coefficient relating log(body weight) to conversion efficiency (user-defined parameter)
$Weight_a$ = body weight of age a kokanee (from equation 5-9)

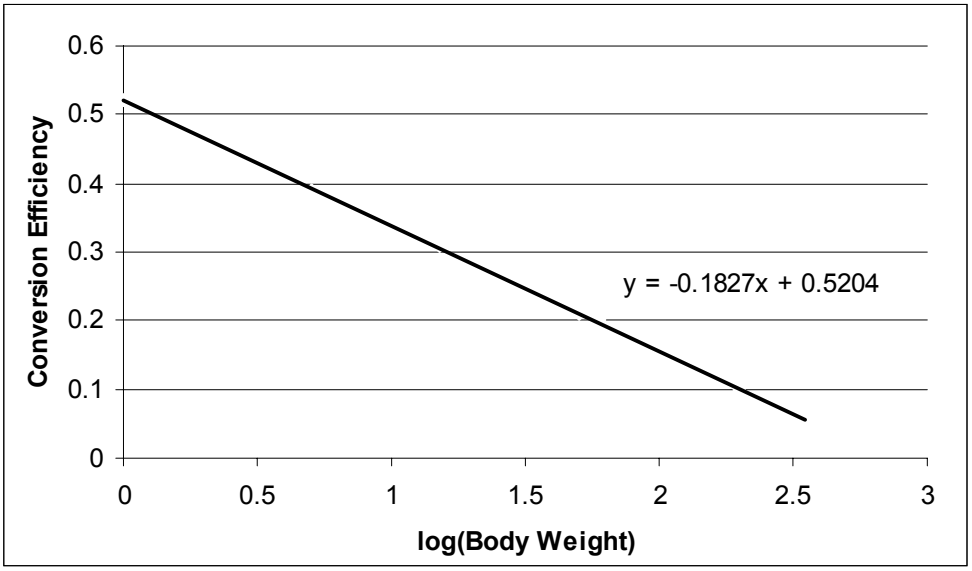


Figure 5.5. Conversion efficiency as a function of average body size. Based on data from Korman et al. 1993.

Based on computed body sizes and equation 5-3, kokanee production in terms of Age 2 equivalents is:

$$ProdAge2Eq_{k,a,t-1} = KokAdProd_{a,t-1} * (P{:}B_{k,2,t-1}/P{:}B_{k,a,t-1}) \quad \text{[eq. 5-4]}$$

where: $ProdAge2Eq_{k,a,,t-1}$ = production of age a kokanee (kg/ha) in age 2 kokanee equivalents

$KokAdProd_{a,t-1}$ = production from age a kokanee biomass (kg/ha) in previous year; computed from equation 5-31 using the equivalence factor $KokAdEquiv_{AdGrowth}$ (which by definition = 1)

$P{:}B_{k,2,t-1}$ = Production:Biomass of age 2 kokanee in year t-1 (derived from equation 4-13 and 5-3)

$P{:}B_{k,a,t-1}$ = Production:Biomass of age a kokanee (derived from equation 4-13 and 5-3)

The total production of all age classes of kokanee in age 2 equivalents is:

$$ProdAge2Eq_{k,t-1} = \Sigma_a ProdAge2Eq_{k,a,t-1} + KokFryProd_t * (P{:}B_{k,2,t-1}/P{:}B_{k,fry,t}) \quad \text{[eq. 5-5]}$$

where: $ProdAge2Eq_{k,a,t-1}$ = production of age a kokanee in age 2 kokanee equivalents (equation 5-4)

$KokFryProd_t$ = production from kokanee fry biomass (kg/ha) in current year; computed from equation 5-27 using the equivalence factor $KokFryEquiv_{AdGrowth}$

$P{:}B_{k,2,t-1}$ = Production:Biomass of age 2 kokanee in year t-1 (derived from equation 4-13 and 5-3)

$P{:}B_{k,fry,t}$ = Production:Biomass of kokanee fry (derived from equation 4-13 and 5-3)

Sockeye equivalents

Growth and survival predictions in the kokanee model are assumed to be representative of conditions in the fall. Length at age 3 in the fall of year t is therefore determined by age 2 kokanee equivalent production in the fall of year t-1. Ideally, the sockeye model would compute a biomass of juveniles in the fall, but with the proposed model design juvenile biomass can be computed only for fry after emergence (in the spring) or smolts prior to migration (also in the spring). As a simplifying assumption, we will assume that kokanee length at age 3 (as measured in the fall of year t) is potentially affected by production of sockeye fry that emerge in the spring of year t. The influence of sockeye fry on growth of kokanee adults is determined by the $SxEquiv_{AdGrowth}$ adjustment factor used in equation 4-14 to determine the production of sockeye fry in equation 5-5:

$$ProdAge2Eq_{s,t-1} = SxFryProd_t * (P{:}B_{k,2}/P{:}B_{SxFry}) \quad \text{[eq. 5-6]}$$

where: $SxFryProd_t$ = production of sockeye fry (kg/ha) from equation 4-14, using the equivalence factor $SxEquiv_{AdGrowth}$

$P{:}B_{k,2}$ = Production:Biomass of age 2 kokanee (derived from equation 4-13 and 5-3)

$P{:}B_{SxFry}$ = Production:Biomass of sockeye fry (from equation 4-13 and 5-3)

Mysis equivalents

Length at age 3 kokanee in year t is assumed to be determined by production from mysis biomass in the previous year. Mysis are assumed to have similar conversion efficiencies to kokanee (Cooper et al. 1992), but different feeding rates. The conversion of mysis biomass to age 2 kokanee equivalents is:

$$ProdAge2Eq_{m,t-1} = MysImmProd_{t-1}*(P{:}B_{k,2}/P{:}B_{m,imm})+MysMatProd_{t-1}*(P{:}B_{k,2}/P{:}B_{m,mat}) \quad \text{[eq. 5-7]}$$

where: $ProdAge2Eq_{m,t-1}$ = production of mysis in age 2 kokanee equivalents

$MysImmProd_{t-1}$ = production of immature mysis (kg/ha) from mysis submodel equation 6-11b, using equivalence factor $ImmMysEquiv_{AdGrowth}$

$MysMatProd_{t-1}$ = production of mature mysis (kg/ha) from mysis submodel equation 6-11a, using equivalence factor $MatMysEquiv_{AdGrowth}$

$P{:}B_{k,2}$ = Production:Biomass of age 2 kokanee (from equation 4-13 and 5-3)

$P{:}B_m$ = Production:Biomass of mysis (from equation 6-10)

Total Age 2 Equivalents

The total production (kg/ha) of age 2 equivalents in year t-1 for calculating age 3 length in year t is:

$$ProdAge2Eq_{t-1} = ProdAge2Eq_{k,t-1} + ProdAge2Eq_{s,t-1} + ProdAge2Eq_{m,t-1} \quad \text{[eq. 5-8]}$$

where: $ProdAge2Eq_{k,t-1}$ = production of kokanee in age 2 kokanee equivalents (from equation 5-5)

$ProdAge2Eq_{s,t}$ = production of sockeye in age 2 kokanee equivalents (from equation 5-6)

$ProdAge2Eq_{m,t-1}$ = production of mysis in age 2 kokanee equivalents (from equation 5-7)

The $ProdAge2Eq_{t-1}$ value is used in equation 5-2 to estimate the length of age 3 kokanee in year t, as illustrated in Figure 5-3.

5.1.3 Length-Weight relationship

Lengths at age t (mm) are converted to weights (g) using the equation:

$$Weight_a = WeightA_a * Length_a^{WeightBa} \quad \text{[eq. 5-9]}$$

where: $Length_a$ = average length (mm) at age a, computed from equation 5-1
$WeightA_a$, $WeightB_a$ = age-specific coefficients (user-defined parameters; LLKM default values are shown in Table 5.1)

Table 5.1. LLKM default (provincial standard) values for length-weight coefficients (Korman et al. 1993).

Age	WeightA	WeightB
0	6.76E-06	3.08
1	2.63E-06	3.28
2	1.35E-06	3.40
3	1.17E-06	3.43
4	1.17E-06	3.43

5.2 Predation losses

The predator submodel (see Section 7) calculates the maximum biomass of kokanee that must have been consumed during the previous year to produce the biomass at each predator age class in the current year (predator age classes are designated as subscript p to distinguish them from kokanee age classes, which are designated as subscript a). This section describes the process to compute the kokanee losses due to consumption that have occurred between year t-1 and year t. Predation losses for age 0 and older fish during this year are determined by kokanee density and size at year t-1. Because fry emerge during the spring, predation losses for this age class are determined from density and fry size in year t. The notation in the following discussion is for age 0-4 fish, but otherwise the equations and approach apply to both fry and the 0-4 age classes.

The biomass required by the predator population is based solely on its consumptive requirements, and must be adjusted to account for the density of kokanee that was available. At low prey densities, predators will presumably shift to an alternate prey source and realised predation rates will decline. This relationship is illustrated in Figure 5-6.

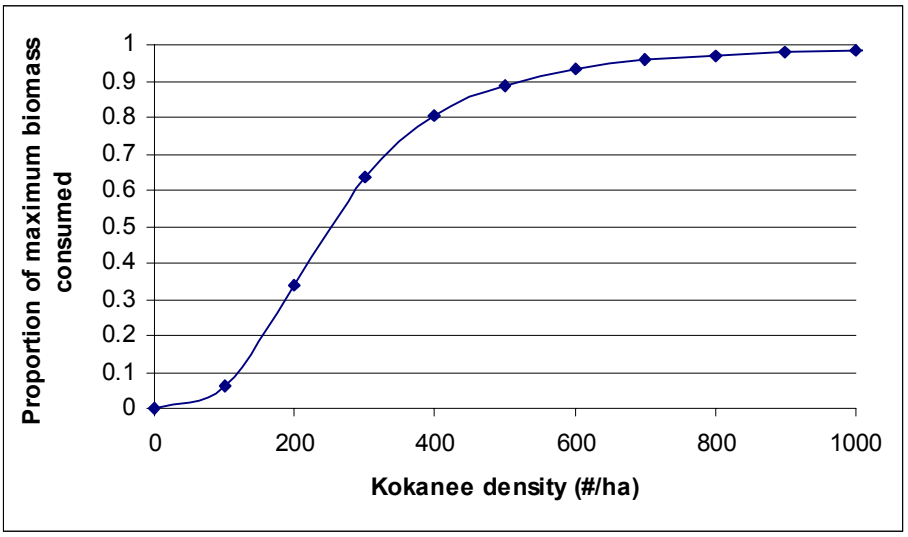


Figure 5.6. Density-dependent adjustment of biomass consumed by predators.

The relationship is Figure 5.6 determines the actual proportion of kokanee biomass consumed by a predator age class p during year t (between year t-1 and year t) and has the equation:

$$PropCons_{p,t} = KokDensity_{t-1}^{KokConsShape}/(KokConsHalf^{KokConsShape}+KokDensity_{t-1}^{KokConsShape}) \quad \text{[eq. 5-10]}$$

where: KokConsShape = shape parameter (user-defined parameter)
KokConsHalf = kokanee density giving half of the maximum proportion consumed (user-defined parameter)
$KokDensity_{t-1}$ = total kokanee density (#/ha)
= $\Sigma_a \#Kokanee_{a,t-1}$ / LakeArea

The proportion of kokanee biomass consumed by each predator age class must be allocated among the vulnerable kokanee age classes. The LLKM includes two alternative mechanisms for determining the size preference of predators. One mechanism bases size preference entirely on relative body size of predator and prey; the other bases size preference on both relative body size and relative density of kokanee age classes. In this model, we will implement only the second (size and density-dependent).

Relative vulnerability of kokanee to predation is assumed to be a function of the relative prey/predator fork lengths, based on rainbow trout stomach content data from Kootenay and Quesnel Lakes (Korman et al. 1993). This ratio for a particular combination of predator age class p and kokanee age class a is calculated as:

$$PreyLengthRatio_{a,p,t-1} = Length_{a-1,t-1} / Length_{p-1,\,t-1} \quad \text{[eq. 5-11]}$$

where: $Length_{a,t-1}$ = length of kokanee at age a in year t-1 (from equation 5-1)
$Length_{p-1,\,t-1}$ = length of predators at age p-1 in year t-1 (user-defined parameter)

The relationship between relative vulnerability and size ratios can be closely approximated by a normal distribution with mean of 0.16 and standard deviation of 0.06 (Figure 5.7). This function defines the relative vulnerability of kokanee in age class a to predation by predators in age class p. The equation for this function is:

$RelVuln_{a,p,t-1}$= Normal($PreyLengthRatio_{a,p,t-1}$, RelVulnMean, RelVulnStDev) [eq. 5-12]

where: $PreyLengthRatio_{a,p,t-1}$ =ratio of fork lengths (from equation 5-11)
RelVulnMean = user-defined parameter
RelVulnSteDev = user-defined parameter

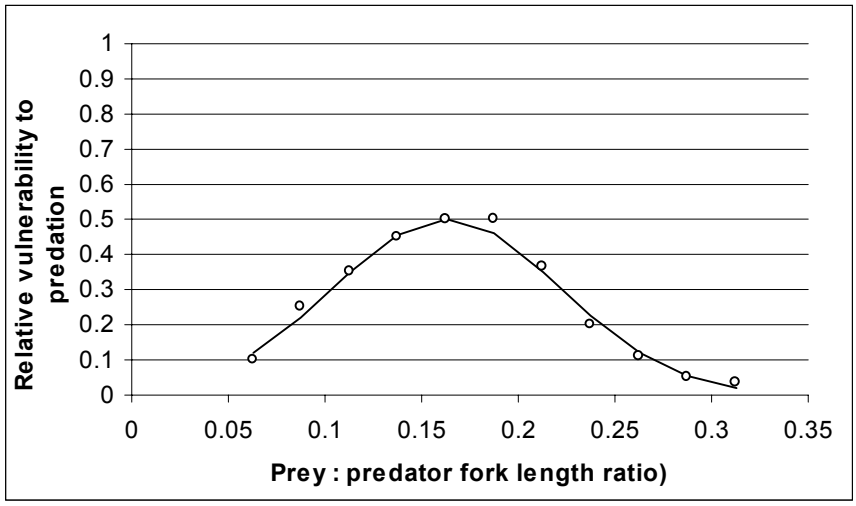


Figure 5.7. Size-dependent relative vulnerability to predation.

Once the relative vulnerability has been determined, the relative biomass (kg) of kokanee in each age class a consumed by predators in age class p during year t can be computed as:

$RelBio_{a,p,t}$= $\#Kokanee_{a,t-1}$ * $RelVuln_{a,p,t-1}$ * $Weight_{a,t-1}$ [eq. 5-13]

where: $\#Kokanee_{a,t-1}$ = # of kokanee in age class a in previous year (from equation 5-23)
$RelVuln_{a,p,t-1}$ = relative vulnerability of age class a (from equation 5-12)
$Weight_{a,t-1}$ = weight (g) of fish in age class a (from equation 5-8)

The actual biomass consumed in each age class of kokanee by each predator age class during year t is determined from the biomass required by predators, the density-dependent proportion of the required biomass that is consumed, and the relative biomass in each kokanee age class:

$BiomassCons_{a,p,t}$= $PropCons_{p,t}$ * $KokBioCons_{a,t}$ * $RelBio_{a,p,t}$ / $\Sigma_a RelBio_{a,p,t}$ [eq. 5-14]

where: $PropCons_{p,t}$ = proportion of biomass consumed (from equation 5-10)
$KokBioCons_{a,t}$ = kokanee biomass required by predators (from equation 7-8)
$RelBio_{a,p,t}$ = relative biomass in age a consumed (from equation 5-13)

The total biomass (kg) of kokanee in age class a is obtained by summing equation 5-14 over all predator age classes:

$BiomassCons_{a,t} = \Sigma_p BiomassCons_{a,p,t}$ [eq. 5-15]

where: $BiomassCons_{a,p,t}$ = biomass of age a kokanee consumed by age p predators (from equation 5-14)

Finally, the fraction of age a kokanee consumed by predators is calculated as:

$FractionCons_{a,t} = (BiomassCons_{a,t} / (Weight_{a,t-1} * 1000)) / \#Kokanee_{a,t-1}$ [eq. 5-16]

where: $BiomassCons_{a,t}$ = biomass of age a kokanee consumed during year t (kg; from equation 5-15)
$Weight_{a,t-1}$ = weight of age a kokanee in year t-1 (g; from equation 5-8)
$\#Kokanee_{a,t-1}$ = # of age a kokanee in year t-1 (from equation 5-)

5.3 Survival from Age 0 to Adult

The survival rate of Age 0 and older fish (age classes that reside in rearing lakes) in year t-1 to year t is determined by natural survival rates, predation losses during the year by lake-residing predators, and harvest during the year. Survival and harvest rates for age classes 0 and older are assumed to be density- and size-independent, and are held constant for the duration of the simulation. Predation losses are calculated as described in the previous section. The number of fish surviving to ages 1 and older in year t is given by:

$\#Kokanee_{a,t} = \#Kokanee_{a-1,t-1} * NatSurvFrac_{a-1} * (1-FractionCons_{a-1,t}) * (1-HarvRate_a)$ [eq. 5-17]

where: $\#Kokanee_{a-1,t-1}$ = number of kokanee of age a-1 in the previous year
$NatSurvFrac_{a-1}$ = natural survival fraction for kokanee of age a-1 (user-defined parameter)
$FractionCons_{a-1,f}$ = fraction of age a-1 kokanee consumed by predators during year t (from equation 5-16)
$HarvRate_a$ = harvest rate of age a kokanee (user-defined parameter)

5.4 Maturation and age 0 production

5.4.1 Spawner abundance

The LLKM calculates the proportion of mature Age 3 adults as a function of average length for that age (Figure 5.8). The X-intercept of this function is the minimum spawning length of age 3 fish (200 mm in Figure 5.8), while the size at 100% spawning is the average length of age 4 fish (260 mm in Figure 5.8). This assumes that no age-2 fish spawn, and that all age 4 fish spawn. The slope of this line will change from year to year as density-dependent growth processes determine the length of age 4 fish. All mature fish are assumed to die after spawning.

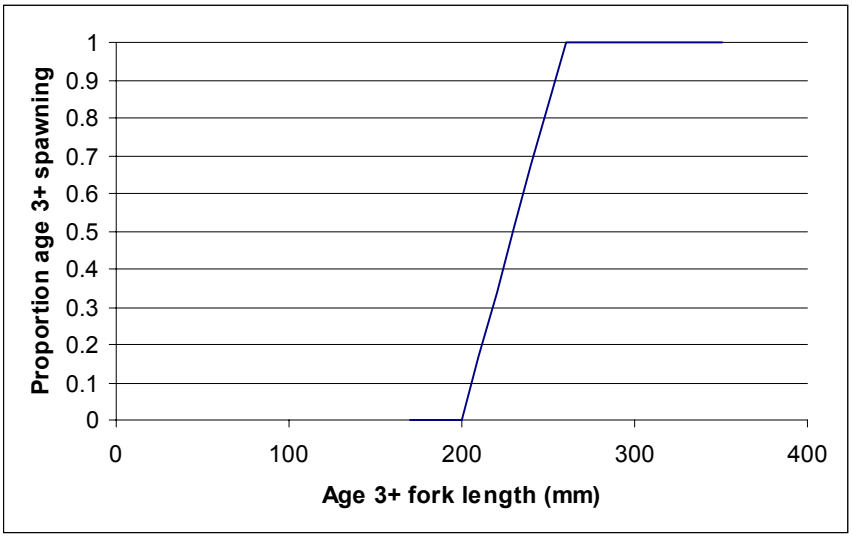


Figure 5.8. Maturation function in LLKM.

The equation to calculate the proportion of age 3 fish maturing is:

$PropMature_3 = (Length_3 - MinMatLength) / (MaxMatLength - MinMatLength)$ [eq. 5-18]

where: $Length_3$ = average length (mm) at age 3, computed from equation 5-1
MinMatLength = minimum spawning length (user-defined parameter) (mm)
MaxMatLength = maximum spawning length (average length of age 4 fish, derived from equation 5-1) (mm)

The number of spawners is therefore given by:

$\#Spawners_{kokanee} = \#Kokanee_4 + \#Kokanee_3 * PropMature_3$ [eq. 5-19]

where: $\#Kokanee_4$ = # of age 4 kokanee (from equation 5-17)
$\#Kokanee_3$ = # of age 3 kokanee (from equation 5-17)
$PropMature_3$ = proportion of age 3 fish maturing (from equation 5-18)

5.4.2 Spawner capacity

Determination of spawning habitat for Skaha Lake kokanee uses a similar approach as Skaha sockeye. Potential spawning habitat for Skaha Lake sockeye and kokanee is available in the channelled portion of the Okanagan River between Okanagan Lake and Skaha Lake. The amount of spawning habitat is related to flows, as shown in Figure 4.3 and equation 4-2; only the area designated as “medium quality” is assumed to be suitable for kokanee spawning. Overlap between sockeye and kokanee spawners is modelled using a similar approach to the one described for Skaha Lake sockeye in equation 4-4. As described there, the SpawnOverlap parameter represents the degree of spatial and temporal overlap between the two spawning populations. Because the two populations overlap to some extent in both space and time, this value should be set close to 1. The equation for determining the amount of spawning habitat for kokanee is:

$$SpawnHabFrac_{kokanee} = \#Spawners_{kokanee} / (\#Spawners_{sockeye} + \#Spawners_{kokanee}) * (SpawnOverlap) + (1 - SpawnOverlap) \quad \text{[eq. 5-20]}$$

where: $\#Spawners_{sockeye}$ = obtained from equation 4-37
$\#Spawners_{kokanee}$ = obtained from equation 5-19
SpawnOverlap = fraction of habitat competed over by kokanee and sockeye (user-defined parameter)

The total habitat available for use by Skaha Lake kokanee is calculated using equation 5-21:

$$SpawnHab_{Total,kokanee} = (SpawnHab_{Current,med} + SpawnHab_{New,\ med}) * SpawnHabFrac_{kokanee} \quad \text{[eq. 5-21]}$$

where: $SpawnHab_{Current,med}$ = amount of medium quality habitat, obtained from equation 4-3 and parameter values given in Figure 4.3 (bottom panel).
$SpawnHabFrac_{kokanee}$ = obtained from equation 5-20
$SpawnHab_{New,med}$ = amount of new medium-quality spawning habitat created (user-defined parameter)

Calculated values of spawning habitat are used to estimate the spawning capacity (maximum number of female spawners on the spawning grounds) based on an optimal female density. The equation is:

$$SpawnCapacity = SpawnHab_{Total,kokanee} * FemaleDensity_k \quad \text{[eq. 5-22]}$$

where: $SpawnHab_{Total,kokane}$ = obtained from equation 5-21
$FemaleDensity_k$ = # of females per sq. m of spawning habitat (user-defined parameter)

5.4.3 Spawner-egg (fecundity)

Fecundity (# eggs per female) is assumed to be a function of fork length of mature females:

$$\log_{10}(Fecundity_a) = FecA + FecB*\log_{10}(Length_a) \quad \text{[eq. 5-23]}$$

where: $Length_a$ = average length (mm) of mature fish at age a, computed from equation 5–1
FecA, FecB = coefficients (user-defined parameters)

For Okanagan lake kokanee the FecA and FecB parameters are –5.275 and 3.2899, respectively (Andrusak et al. 2001).

The number of eggs laid in a brood year is a Beverton-Holt function based on the number of spawners. This function produces a density-dependent relationship between spawner abundance and egg abundance. The function is mediated by spawning flow through its effect on the capacity of spawning habitat (equation 5-22).

$$\#Eggs = \frac{\#Spawners_{kokanee} * FemaleProp * AveFecundity}{[1+(AveFecundity/EggCap * (\#Spawners_{total} * FemaleProp)]} \quad \text{[eq. 5-24]}$$

where: #Eggs = total number of eggs deposited
$\#Spawners_{kokanee}$ = total number of kokanee spawners from equation 5-19

AveFecundity = age-weighted average fecundity (using equation 5-23)
EggCap = egg capacity of spawning habitat
= SpawnCapacity (equation 5-22) * FemaleProp * AveFecundity (equation 5-23)

5.4.4 Egg - Emergent Fry

Egg-fry survival rates are selected from a log-normal distribution with user-specified mean and standard deviation:

EggFrySurv = N(EggSurvMean, EggSurvStDev) [eq. 5-25]

where: EggSurvMean = mean of loge-transformed distribution of survival rates (user-defined parameter)
EggSurvStDev = standard deviation of loge-transformed distribution of survival rates (user-defined parameter)

Presumably these survival rates are affected by flows and temperatures in spawning areas during the incubation period, but at this point we have no data to formulate any hypotheses about these relationships. The geometric mean egg-fry survival rate in Mission Creek spawning channel from 1990-1999 was 21.3% (Andrusak et al. 2001).

The number of fry in year t produced from eggs deposited in year t-1 is:

$\#EmergFry_t = \#Eggs_{t-1} * EggFrySurv$ [eq. 5-26]

where: $\#Eggs_{t-1}$ = computed from equation 5-23
EggFrySurv = computed from equation 5-25

The production of kokanee fry is needed to calculate rearing capacities for sockeye, kokanee, and mysis juveniles, and to calculate kokanee adult growth rates:

$KokFryProd = (\#EmergFry * Weight_{EmFry}/1000) / LakeArea * P{:}B_{k,fry} * KokFryEquiv$ [eq. 5-27]

where: #EmergFry = number of emerging fry (from equation 5-26)
$Weight_{EmFry}$ = body weight (g) of kokanee fry (user-defined parameter)
$P{:}B_{k,fry}$ = Production:Biomass of kokanee fry (from equation 4-13 and 5-3)
LakeArea = area of rearing lake(ha)
KokFryEquiv = as defined below

Two equivalence factors (KokFryEquiv) are required for determining the effects of kokanee fry on sockeye and mysid survival, and on growth of kokanee adults:

1. The equivalence factor $KokFryEquiv_{JuvSurv}$ is needed for partitioning lake carrying capacity for survival of sockeye and mysis juveniles. Because the juvenile survival equivalence factors for sockeye and mysis are expressed in terms of kokanee fry, $KokFryEquiv_{JuvSurv} = 1$ by definition.

2. The equivalence factor $KokFryEquiv_{AdGrowth}$ is needed to account for the effects of kokanee fry production on growth rates of adult kokanee. As a preliminary assumption, we assume that $KokFryEquiv_{AdGrowth} = 1$.

5.4.5 Emergent Fry – Rearing Fry (Age 0)

Survival of emerging fry is assumed to be a density-dependent Beverton-Holt function (Figure 5.9).

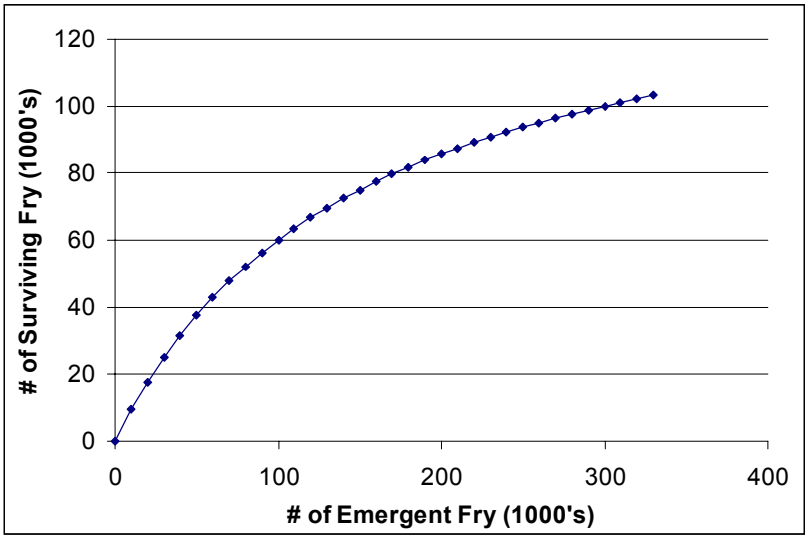


Figure 5.9. Relationship between # of surviving fry and # of emerging fry (example only).

The function assumes that survival rate approaches 100% at very low fry densities, and approaches 0% as the number of fry approaches the capacity of the lake. The fry production capacity can be inferred from the phosphorus concentration of Skaha Lake as described above in section 4.3.1 for sockeye. As with sockeye juveniles, the rearing capacity must be adjusted to account for kokanee-sockeye-mysis interactions. The analogous equation for kokanee is:

$$TotalCap_{k,t} = \frac{KokFryProd_t * TotalCap_t}{(SxFryProd_t + KokFryProd_t + KokAdProd_{t-1} + ImmMysProd_{t-1} + MatMysProd_{t-1}} \quad \text{[eq. 5-28]}$$

where:

$TotalCap_t$	=	derived from equation 4-19 (kg/ha)
$KokFryProd_t$	=	production of kokanee fry from equation 5-27, using the equivalence factor $KokFryEquiv_{JuvSurv}$ (which by definition = 1)
$SxFryProd_t$	=	sockeye fry production (kg/ha) from equation 4-14, using the equivalence factor $SxEquiv_{JuvSurv}$
$KokAdProd_{,t-1}$	=	kokanee ages 0-4 production (kg/ha) from equation 5-31, using the equivalence factor $KokAdEquiv_{JuvSurv}$
$ImmMysProd_{t-1}$	=	production (kg/ha) of immature mysis in year t-1 from mysis submodel equation 6-11b, using the equivalence factor $ImmMysEquiv_{JuvSurv}$
$MatMysProd_{t-1}$	=	production (kg/ha) of mature mysis in year t-1 from mysis submodel equation 6-11a, using the equivalence factor $MatMysEquiv_{JuvSurv}$

The kokanee age 0 capacity (in numbers of fish) is:

$Age0Cap = TotalCap_{k,t} * LakeArea / (Weight_0 /1000)$ [eq. 5-29]

where: $TotalCap_{s,t}$ = capacity of lake for kokanee age 0 (kg/ha); derived from equation 5-28
LakeArea = area of the rearing lake (ha)
$Weight_0$ = derived from Length0 (user-defined parameter) and equation 5-9 (g)

The equation to determine the number of Age 0 kokanee in a given year is then:

$\#Kokanee_0 = \#EmergFry/(1+(\#EmergFry/Age0Cap)) * (1- FractionCons_{fry,t})$ [eq. 5-30]

where: #EmergFry = # of emerging fry (from equation 5-26)
Age0Cap = rearing capacity for kokanee fry (from equation 5-29)
$FractionCons_{fry,t}$ = fraction of fry consumed (from equation 5-16)

The fraction of fry consumed represents both predation on smolts at the time of migration into the lake and predation during the summer while they are rearing.

5.5 Total production

Total production of adult kokanee (defined for documentation purposes as age 0+) in kg/ha is required to partition lake rearing capacity among kokanee, sockeye, and mysis. As for sockeye, kokanee fry, and mysis, we first calculate a base production rate then adjust that production using different equivalence factors to account for inter- and intra-specific differences in competitive ability and ecological overlap. Base production is calculated as

$KokProd_a = \#Kokanee_a*(Weight_a/1000) / LakeArea * P:B_{K,a} * KokAdEquiv$ [eq. 5-31]

where: $\#Kokanee_a$ = number of kokanee of age a (0-4, from equation 5-30)
$Weight_a$ = body weight (g) of kokanee of age a (from equation 5-8)
$P:B_{K,a}$ = Production:Biomass of age a kokanee (from equation 4-13 and 5-3)
LakeArea = area of rearing lake(ha)
KokAdEquiv = equivalence factor

Two equivalence factors are required:

1. The equivalence factor $KokAdEquiv_{JuvSurv}$ is needed for partitioning lake carrying capacity for survival of sockeye, kokanee and mysis juveniles. As a preliminary assumption, we assume that $KokAdEquiv_{JuvSurv} = 1$.
2. The equivalence factor $KokAdEquiv_{AdGrowth}$ is by definition = 1.

Total kokanee production is the sum of the kokanee production over all adult age classes.

6.0 Mysis Submodel

The mysis submodel provides annual estimates of mysis biomass to allow for effects of competitive interactions between mysis and nerkids on the productive capacity of the lake. Sampling for mysis has occurred in Okanagan Lake since 1989, where mean densities have varied from $150/m^2$ to $450/m^2$. Mysis densities in Skaha Lake are around $90/m^2$ and around $6/m^2$ in Osoyoos Lake (data provided by workshop participants). The downstream gradient is thought to be a result of gradual downstream migration from Okanagan Lake (where it was first stocked in 1966) to downstream lakes. Overall trends in mysis densities in Okanagan Lake appear to be highly variable from year to year but the average since the mid-1990's has been relatively constant (Andrusak et al. 2001). This is consistent with Kim Hyatt's observation that it takes about 30 years or so for mysis to become fully established after introduction (workshop comment).

6.1 Survival, harvest, and predation

Our proposed modelling approach is based on a logistic growth function over time. We assumed, based on comments by workshop participants, that Okanagan mysis populations have a 2-year life cycle. We model two life stages: immature (1 year-olds) and mature (2-year olds). The maturation process is continuous but this division of life stages provides a reasonable approximation.

Density of immature mysis is calculated from the # of mature mysis the previous year:

$$MysisDensity_{Imm,t} = MysisDensity_{Mat,t-1} * MysisFemProp * MysisRecruitRate \qquad \text{[eq. 6-1]}$$

where: $MysisDensity_{Mat,t-1}$ = density of mature mysis in year t-1 (#/ha; from equation 6-9)
MysisFemProp = proportion of mature mysis that are female (user-defined parameter)
MysisRecruitRate = # of immature mysis produced per mature mysis female (user-defined parameter). This incorporates the # of eggs/female and the survival rate from egg to immature mysis

Survival from the immature to mature life stage is density-dependent (Figure 6.1). Recruitment is represented as the density of mature mysis in year t+1 per immature mysis in year t). Density is expressed as the percentage of total capacity in year t that is occupied. The capacity will change from year due to fluctuations in phosphorus concentrations (which drive total lake productivity) and kokanee and sockeye abundance. As the % capacity filled increases, mysis survival rate declines.

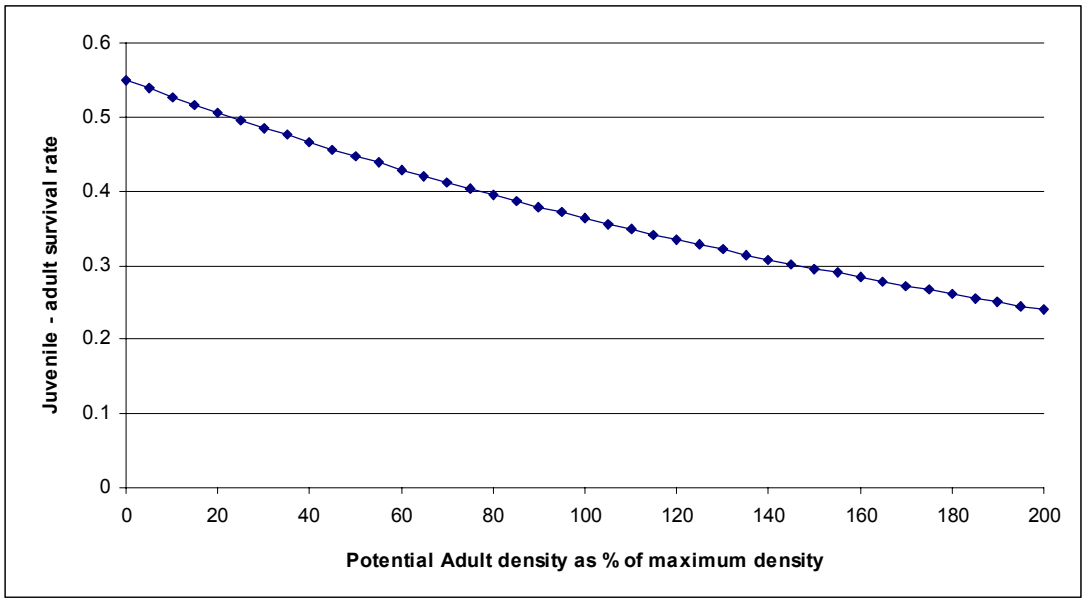


Figure 6.1. Mysis survival rate as a function of density.

Parameterisation of the relationship in Figure 6.1 requires two pieces of information. The first is the maximum survival rate at very low adult densities (i.e., the y-intercept). This is a user-defined parameter, representing the rate of population increase in the absence of significant intra-specific competition. Maximum survival rate can theoretically be measured in controlled experiments or in lakes with low mysis densities. We use information from Okanagan Lake to develop a rough estimate of the maximum survival rate. Current density of mysis in Okanagan Lake is around 300/m2 and has been relatively constant over the last several years (Andrusak et al. 2001). We assume that this density represents the current carrying capacity of Okanagan lake for mysis (i.e., mysis in Okanagan Lake are at 100% of capacity). Kim Hyatt (workshop comments) suggested that mysis generally take about 30 years to reach constant densities. Based on these two pieces of information, we estimate that the maximum survival rate from immature to mature would have had to be around 0.55 to account for the temporal trend in Okanagan Lake. This value is likely a function of lake productivity and the model will allow for lake-specific values, but this preliminary estimate provides an order of magnitude approximation as a preliminary parameter value for Skaha and Osoyoos Lakes.

The second piece of information defines how steeply the curve in Figure 6.1 declines. To determine this, we make the simple assumption that the recruitment rate is 1 (i.e., the population replaces itself) when the capacity is 100% filled. That is, population densities remain constant once capacity has been reached. The survival rate at 100% capacity value can be computed from the maximum survival rate, the proportion of mature individuals that are female, and the rate of immature mysis production.

The equation describing the survival rate function is:

$$MysSurvRate_t = MaxSurvRate * \exp(-SurvShape * (MysisDensity_{Imm,t-1} / TotalCap_{m,t})) \quad \text{[eq. 6-2]}$$

where: MaxSurvRate = maximum survival rate at low adult density (user-defined parameter)
SurvShape = calculated steepness parameter

= ln(1/(MysisFemProp*MysisRecruitRate)/MaxSurvRate)/-100
assuming that the recruitment rate is 1 at 100% of capacity

$MysisDensity_{Imm,t-1}$ = density of immature mysis in year t-1 (#/ha); from equation 6-1

$TotalCap_{m,t}$ is the rearing capacity in the lake for mysis in the year t, assuming that the total rearing capacity is partitioned between sockeye, kokanee, and mysis according to their relative production. The equation to calculate capacity for producing mature mysis from immature mysis in a given year is:

$$TotalCap_{m,t} = \frac{ImmMysProd_{Mysis,t-1} * (TotalCap_t / MysisWeight_{Mat} * 1000)}{(SxFryProd_t + KokFryProd_t + KokAdProd_{t-1} + ImmMysProd_{t-1} + MatMysProd_{t-1}} \quad \text{[eq. 6-3]}$$

where:
- $TotalCap_t$ = derived from phosphorus concentrations (equation 4-19; kg/ha)
- $MysisWeight_{Mat}$ = body weight per mysis (g; user-defined parameter)
- $KokFryProd_t$ = production of kokanee fry in year t from equation 5-27, using the equivalence factor $KokFryEquiv_{JuvSurv}$ (which by definition = 1)
- $SxFryProd_t$ = sockeye fry production (kg/ha) in year t from equation 4-14, using the equivalence factor $SxEquiv_{JuvSurv}$
- $KokAdProd_{,t-1}$ = kokanee ages 0-4 production (kg/ha) from the fall of year t-1 to the fall of year t from equation 5-31, using the equivalence factor $KokAdEquiv_{JuvSurv}$
- $ImmMysProd_{t-1}$ = production (kg/ha) of immature mysis in year t-1 from mysis submodel equation 6-11b, ($ImmMysEquiv_{JuvSurv}$ = 1 by definition).
- $MatMysProd_{t-1}$ = production (kg/ha) of mature mysis in year t-1 from mysis submodel equation 6-11a, using the equivalence factor $MatMysEquiv_{JuvSurv}$

The potential mature mysis density in year t is then:

$$MysisDensity_{Mat,t} = MysisDensity_{Imm,t-1} * MysSurvRate_t \quad \text{[eq. 6-4]}$$

where:
- $MysisDensity_{Imm,t-1}$ = density of immature mysis (#/ha) from equation 6-1.
- $MysSurvRate_t$ = survival rate from immature to mature from equation 6-2

Equations 6-1 and 6-4 describe potential mysis production. This can be adjusted to account for potential reductions in mysis densities due to mysis harvest and predation by kokanee. Harvest is modelled using a simple loss adjustment representing the fraction of a particular cohort removed in each year. The harvest rate is assumed to take the same proportion of mature and immature mysis.

There was disagreement over the importance of predation by kokanee adults in controlling mysid populations. We have included kokanee predation on mysis, in which the maximum contribution of mysis to the diet of kokanee is a function of age of kokanee. The actual contribution of mysis to kokanee diet is a function of mysid density (higher contribution at higher density; Figure 6.2). Such a function is likely to be difficult to parameterise with existing data but could in theory be tested through controlled field experiments.

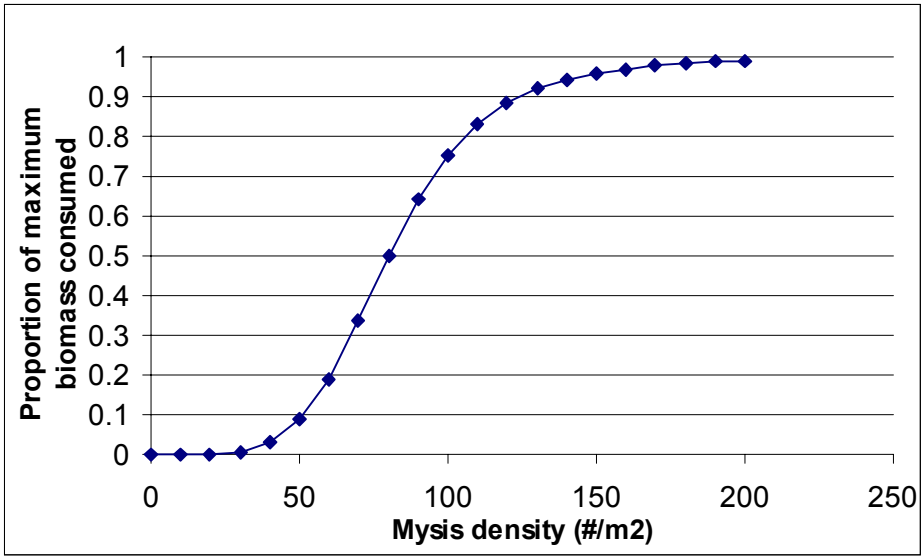


Figure 6.2. Example relationship between mysis contribution to kokanee diet and mysid density.

The contribution of mysis to the diet of age a kokanee is:

$$MysisContr_a = MaxContr_a * \frac{(MysisDensity_{Mat+Imm})^{ContrShape}}{(ContrHalf_a^{ContrShape} + (MysisDensity_{Mat+Imm})^{ContrShape})} \quad \text{[eq. 6-5]}$$

where: $MaxContr_a$ = maximum contribution of mysis to age a kokanee (user-defined parameter)
$MysisDensity_{Mat+Imm}$ = total (mature + immature) mysis density from equation 6-1 and 6-4
ContrHalf = mysis density at which actual mysis contribution is half of the maximum (user-defined parameter)
ContrShape = shape parameter (user-defined parameter; assume same for all kokanee age classes)

This function can be parameterized to represent the hypothesis of no kokanee predation on mysis by setting the $MaxContr_a$ parameter to zero for all age classes.

The biomass of mysis (kg/ha) consumed in year t is found from equation 6-5 and the production and conversion efficiency of kokanee in each age class:

$$MysisBiomassCons_t = \Sigma_a([KokProd_{a,t-1} / ConvEff_{a,t-1})*MysisContr_{a,t} \quad \text{[eq. 6-6]}$$

where: $KokProd_{a,t-1}$ = production from age a kokanee (kg/ha)
= $\#Kokanee_a*(Weight_a/1000) / LakeArea * P{:}B_{K,a}$
#Kokanee = number of kokanee at age a from equation (5-30)
$Weight_a$ = body weight (g) of kokanee of age a (from equation 5-8)
$P{:}B_{K,a}$ = Production:Biomass of age a kokanee (from equation 4-13 and 5-3)
$ConvEff_a$ = conversion efficiency of age a (from equation 5-3)
$MysisContr_a$ = contribution of mysis to diet of age a kokanee from equation 6-5

The total biomass consumed (in kg/ha) is apportioned to immature and mature mysis age classes based on their relative biomasses in year t-1:

$$MysisBiomassCons_{Imm,t} = \frac{MysisBiomassCons_t * MysisDensity_{Imm,t-1} * MysisWeight_{Imm,t-1}}{MysisDensity_{Imm,t-1} * MysisWeight_{Imm,t-1} + MysisDensity_{Mat,t-1} * MysisWeight_{Mat,t-1}} \quad \text{[eq. 6-7a]}$$

$$MysisBiomassCons_{Mat,t} = \frac{MysisBiomassCons_t * MysisDensity_{Mat,t-1} * MysisWeight_{Mat,t-1}}{MysisDensity_{Imm,t-1} * MysisWeight_{Imm,t-1} + MysisDensity_{Mat,t-1} * MysisWeight_{Mat,t-1}} \quad \text{[eq. 6-7b]}$$

where: $MysisBiomassCons_t$ = total biomass of mysis consumed (kg/ha)
$MysisDensity_{Mat,t-1}$ = density of mature mysis (#/ha; from equation 6-4)
$MysisDensity_{Imm,t-1}$ = density of immature mysis (#/ha; from equation 6-1)
$MysisWeight_{Imm,t-1}$ = body weight of immature mysis (user-defined parameter)
$MysisWeight_{Mat,t-1}$ = body weight of mature mysis (user-defined parameter)

The reduction in density in each mysis age class due to predation therefore is:

$$MysisDensityCons = MysisBiomassCons * 1000 / (MysisWeight) \quad \text{[eq. 6-8]}$$

where: MysisBiomassCons = biomass (kg/ha) of mysis consumed by kokanee (from equation 6-6)
MysisWeight = body weight (g) of mysis (user-defined parameter)

The final density of mysis in the lake is found by reducing the potential immature and mature mysis density by the harvest and predation losses:

$$MysisDensity = PotMysisDensity * (1-MysisHarvRate) - MysisDensityCons \quad \text{[eq. 6-9]}$$

where: PotMysisDensity = potential mysis density (#/ha) (from equation 6-1 or 6-3)
MysisHarvRate = fraction of mysis cohort lost to harvest (user-defined parameter)
MysisDensityCons = # of mysis consumed per ha by kokanee (from equation 6-8)

6.2 Total production

Total production of mysis in kg/ha is required to partition lake rearing capacity among kokanee, sockeye, and mysis. Production:Biomass ratios are calculated for immature and mature mysis from each age class's conversion efficiencies and feeding rates:

$$P{:}B_{m,mat} = ConvEff_{m,mat} * FeedingRate_{m,mat} \quad \text{[eq. 6-10a]}$$
$$P{:}B_{m,imm} = ConvEff_{m,imm} * FeedingRate_{m,imm} \quad \text{[eq. 6-10b]}$$

where: $ConvEff_{m,mat}$ = conversion efficiency of mature mysis (user-defined parameter)
$ConvEff_{m,imm}$ = conversion efficiency of immature mysis (user-defined parameter)
$FeedingRate_{m,mat}$ = feeding rate of mature mysis (user-defined parameter)
$FeedingRate_{m,imm}$ = feeding rate of immature mysis (user-defined parameter)

The production for each age class is

$$MatMysProd = MysisDensity_{Mat} * MysisWeight_{Mat} / 1000 * P{:}B_{mysis,mat} * MatMysEquiv \quad \text{[eq. 6-11a]}$$
$$ImmMysProd = MysisDensity_{Imm} * MysisWeight_{Imm} / 1000 * P{:}B_{mysis,Imm} * ImmMysEquiv \quad \text{[eq. 6-11b]}$$

where: MysisDensity = density of mysis (from equation 6-9; #/ha)
MysisWeight = body weight of mysis (g; user-defined parameter)
P:B = Production:Biomass, from equation 6-10
$MatMysEquiv_{Nerkid}$ = mature mysis equivalence factor
$ImmMysEquiv_{Nerkid}$ = immature mysis equivalence factor

Equivalence factors for expressing the effects of mysid production on mysid survival are 1, by definition. Equivalence factors for expressing the effects of mysid production on kokanee and survival rates can be adjusted by the user to represent alternative hypotheses about interactions between these species. As for sockeye and kokanee, two equivalence factors are required for each age class of mysis (four in total):

1. The equivalence factor $MatMysEquiv_{JuvSurv}$ is needed to account for the effects of production by mature mysis on lake carrying capacity for survival of sockeye, kokanee and mysis juveniles. This factor is likely to be zero or close to zero because mature mysis are already fully grown and most of their production goes into eggs and newly-hatched mysids that do not compete directly with nerkids (small mysids are primarily herbivorous; Chipps and Bennett 2000).
2. The equivalence factor $MatMysEquiv_{AdGrowth}$ is needed to account for the effects of production by mature mysis on growth rates of adult kokanee. This factor is likely to be close to zero for the same reasons outlined above for $MatMysEquiv_{JuvSurv}$.
3. The equivalence factor $ImmMysEquiv_{JuvSurv}$ accounts for the effects of production by immature mysis on lake carrying capacity. Immature mysids (1-year olds) are actively growing and feeding on zooplankton and thus have exert more competiive influence on nerkids than mature mysids. The immature mysid-nerkid equivalence factor is potentially a function of lake productivity, as described in section 6.3.
4. The equivalence factor $ImmMysEquiv_{AdGrowth}$ accounts for the effects of production by immature mysis on lake carrying capacity. For convenience, we assume that $ImmMysEquiv_{AdGrowth}$ = $ImmMysEquiv_{JuvSurv}$. The immature mysid equivalence factor is potentially a function of lake productivity, as described in section 6.3.

6.3 Immature mysis-nerkid equivalence factor

The mysis-nerkid equivalence factor is intended to represent the relative competitive abilities of mysis and nerkids. Differences in competitive advantage could be due to different feeding efficiencies or degrees of overlap between different species. The model will allow two alternative hypotheses about this equivalence factor:

1. The equivalence factor is dependent on nutrient status (total Phosphorus concentration) of the lake (Figure 6.3). The hypothesis is that mysis are generally more efficient than nerkids at obtaining common food items, and that this advantage is more pronounced when food resources are scarce.
2. Mysis-nerkid equivalence is independent of trophic status.

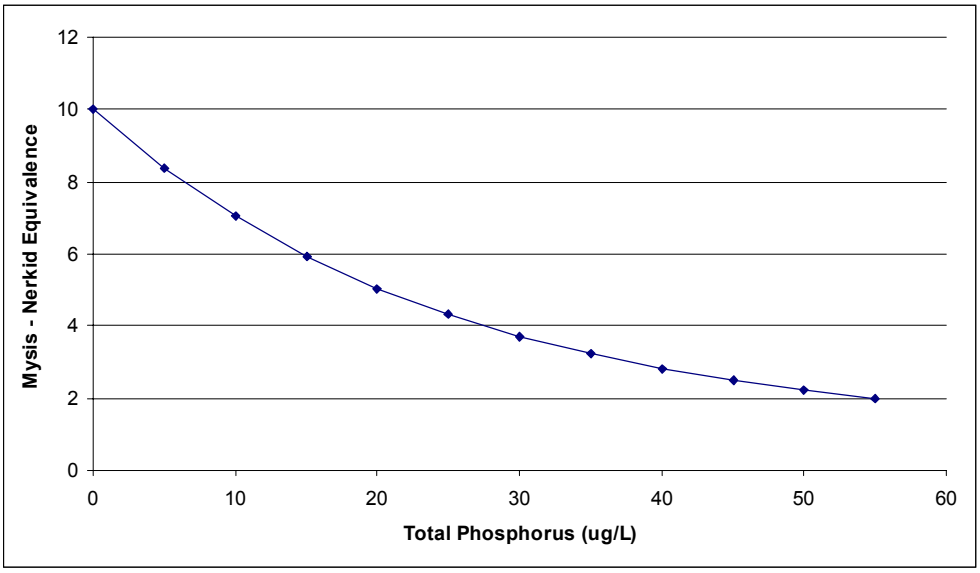


Figure 6.3. Mysis-nerkid equivalence factor as a function of lake productivity (represented by total P concentrations). Function shown is an example only.

The equation to calculate the nerkid equivalency is:

$$MysEquiv_{Nerkid} = MysEqMax - MysEqMin * e^{(-MysEqShape*TotalP)} + MysEqMin \qquad \text{[eq. 6-12]}$$

where:

MysEqMax	=	maximum mysis equivalence factor at very low productivities (user-defined parameter)
MysEqMin	=	minimum mysis equivalence factor at very high productivities (user-defined parameter)
MysEqShape	=	shape parameter; determines how quickly minimum value is reached (user-defined parameter)
TotalP	=	Total P concentration, selected according to water year (see Section 3.6).

Evidence for hypothesis (1) is equivocal. Cooper et al. 1992 review mysid Production:Biomass ratios (which, if one assumes that conversion efficiencies and feeding rates of mysids and nerkids are equal, approximates the equivalence factor) in lakes with different trophic status (Figure 6.3). Higher P:B ratios are generally associated with lower productivity measures, but this observation is confounded by the fact that the mysids with the highest P:B ratios were all of the species Neomysis rather than Mysis. Among the Mysis populations, there appears to be no clear relationship between P:B and trophic status. Hypothesis (2) can be represented using equation 6-12 by setting MysEquivMax = MysEquivMin = some constant value.

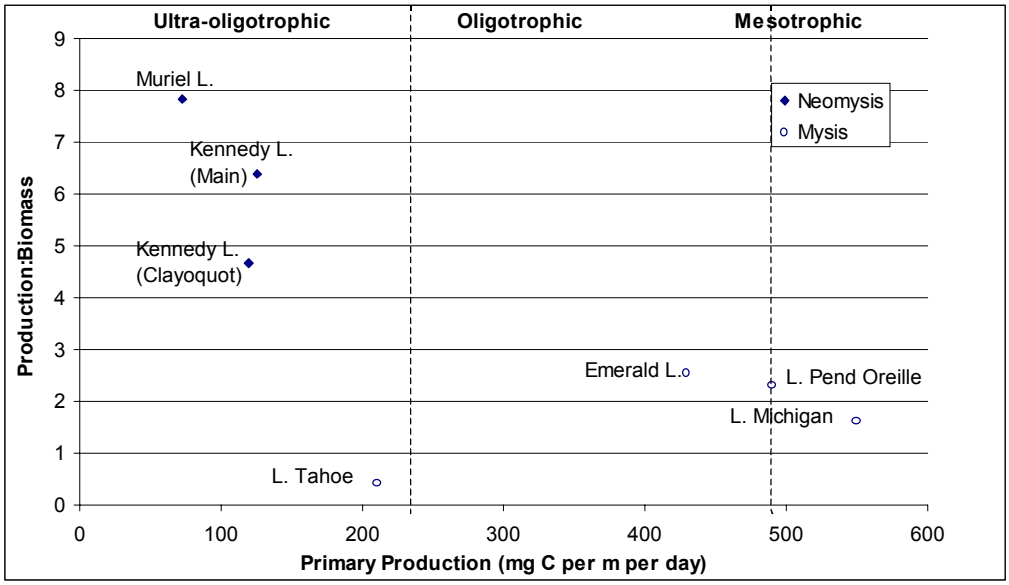


Figure 6.4. Mysid Production:Biomass ratios in lakes of different trophic status (from Cooper et al. 1992).

7.0 Predator submodel

Workshop participants suggested that the model should include an explicit predator submodel to allow exploration of management scenarios in which predator populations (primarily rainbow trout and smallmouth bass) are controlled through directed harvests. There are two potentially important predation processes that could affect sockeye and kokanee rearing in Osoyoos and Skaha lakes.

1. Predation on sockeye fry and kokanee juveniles while rearing in rearing lakes.
2. Predation during specific migration events, such as the outmigration of sockeye smolts in the spring. This is particularly important for sockeye smolts migrating through Vaseaux Lake, which has a high density of predaceous fish.

Specific migration predation is modelled separately in the kokanee and sockeye submodels. In this section, we describe predation by lake-resident predator populations.

The LLKM includes detailed, age-structured predator modules for lake trout, rainbow trout, dolly varden, and other predator species. We have adapted the LLKM predator module for use in the Okanagan sockeye model. This module is a generic "predator" submodel, which can be parameterised to represent any potential predator species. In this version of the model, we have chosen to parameterize the predator submodel to represent rainbow trout as the primary predator species, for two reasons. First, there has been a considerable amount of research on this species in B.C. lakes and the LLKM includes preliminary default parameter values. In contrast, very little is known about smallmouth bass. Second, rainbow trout are probably more significant predators than smallmouth bass because migrating kokanee fry appear to spend little time in the littoral zone where smallmouth bass accumulate. Instead, they appear to migrate directly to the deeper parts of the lake where rainbow trout would have a greater influence (S. Matthews, WLAP Pentiction, pers. comm.).

The predator module of the LLKM calculates egg deposition and emergent fry abundance based on initial age distributions, age-specific fecundities and maturation proportions, and a constant egg-fry survival rate. Rainbow trout are assumed to require at least a year of rearing in a stream before emigration to the lake. The number of fry migrating into the lake is a density-dependent function of the number of emerging fry, and requires assumptions about the carrying capacity of the lake (as a simplifying assumption, we assume that this capacity is fixed and independent of the densities of kokanee, sockeye, and mysis). The number and size of fish at older age classes are determined using constant age-specific weights and survival rates. Equations for each of these life stages are provided below; Table 7.1 summarises the default LLKM parameter values for rainbow trout.

7.1 Egg deposition

Egg deposition is calculated using age-specific fecundity and maturation proportions:

$$\#Eggs = \Sigma_p (\#Pred_p * PropMature_p * Fecundity_p * FemaleProp) \qquad \text{[eq. 7-1]}$$

where: $\#Pred_p$ = number of predators at age p (from equation 7-4)
$PropMature_p$ = proportion of fish at age p that are mature (user-defined parameter)

$Fecundity_p$ = fecundity (eggs/female) of fish at age a (user-defined parameter)
FemaleProp = proportion of fish that are female (user-defined parameter; constant for all ages)

7.2 Emerging fry

The number of emerging fry is given by:

#EmFry = #Eggs * EggFrySurv [eq. 7-2]

where: #Eggs = number of eggs deposited (from equation 7-1)
EggFrySurv = egg-fry survival rate (user-defined parameter)

7.3 Rearing fry

The number of rearing fry in a given year t is computed using a modified Beverton-Holt relationship:

$\#RearingFry_t = \#EmFry_{t-1} / (1 + \#EmFry_{t-1} / PredFryCapacity)$ [eq. 7-3]

where: $\# EmFry_{t-1}$ = number of emergent fry in the previous year (from equation 7-2)
PredFryCapacity = maximum carrying capacity for predator fry (lake-specific user-defined parameter)

Note that for simplicity, we have assumed that the rearing capacity for predator juveniles is unaffected by the densities of kokanee, sockeye, and mysis. That is, we assume that because rainbow trout juveniles rear in streams they do not directly compete with lake-rearing nerkids and mysis.

7.4 Adults

The number of fish in older age classes in year t are computed using age-specific natural survival rates, and age-specific harvest rates. This allows the user to explore the effects of actions to reduce predator densities.

$\#Pred_{p,t} = \#Pred_{p-1,t-1} * NatSurvRate_{p-1} * (1-HarvRate_{p-1})$ [eq. 7-4]

where: $\#Pred_{p-1,t-1}$ = number of fish in the previous age class in the previous year
$NatSurvRate_{p-1}$ = natural survival rate of age a-1 fish (user-defined parameter)
$HarvRate_{p-1}$ = harvest rate of age a-1 fish (user-defined parameter)

7.5 Predation

The predator submodel calculates predation on juvenile kokanee and sockeye based on the net production of each age class during the previous year, the biomass of prey required to support this production, and the proportion of each species to the predator's diet. The equations to represent this process are:

Net production (kg) of a given age class from simulation year t-1 to year t is computed from the number of fish surviving to that age class * the increase in body weight from one age class to the next:

$Prod_{p,t} = \#Pred_{p-1,t-1} * NatSurvRate_{p-1} * (1-HarvRate_{p-1}) * (Weight_p - Weight_{p-1})$ [eq. 7-5]

where: $\#Pred_{p-1,t-1}$ = number of fish in the previous age class in year t-1 (from equation 7-4)
$NatSurvRate_{p-1}$ = natural survival rate of age p-1 fish (user-defined parameter)
$HarvRate_{p-1}$ = harvest rate of age p-1 fish (user-defined parameter)
Weight = the body weights at ages p and p-1 (user-defined parameter)

The biomass of prey required to support production in each predator age class (p) depends on the conversion efficiency (younger fish are more efficient and require consumption of less biomass). Conversion efficiency is related to body weight by the function:

$ConvEff_r = ConvEffConst_r + ConvEffSlope_r*\log(Weight_p)$ [eq. 7-6]

where: $ConvEffConst_r$ = constant (user-defined parameter)
$ConvEffSlope_r$ = coefficient relating log(body weight) to conversion efficiency (user-defined parameter)
$Weight_p$ = body weight of age p predators (user-defined parameter)

Data to parameterize this relationship for rainbow trout is available from Korman et al. (1993).

The biomass of prey required to support production of predator production at each age p is:

$BioCons_{p,t} = Prod_{p,t} / ConvEff_{p-1}$ [eq. 7-7]

where: $Prod_{p,t}$ = production of age class p (from equation 7-5)
$ConvEff_p$ = conversion efficiency of age p-1 fish (from equation 7-6)

The biomass of kokanee and sockeye consumed during year t depends on the predator diet composition:

$KokBioCons_{p,t} = BioCons_{p,t} * KokDietProp_p$ [eq. 7-8]
$SoxBioCons_{p,t} = BioCons_{p,t} * SoxDietProp_p$

where: $BioCons_{p,t}$ = biomass of prey consumed by age class p (from equation 7-7)
KokDietProp = maximum proportion of kokanee in predator diet (user-defined parameter)
SoxDietProp = maximum proportion of sockeye in predator diet (user-defined parameter)

Table 7.1. LLKM default parameter values for rainbow trout.

Age	Proportion Mature	Fecundity	Natural Survival Rate	Weight (g)	Proportion kokanee in diet
Egg	0	0	0.45	0	0
Fry	0	0	0.61	0	0
0	0	0	0.50	0	0
1	0	0	0.74	3	0
2	0	0	0.80	34	0
3	0	1000	0.85	302	0.20
4	0.2	1500	0.88	920	0.60
5	0.6	2500	0.70	1820	0.95
6	0.9	3000	0.64	2985	0.95
7	1.0	3500	0.61	3740	0.95
8	1.0	3800	0.61	5137	0.95
9	1.0	4000	0.61	5700	0.95

8.0 Summary of Parameters and Preliminary Parameter Values

Table 8.1 below summarises the parameters required by the proposed model design, and some preliminary parameter values based on our review of relevant literature. Preliminary values should be regarded as representing only one of many possible hypotheses. These hypotheses will be refined over time as the model and underlying data are improved. One of the benefits of models is that it allows users to explore the effects of alternative assumptions about various parameters on model outputs. Sensitivity analyses quantitatively measure the relative influence of each model parameter on the model outcome. This provides a useful approach for identifying critical model assumptions, and is helpful in defining priorities for future research and monitoring.

Table 8.1. Preliminary parameter values.

Functional Relationship	Equation #	Parameter	Prelim. Value	Comments
Hydrology Submodel				
Water temperature at OK Falls	3-1	$Slope_{OkFallsTemp}$	0.87	Hyatt and Stockwell (2002)
		$Int_{OkFallsTemp}$	3.18	
Water temperature at Oroville	3-2	$Slope_{OrovilleTemp}$	0.97	Hyatt and Stockwell (2002).
		$Int_{OrovilleTemp}$	1.62	
Water temperature at Similkameen	3-3	$Const_{SimTemp}$	6.22692	Estimated from 1991 – 1999 data.
		$TempCoef_{SimTemp}$	0.58611	
		$FlowCoef_{SimTemp}$	-0.0005	
Secchi Depth	3-5	$Int_{SecchiDepth}$	1.3892	Estimated from 1997-2000 Okanagan Lake data (Andrusak et al. 2001)
		$Slope_{SecchiDepth}$	-0.6529	
Sockeye Submodel				
Age-specific fecundity	4-1	Fec_a	Table 4.2	Major and Craddock 1965, as reported by Fryer 1995
Current spawning habitat	4-2	$MaxHabitat_{Os}$	140,000	Estimated from Environment Canada (1973) estimates of spawning habitat vs. flow (Figure 4.2).
		$FHalfMaxHabitat_{Os}$	2.4 cms	
		$MaxHabitat_{Skaha,High}$	63	Based on estimates in ONFC (2002)
		$FHalfMaxHabitat_{Skaha,High}$	0.05 cms	
		$MaxHabitat_{Skaha,Med}$	7000	
		$FHalfMaxHabitat_{Skaha,Med}$	0.05 cms	
Total spawning habitat	4-3	$SpawnHab_{New,\ Osoyoos}$		Potential management action
		$SpawnHab_{New,\ Skaha,\ High}$		
		$SpawnHab_{New,\ Skaha,\ Med}$		
Fraction of spawning habitat available for sockeye (Skaha only)	4-4	SpawnOverlap	1	Preliminary assumption.
Spawning capacity	4-6	$FemaleDensity_s$	1.48	Average from other sockeye stocks (Hyatt and Rankin 1999).
#Eggs	4-7	FemaleProp	0.52	Hyatt et al. (2002)
Stranding rate vs. minimum incubation flow	4-8	$StrandAdj_{Osoyoos}$	0	Assumes stranding mortality not a major factor
		$StrandAdj_{Skaha}$	0	Assumes stranding mortality not a major factor

Functional Relationship	Equation #	Parameter	Prelim. Value	Comments
Flushing rate vs. maximum incubation flow	4-9	FHalfFlush	42 cms	Based on data from Hyatt and Rankin (1999) and Stockwell et al. (2001).
		FlushShape	11	
Egg-Fry survival rate	4-10	$EggFrySurvMean_{High}$	-1.69	Maximum and standard deviation of ln(EggFry survival) estimated by Bradford (1995) for 9 sockeye stocks.
		$EggFrySurvStDev_{High}$	0.5	
		$EggFrySurvMean_{Med}$	-2.375	Mean and standard deviation of ln(EggFry survival) estimated by Bradford (1995) for 9 sockeye stocks.
		$EggFrySurvStDev_{Med}$	0.5	
Female broodstock for fry supplementation	4-12	$FrySupp_{Sk,t}$		Potential management action
		HatcheryEggFrySurv	0.7	Workshop comments, October 15 2002
		$MinFemale_{Os}$	5000	Preliminary value; potential management action
P:B $Ratio_{SxFry}$	4-13	$FeedingRate_{SxFry}$	8.5	Estimate for kokanee juveniles from Kay (2002)
Sockeye fry production	4-14	$LakeArea_{Osoyoos}$	1000 ha	North basin only
		$LakeArea_{Skaha}$	2010 ha	
		$Weight_{SxFry}$	0.2 g	Shepherd and Inkster (1995); Burgner (1991).
		$SxEquiv_{JuvSurv}$	1	Assumes sockeye and kokanee fry are ecological analogs.
		$SxEquiv_{AdGrowth}$	0	Assumes sockeye fry do not affect kokanee adults.
Length of sockeye fry		LengthFry	28 mm	Shepherd and Inkster (1995).
Total Lake Capacity	4-19	$Int_{TotalCap}$	0.7782	Hyatt and Rankin (1999).
		$Slope_{TotalCap}$	0.6529	
Smolt weight	4-21	$SmoltSizeMax_{Osoyoos}$	0	Based on data in Hyatt and Rankin (1999) Figure 12b
		$SmoltSizeShape_{Osoyoos}$	-0.52	
		$SmoltSizeSlope_{Osoyoos}$	719.69	
		$SmoltSizeMax_{Skaha}$	20.387	
		$SmoltSizeShape_{Skaha}$	1	
		$SmoltSizeSlope_{Skaha}$	-0.0032	
#Smolts	4-23	MaxFrySurv	0.5	Highest recorded fry-smolt survival rate in Bradford (1995).
Smolt supplementation	4-24	$\#Smolts_{supp,Osoyoos}$	0	Cassimer Bar hatchery no longer operating.
		$\#Smolts_{supp,Skaha}$	0	Potential management action.
Smolt survival to Wells Dam	4-25	$SmoltSurvWells_{Osoyoos}$	1	Preliminary guess; no data on this. Can use the model to game with these values.
		$SmoltSurvWells_{Skaha}$	1	
Smolt-adult returns (SARs)	4-26	SARMean	-5.6	Mean of ln(SAR) from Table 4.3. Year effects based on time series from Robertson Creek coho (Hyatt et al. 2000).
		SARYearEffect	Figure 4.11	
Maturity schedule	4-27	$PropAge_{1.X}$	Table 4.1	Hyatt et al. (2002); assumes all fish are 1.X
Fraction of surplus caught	4-29	HarvRateFirstYear	0.1022	Estimated from harvest and escapement data 1980-2001 (Hyatt et al. 2002; Figure 4.12). MaxFraction is the highest observed fraction over that time period.
		HarvShape	1.5349	
		MaxFraction	2.25	
Commercial harvest	4-30	$EscTarget_{Bon}$	75,000	Current values under 2001 – 2003 Interim Management Plan (ODFW&WDFW 2001)
		FracSurplusAvail	1.0	
Treaty ceremonial and subsistence harvest	4-31	TreatyC&SHarvestRate	Table 4.4	
Upstream survival rate	4-32	PerProjSurv	Figure 4.14	Estimated from dam count data 1980-2001.
Critical temperature for migrating up lower Okanagan River		LowerOkCritTemp	21 degrees	Fryer (1995); Hyatt and Rankin (1999); Alexander et al. (1998).
Prespawning mortality	4-34	MaxPreMort	0.13	No data to support hypothesis that delay causes lower mortality. Assume constant 0.13 from 1997 radio-tag study.
		MinPreMort	0.0	

Functional Relationship	Equation #	Parameter	Prelim. Value	Comments
		PreMortShape	0	
Okanagan River harvest rate	4-35	OkanHarvest	0.03	Average upriver harvest rate 1971-2001; Hyatt et al. 2002
Spawners returning to Skaha Lake	4-36	UpstreamCritTemp	15 degrees	Workshop comments.
Adult supplementation	4-37	$\#Spawners_{Skaha,supp}$		Potential management action
Kokanee Submodel				
Size at age	5-1	K_{Brody}	0.55	LLKM default value
		$Length_0$	55 mm	Average for Okanagan Lake kokanee (Andrusak et al. 2001)
$Length_3$ vs. $Length_2$ and Secchi Depth	5-2	$MaxLength_3$	345	LLKM default values; based on data from Rieman and Myers (1992).
		ProdCoeff	12.0	
		SecchiCoeff	11.3	
		$Secchi_{Skaha}$	4.5 m	D. Hatch, 1996 Okanagan Sockeye Workshop
Conversion efficiency	5-3	$ConvEffConst_k$	0.5204	Based on CE lookup table in Korman et al. 1993
		$ConvEffSlope_k$	-0.1827	
Length vs. weight	5-9	$WeightA_a$	Table 5.2	LLKM default values (provincial standards)
		$WeightB_a$		
Age-specific natural survival and harvest rates	5-17	$NatSurvFrac_a$	0 = 0.4 1 = 0.6 2 = 0.7 3 = 0.8 4 = 0.8	LLKM default values (Kornan et al. 1993).
		$HarvRate_a$		Potential management action
Maturation	5-18	MinMatLength	200 mm	Lowest spawner length observed in Mission Creek (Andrusak et al. 2001)
Spawning capacity	5-22	$FemaleDensity_k$	2	≈1.4X of sockeye female density, based on relative lengths kokanee and sockeye spawners
Fecundity	5-23	FecA	-5.275	Data from Mission Creek; Andrusak et al. 2001
		FecB	3.2899	
#Eggs	5-24	FemRatio	0.50	No data
Egg-Fry survival	5-25	EggSurvMean	-3.0	Mean egg-fry in natural streams (Andrusak et al. 2001, citing Redfish Consulting 1999). Standard deviation of ln(EggFry survival) estimated for Okanagan lake kokanee in Mission Creek spawning channel (Andrusak et al. 2001).
		EggSurvStDev	0.5	
Production of Age 0 fry	5-27	$Weight_{EmFry}$	0.1 g	Data from Mission Creek; Shepherd and Inkster (1995).
		$KokFryEquiv_{JuvSurv}$	1	By definition
		$KokFryEquiv_{AdGrowth}$	1	Preliminary assumption
Kokanee adult production	5-31	$KokAdEquiv_{JuvSurv}$	1	Preliminary assumption
		$KokAdEquiv_{AdGrowth}$	1	By definition
Maximum contribution of mysis to age a kokanee diet	6-5	$MaxContr_a$	a2 = 0 a3 = 0 a4 = 0	Preliminary assumption of no predation by kokanee on mysis.
		MysConsHalf	a2 = 80 a3 = 80 a4 = 80	
		MysConsShape	5 (all ages)	

Functional Relationship	Equation #	Parameter	Prelim. Value	Comments
Mysis Submodel				
Immature mysis density	6-1	MysisFemProp	0.55	Data from Okanagan Lake; Andrusak et al. 2001
		$MysisRecruitRate_{Osoyoos}$	5	Preliminary guess (workshop participants suggested < 10)
		$MysisRecruitRate_{Skaha}$	5	
Mysis survival rate	6-2	$MaxSurvival_{Osoyoos}$	0.55	Based on rate of population growth in Okanagan Lake
		$MaxSurvival_{Skaha}$	0.55	
Total capacity for mysis	6-3	$MysisWeight_{Mat}$	0.02g	15 mm in Lake Ontario (Johannson et al. 2001)
Biomass of mysis consumed	6-7	$MysisWeight_{Imm}$	0.002g	Data from Lake Pend Oreille (Chipps and Bennett 2000)
Actual mysis density	6-9	MysisHarvRate		Potential management action
Mysis P:B	6-10	$ConvEff_{m,mat}$	0.15	Kay (2002)
		$ConvEff_{m,imm}$	0.221	
		$FeedingRate_{m,mat}$	18	
		$FeedingRate_{m,mat}$	25	
Mysis Production	6-11	$MatMysEquiv_{JuvSurv}$	0	Preliminary assumption that mature mysid production has no effect on nerkids
		$MatMysEquiv_{AdGrowth}$	0	
Mysis – nerkid equivalence	6-12	ImmMysEqMax	1	Preliminary assumption
		ImmMysEqMin	1	
		ImmMysEqShape	0	
Predator Submodel				
Sockeye fry consumption by predators	4-15	SoxConsHalf	1000	Preliminary guesses; no data on this. Can use the model to game with these values.
		SoxConsShape	2	
Kokanee consumption by predators	5-10	KokConsHalf	250	Default LLKM values; no data on this. Can use the model to game with these values.
		KokConsShape	3	
Size-dependent vulnerability of kokanee to predators	5-12	RelVulnMean	0.16	Estimated from rainbow trout gut content data (Korman et al. 1993).
		RelVulnStDev	0.06	
#Eggs	7-1	$PropMature_p$	Table 7.1	LLKM default values (Korman et al. 1993).
		$Fecundity_p$		
		FemaleProp	0.50	No data; assume 50%
#Emerging Fry	7-2	EggFrySurv	Table 7.1	LLKM default value (Korman et al. 1993).
#Rearing Fry	7-3	PredFryCapacity	???	No data; use model to game.
#Adults	7-4	$NatSurvRate_p$	Table 7.1	LLKM default values (Korman et al. 1993).
		$HarvRate_p$		Potential management action
Predator production	7-5	$Weight_p$	Table 7.1	LLKM default values (Korman et al. 1993).
Conversion efficiency	7-6	$ConvEffConst_r$	0.5514	Based on CE lookup table in Korman et al. 1993
		$ConvEffSlope_r$	-0.1452	
Biomass consumed	7-8	$KokDietProp_p$	Table 7.1	LLKM default values (Korman et al. 1993).
		$SoxDietProp_p$	Table 7.1	No data; assume no predation

Table 8.2 summarises a preliminary set of initial conditions needed to initialise the model. These values represent the current state of sockeye, kokanee, mysis, and predator populations included in the model. We have used data wherever possible to derive these preliminary values, but in many cases the values are very rough estimates that should be explored through sensitivity analysis.

Table 8.2. Initial conditions required to initialise the model (values are preliminary hypotheses).

Parameter	Osoyoos	Skaha	Comments
Sockeye			
Initial fry abundance	1,500,000	0	Osoyoos: Initial adult abundance approximates recent average; juvenile abundances consistent with initial adult abundance assuming average fry-smolt, SARs. Skaha: No sockeye population at present.
Initial smolt abundance	750,000	0	
Initial adult abundance (at Wells)	15,000	0	
Kokanee			
Initial Age 0 abundance	0	73,000	Osoyoos: Assume minimal kokanee population in Osoyoos lake. Skaha: Age 3 and 4 abundance consistent with recent average number of spawners; numbers at ages 0-2 consistent with recent average spawners and approximate age structure in Okanagan Lake.
Initial Age 1 abundance	0	24,000	
Initial Age 2 abundance	0	16,000	
Initial Age 3 abundance	0	10,000	
Initial Age 4 abundance	0	900	
Initial Age 0 length	0	55	Values based on Okanagan lake data.
Initial Age 1 length	0	177	
Initial Age 2 length	0	231	
Initial Age 3 length	0	256	
Initial Age 4 length	0	267	
Mysis			
Initial immature density (#/m2)	4	63	Total (immature + mature) densities consistent with estimates from Feb 27th review meeting; immature/mature population structure a preliminary guess.
Initial mature density (#/m2)	2	27	
Predators			
Initial Age 0 abundance	0	0	No data on rainbow trout abundance in Skaha Lake. Assume for model testing and validation purposes that rainbow trout population is minimal / predation effects are insignificant.
Initial Age 1 abundance	0	0	
Initial Age 2 abundance	0	0	
Initial Age 3 abundance	0	0	
Initial Age 4 abundance	0	0	
Initial Age 5 abundance	0	0	
Initial Age 6 abundance	0	0	
Initial Age 7 abundance	0	0	
Initial Age 8 abundance	0	0	
Initial Age 9 abundance	0	0	

9.0 References

Alexander, R.F., K.K. English, B.L. Nass, and S.A. Bickford. 1998. Distribution, timing and fate of radio-tagged adult sockeye, chinook, and steelhead tracked at or above Wells Dam on the Mid-Columbia River in 1997.

Andrusak, H., S. Matthews, I. McGregor, K. Ashley, G. Wilson, L. Vidmanic, J. Stockner, K. Hall, D. Sebastian, G. Scholten, G. Andrusak, J. Sawada, D. Cassidy, and J. Webster. 2001. Okanagan Lake Action Plan Year 5 (2000) Report. Fisheries Project Report No. RD89.. Fisheries Management Branch, B.C. Ministry of Water, Land, and Air Protection.

B.C. WLAP (Ministry of Water, Land, and Air Protection). 2001. Okanagan Kokanee Spawning Summary for 2001.

Bradford, M.J. 1995. Comparative review of Pacific salmon survival rates. Can. J. Fish. Aquat. Sci. 52: 1327-1338.

Bull, C. 1999. Fisheries Habitat in the Okanagan River Phase 2: Investigation of Selected Options (Draft). Glenfir Resources.

Burgner, R.L. 1991. Life History of sockeye salmon. In Groot, C. and Margolis, L. (eds.) Pacific Salmon Life Histories. UBC Press, Vancouver B.C.

Chapman, D, C. Peven, A. Giorgi, T. Hillman, F. Utter, M. Hill, J. Stevenson, and M. Miller. 1995. Status of sockeye salmon in the mid-Columbia region. Don Chapman Consultants, Inc., Boise, Idaho.

Cooper, K.L., K.D. Hyatt, and D.P. Rankin. 1992. Life history and production of Neomysis mercedis in two British Columbia coastal lakes. Hydrobiologia 230: 9-30.

ESSA Technologies Ltd. and Summit Environmental Consultants. 2002. Development of Decision Support Software for Fish/Water Management in Okanagan Basin Lakes and River System: Draft Design Document. September 6, 2002

Fish Passage Center. Annual Report 2001. Fish Passage Center, Portland, Ore. Available from www.fpc.org

Fish Passage Center. Annual Report 2001. Fish Passage Center, Portland, Ore. Available from www.fpc.org

Fish Passage Center. Annual Report 1999. Fish Passage Center, Portland, Ore. Available from www.fpc.org

Fish Passage Center. Annual Report 1998. Fish Passage Center, Portland, Ore. Available from www.fpc.org

Fish Passage Center. Annual Report 1997. Fish Passage Center, Portland, Ore.

Fish Passage Center. Annual Report 1996. Fish Passage Center, Portland, Ore.

Fish Passage Center. Annual Report 1995. Fish Passage Center, Portland, Ore.

Fisheries Service Environment Canada 1973

Fryer, K.K. 1995. Columbia Basin Sockeye Salmon: Causes of their past decline, factors contributing to their present low abundance, and the future outlook. Ph.D. Thesis, university of Washington.

Hyatt, K.D. and M. M. Stockwell. 2002. Status report on reconstructing seasonal thermal regimes of Okanagan Lake kokanee and Okanagan River sockeye salmon habitats for the Fish and Water Management Tools (FWMT) Project. Report to file: ASIDS: Sre 01-02. Stock Assessment Division, Fisheries and Oceans Canada, Nanaimo, B.C., V9T 6N7.

Hyatt, K.D., M. Stockwell, and D.P. Rankin. 2002. Fish Water management Tools Project – Okanagan Sockeye Salmon, Core Numbers and Traits (CNAT) Data Set Version 1.0. June 20, 2002.

Hyatt, K.D., W. Luedke, J. Till, P. Rankin, and D. Lewis. 2000. Review of the 1999 Return of Barkely Sound Sockeye Salmon and Forecasts for 2000. Research Document 2000/174. Fisheries and Oceans Canada, Stock Assessment Division, Nanaimo B.C.

Hyatt, K.D. and D.P. Rankin. 1999. A habitat based evaluation of Okanagan sockeye salmon escapement objectives. Canadian Stock Assessment Secretariat Research Document 99/191. Canada Department of Fisheries and Oceans.

Johannson, O.E., M.F. Leggett, L.G. Rudstam, M.R. Servos, M.A. Mohammadian, G. Gal, R.M. Dermott, and R.H.Hesslein. 2001. Diet of Mysis relicta in Lake Ontario as revealed by stable isotope and gut content analysis. Can. J. Fish. Aquat. Sci. 58: 1975-1986.

Kay, A.S. 2002. Mysis relicta and kokanee salmon (Oncorhynchus nerka) in Okanagan Lake, British Columbia: From 1970 and into the future. M.Sc. Thesis, University of British Columbia.

Korman, J., T.M. Webb, and E. Parkinson. 1993. Large Lakes Kokanee Model Version 2.0. Users Guide. B.C. Fisheries Technical Circular #35.

Major, R.L., and D.R. Craddock. 1962. Influence of early maturing females on reproductive potential of Columbia River blueback salmon Oncorhynchus nerka. United States Fish and Wildlife Service Fishery Bulletin 61(194): 429-437.

ODFW (Oregon Department of Fish and Wildlife) and WDFW (Washington Department of Fish and Wildlife). 2002. Joint staff report concerning commercial seasons for spring chinook, steelhead, sturgeon, shad, smelt and other species and miscellaneous regulations for 2002.

1996 Okanagan Sockeye Workshop. Draft Workshop Proceedings.

Okanagan Nation Fisheries Commission. 2002. Evaluation of an experimentatiion re-introduction of sockeye salmon into Skaha Lake (Objectives 1-3). DRAFT Year 2 Reports. February 28, 2002.

Peters. C.N., D.P. Bernard and D.R. Marmorek. 1998. Should sockeye be re-introduced to Okanagan Lake? An exploration of potential benefits, impacts and uncertainties. Prepared by ESSA Technologies Ltd., Vancouver, BC for Participants of the Okanagan Sockeye Workshop (hosted by the Okanagan Nation Fisheries Commission). 50pp.

Quinn, T.P., S. Hodgson, and C. Peven. 1997. Temperature, flow, and the migration of adult sockeye salmon (*Oncorhynchus nerka*) in the Columbia River. Can. J. Fish. Aquat. Sci. 54: 1349-1360.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin 191, Fisheries Research Board of Canada.

Rieman, B.E. and D.L.Myers. 1992. Influence of fish density and relative productivity on growth of kokanee in ten oligotrophic lakes and reservoirs in Idaho. Trans. Am. Fish. Soc. 121: 178-191.

Shepherd, B.G. 1997. Impacts of flow releases on Okanagan nerkid stocks. Progress Report No. 6, Fisheries Section, Southern Interior Region, BC Ministry of Environment, Lands, and Parks.

Shepherd, B.G. and G.A. Inkster. 1995. Sockeye and kokanee fry migration study Okanagan River above Osoyoos Lake, 1994. Fisheries Project Report No. OK-18. BC Ministry of Environment, Lands, and Parks.

Stockwell, M.M., K.D. Hyatt, and D.P. Rankin. 2001. A compendium of historical physical variable observations, including air temperature, water temperature, river discharge, and dissolved oxygen conditions in selected portions of the Okanagan Basin in Canada and the United States. Canadian Data Report of Fisheries and Aquatic Sciences 1078.

Summit Environmental Consultants. 2002. Observations and modelling of bed movement and potential redd scour in Okanagan River. July 2002.

Swan, G.A., L.K. Timme, R.N. Iwamoto, L.C. Stuehrenberg, E.E. Hockersmith, B.L. Iverson, and B.P. Sandford. 1994. Wells Dam radio-telemetry study, 1992.

Appendix A. Project participants

Chris Bull, Glenfir Resources

Elmer Fast, Fisheries and Oceans Canada

Chris Fisher, Colville Confederated Tribes

Kim Hyatt, Fisheries and Oceans Canada (Pacific Biological Station)

Tom Johnston, B.C. Ministry of Water, Land, and Air Protection

Kari Long, Okanagan Nation Fisheries Commission

Deana Machin, Okanagan Nation Fisheries Commission

Dave Marmorek, ESSA Technologies Ltd.

Steve Matthews, B.C. Ministry of Water, Land, and Air Protection

Ian Parnell, ESSA Technologies Ltd.

Calvin Peters, ESSA Technologies Ltd.

Sarah Walsh, Okanagan Nation Fisheries Commission

Andrew Wilson, B.C. Ministry of Water, Land, and Air Protection

Howie Wright, Okanagan Nation Fisheries Commission

Appendix B. OkSockeye Version History

Version	Date	Major Revisions	Comments
1.0	Jun 19, 2002	• Prototype; design as described in June 19th 2002 model Design Document.	• Public release June 19, 2002 • demonstrated Oct 15, 2002.
2.0	Dec 4, 2002	• Added annual SAR year effects based on Barkley Sound coho SARS • Updated water temperature functions and parameter values to be consistent with FWMT assumptions (Hyatt and Stockwell 2002) • Updated sockeye model parameters using escapement, harvest, age data in CNAT v. 1.0 (Hyatt et al. 2002)	• Internal release
2.1	Dec 9, 2002	• Added annual fry supplementation schedule • Added annual adult supplementation schedule • Added SAR and production information to Excel Report	• Internal release
2.1.1	Dec 12, 2002	• Corrected minor bugs related to upstream survival (only had an effect on very large sockeye escapement values) • Minor enhancements to data edit screens	• Internal release
2.1.2	Dec 17, 2002	• Allow working with different databases • Minor enhancements to user interface (Run listbox and Save As dialog boxes) • Revise scour relationships to be consistent with Summit (2002) • Improved efficiency of initialisation	• Internal release • used to generate results in Jan 8 2003 Experimental Design Report • demonstrated Jan 16, 2003.
2.2	Jan 23, 2003	• Revised approach to computing total Okanagan + Wenatchee adult returns	• Public release Jan 31, 2003. • used to generate results in January 31, 2003 Experimental Design Report

FINAL

OBJECTIVE 5
Evaluate Alternative Experimental Strategies for Reintroducing Sockeye Salmon to Skaha Lake

Contribution No. *13* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Authors: Ian J. Parnell
Calvin N. Peters
David R. Marmorek

Evaluate Alternative Experimental Strategies for Reintroducing Sockeye Salmon to Skaha Lake

Evaluate Alternative Experimental Strategies for Reintroducing Sockeye Salmon to Skaha Lake

Prepared for:

Okanagan Nation Fisheries Commission
3255 C Shannon Lake Road
Westbank, BC V4T 1V4

Prepared by:

Ian J. Parnell, Calvin N. Peters, David R. Marmorek
ESSA Technologies Ltd.
#300 – 1765 West 8th Avenue
Vancouver, BC V6J 5C6

May 1, 2003

Citation: **Parnell, I.J., C.N. Peters and D.R. Marmorek.** 2003. Evaluate alternative experimental strategies for reintroducing sockeye salmon to Skaha Lake. Prepared by ESSA Technologies Ltd., Vancouver, BC for the Okanagan Nation Fisheries Commission, Westbank, BC. 85 pp.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the Okanagan Nation Fisheries Commission, Westbank, BC.

Executive Summary

Introduction

Historical records indicate that sockeye salmon were once found in most of the lakes in the Okanagan Basin in the Southern Interior of British Columbia. Currently, the only sockeye population within the Okanagan Basin is found in Osoyoos Lake. The abundance of this stock has declined significantly in the last fifty years, primarily due to extensive hydroelectric development in both Canada and the US, agricultural, urban and forest land use practices, restriction to sub-optimal habitats due to channel engineering, and regional impacts of climate change.

Tribes and First Nations in the U.S. and Canada have proposed re-introducing the species into Okanagan Lake, which has a large rearing capacity. Assessing the potential benefits and risks associated with a re-introduction of sockeye salmon into Okanagan Lake is difficult because of uncertainties about factors that determine production of Okanagan sockeye, and potential interactions with other species in Okanagan Lake. A 1997 workshop to discuss these issues recommended that sockeye be re-introduced to Skaha Lake as an experimental management strategy to resolve some of these uncertainties (Peters et al. 1998). For the last three years, the Skaha Lake working group (which includes representatives from the Okanagan Nation Fisheries Commission (ONFC), the Colville Confederated Tribes (CCT), the Canadian Department of Fisheries and Oceans (DFO), the B.C. Ministry of Water, Land, and Air Protection (WLAP), and ESSA Technologies Ltd.) has coordinated and conducted a research program to explore the benefits and potential risks of an experimental reintroduction of sockeye salmon to Skaha Lake.

As part of this project, ESSA has worked with the other participating agencies to develop a life-cycle model of sockeye salmon (OkSockeye; Peters and Marmorek 2003), and a framework for developing, and implementing an experimental design for the reintroduction that balances learning and conservation objectives. This framework includes sets of objectives, precautionary principles, re-introduction methods, and hypotheses, and a draft monitoring plan. We have also used the life-cycle model to evaluate relative benefits and risks associated with alternative reintroduction methods, and have conducted a preliminary set of statistical power analyses of these methods.

Objectives and Precautionary Principles

The participating agencies have defined the following set of objectives for an experimental reintroduction of sockeye salmon to Skaha Lake.

> ***Learning:*** Conduct a controlled Adaptive Management (AM) experiment to evaluate what level of sockeye can co-exist with kokanee and mysids, so as to better assess risks and alternative methods of introducing sockeye to Okanagan Lake. Use the life-cycle model to help design and interpret the results of experiments.
>
> ***Conservation:*** Establish a quasi-independent centre of sockeye production with better temperature / oxygen conditions than in Osoyoos Lake, increasing the overall resilience of the populations. At the same time, conserve Skaha Lake kokanee populations.
>
> ***Increase Sockeye Production and Harvest:*** This is a longer term objective.

To supplement these overall objectives, the Skaha Lake working group has also defined a set of precautionary principles for how the reintroduction is carried out.

1. Collect adequate pre- and post-experimental data to evaluate impacts well.
2. Use reversible methods of sockeye reintroduction and ensure an acceptable level of impact (e.g., the loss of 1 year class of kokanee may be OK; losing 3 year classes is unacceptable).
3. Evaluate results each year and re-assess next steps.
4. Consider conservation risks to both sockeye and kokanee.
5. Recognise the need to balance the risks of acting too quickly (and making mistakes due to insufficient information) vs. the conservation risk to sockeye induced by acting too slowly.

Hypotheses to be Tested

Working group members have identified the following key hypotheses that the experimental reintroduction should address. These hypotheses represent critical uncertainties to be resolved to allow an assessment of the benefits of risks of reintroducing sockeye salmon to Skaha and (ultimately) Okanagan Lakes.

Hypothesis 1: Sockeye reintroduction will only cause a decline in kokanee growth / survival for certain combinations of sockeye, kokanee, and mysis densities (specific levels outlined in the report).

Hypothesis 2: Sockeye fry to smolt and SAR survival is as good in Skaha as it is in Osoyoos.

Hypothesis 3: Sockeye egg to fry survival is as good in Skaha as it is in Osoyoos.

Hypothesis 4: Egg to fry survival in the Okanagan River above Skaha Lake can be improved to satisfactory levels by adding gravel, reducing milfoil, and/or making channel improvements.

Hypothesis 5: Sockeye fry to smolt survival rates and kokanee fry to age 0 survival rates will increase if mysids are removed, with benefits to both species.

Possible Methods of Re-Introduction

The participants in this project developed three possible methods for implementing a re-introduction to Skaha Lake:

1. Remove all barriers to upstream migration, allowing adults returning to Osoyoos Lake to migrate freely to spawning locations around Skaha Lake.
2. Collect adults returning to Osoyoos Lake spawning grounds and transport them past migration barriers to spawning locations around Skaha Lake (Trap and Transport).
3. Collect female broodstock from Osoyoos Lake spawning grounds, incubate eggs in a hatchery on Skaha Lake, and release known quantities of hatchery-reared fry into Skaha Lake.

These three methods were evaluated qualitatively in terms of the three above objectives, and quantitatively using both existing literature and the OkSockeye model. The alternative methods are not

mutually exclusive, as they each address different hypotheses, and could be implemented sequentially to test a range of hypotheses. Harvesting mysis either prior to or in conjunction with the three reintroduction methods described above may improve both learning (by removing one potential confounding factor) and conservation objectives (by removing a potential competitor for food (of both kokanee and sockeye) from rearing lakes). The sequencing of mysis harvest with reintroduction is an important consideration in the overall design of the reintroduction.

Draft Monitoring Plan

The participants have jointly developed a draft monitoring plan to test out the above listed hypotheses. The plan includes monitoring of water quality, zooplankton, juvenile kokanee, juvenile sockeye, and mysids in Skaha Lake. It also includes monitoring of kokanee and sockeye spawners in the Okanagan River, as well as associated monitoring of control populations in other systems (particularly Osoyoos Lake and Wenatchee Lake, but ideally also another control for Skaha kokanee). The use of hatchery-raised, temperature-marked fry will allow an estimation of the proportion of Skaha raised sockeye that return to spawn, and their smolt to adult survival rates (SARs).

Results and Conclusions

We conducted a series of preliminary, experimental, and power analyses using the life-cycle model. In the preliminary analyses, we determined base case model settings, demonstrated that the model could reproduce the behaviour of the Osoyoos stock for reasonable parameter assumptions, illustrated the effects of natural variability on model results, explored competition effects, and answered some specific questions raised at the October 2002 workshop. We then applied what we learned from our preliminary analyses to develop a framework for the experimental analyses, where we evaluated and compared the learning and conservation implications of the three alternative introduction methods. Finally, we conducted *a priori* power analyses to further evaluate how precisely the example sockeye introduction experiments might detect the effects of sockeye reintroduction on kokanee abundance and survival. Statistical power is defined as the probability that an experiment will detect a true effect.

Results of Preliminary Analyses

- The model is able to reproduce the observed geometric mean abundance of Osoyoos Lake sockeye (around 20,000 spawners), though to do so required a relatively high SAR of 2.6%. With mysids present, the Osoyoos population is expected to gradually decline over time. For example, increasing the density of mysis from $6/m^2$ to about $130/m^2$ (the simulated mysis density in Osoyoos Lake after 25 years) reduces the equilibrium number of sockeye spawners from 20,000 to 6,000. A variable SAR can lead to a higher average number of spawners relative to the average with a constant SAR.
- For simulations that assumed co-occurrence of kokanee, sockeye, and mysis, we found that sockeye and kokanee abundance and survival were much more sensitive to mysis density or feeding rate than they were to each other. Mysis tends to dominate systems where they co-occur with nerkids. This points to the potential benefits of harvesting mysis.
- Skaha Lake can support 80,000 adults kokanee for particular combinations of kokanee habitat area (habitat quantity), egg-to-fry survival rate (habitat quality), and feeding rate (competitive ability). It is believed that Skaha Lake historically supported a population greater than 80,000 adults (e.g., in the late 1960s).

- Preliminary exploration of the conditions necessary to establish a sockeye stock in Skaha Lake showed that it required a combination of actions including the removal of barriers to upstream migration, the concurrent harvest of mysis in both Osoyoos and Skaha Lake, and a program to trap adults on the Osoyoos spawning grounds and transport them to Skaha Lake.

Results of Experimental Analyses

- **Hatchery fry supplementation experiment:** There was no impact to kokanee or mysis for sockeye fry stocking densities of 200/ha, which effectively quadrupled total fry densities (kokanee + sockeye fry). This is consistent with the results of the preliminary analyses. Harvesting mysis in combination with fry supplementation is beneficial for kokanee and sockeye by reducing the strong negative impact mysis competition has on their fry-to-Age 0 and fry-to-smolt survival rates. This allowed the kokanee population to increase and substantially benefited the Osoyoos stock by supplementing it with returning Skaha spawners that could not move upstream to Skaha Lake. The subsequent increase in Osoyoos fry production helped offset the steady decline of the Osoyoos stock over the simulation, more than compensating for earlier broodstock removal.
- **Trap and transport experiment:** More adults were required from the Osyoos stock to meet the fry stocking target for this analysis than for the hatchery fry supplementation analysis (3454 vs. 385). This caused the Osoyoos stock to decline more quickly over the simulation period than under hatchery fry supplementation. There was also a small decrease in kokanee fry abundance over the treatment period, which may have been due to competition between sockeye and kokanee for spawning habitat.
- **Remove barriers experiment:** This experiment had very little effect on either the Skaha kokanee population or the Osoyoos sockeye population. This is because upstream migration conditions in the Okanagan River in most of the simulation years permitted very few spawners to migrate to Skaha Lake.

Results of Power Analyses

- Statistical power of the simple “Before-After” designs we have explored thus far are much less than the commonly applied standard of 0.8. Statistical power could be improved by reducing variation in estimates of fry abundance or survival, increasing the level of statistical significance, or including a control stock that covaried with Skaha Lake kokanee. In practice, simple experiments such as the ones we have modelled will be unlikely to attain a high level of statistical power.
- Given the low level of statistical power, the working group may wish to pursue smaller-scale experiments on kokanee/sockeye/mysis interactions (e.g. lake enclosure experiments). Such experiments, however, also create uncertainty about extrapolating those results to the larger lake system, and generally can only be run for a single season.
- In general, these example analyses suggest that a well-developed statistical design is needed to ensure that an experimental re-introduction of sockeye salmon will satisfy both learning and conservation objectives. Part of this design will require more comprehensive statistical power analyses of more complex experimental designs, more sensitive indicators of effects, more intensive monitoring programs, and further exploration of potential control stocks.

Table of Contents

List of Tables ..... **vii**

List of Figures ..... **viii**

1.0 Background **1**
- 1.1 Overview of the Overall Project 1
- 1.2 Objectives of Modelling Work 2
- 1.3 Structure of this Report 3
- 1.4 Next Steps 4

2.0 Alternative Methods of Re-introduction **7**
- 2.1 Objectives of Skaha Lake Reintroduction 7
- 2.2 Possible Methods of Reintroduction 8
  - 2.2.1 Remove all Barriers 8
  - 2.2.2 Trap and Transport (Truck, or Lift) 10
  - 2.2.3 Egg Incubation and Fry Introduction Experiment 10
- 2.3 Considerations for an Overall Experimental Design 12

3.0 Overview of the Proposed Monitoring Plan **15**
- 3.1 Baseline Information Required to Detect Impacts of Reintroduction on Other Ecosystem Components 15
- 3.2 Hypotheses to be Tested 16
- 3.3 What to Measure: Where, When, Precision 16
  - 3.3.1 Skaha Lake Monitoring 17
  - 3.3.2 Okanagan River Monitoring 17
  - 3.3.3 Columbia River Monitoring 18
  - 3.3.4 Control Populations 18

4.0 Results: Evaluation of Risks and Benefits / Refinement of Experimental Design **19**
- 4.1 Overview of Impact Hypotheses 19
- 4.2 Results of Literature Review 20
- 4.3 Results of Model Analyses (Preliminary analyses) 24
  - 4.3.1 Overview of Preliminary Analyses 24
  - 4.3.2 Results for Analysis 1: Equilibrium settings for sockeye in Osoyoos Lake 26
  - 4.3.3 Results for Analyses 2a-c:Effects of variability 26
  - 4.3.4 Results for Analysis 3: Equilibrium values for kokanee and mysis in Skaha Lake 28
  - 4.3.5 Results for Analysis 4: Explore strength of competitive interactions at different levels of fry supplementation to Skaha Lake 30
  - 4.3.6 Answers to specific questions 36
- 4.4 Results of Model Analyses (Experimental analyses) 41
  - 4.4.1 Advantages of hatchery incubation for fry introduction experiments 42
  - 4.4.2 Results for Analysis 5: Hatchery fry supplementation experiment 45
  - 4.4.3 Results for Analysis 5c: Hatchery fry supplementation experiment with mysis harvest 47
  - 4.4.4 Results for Analysis 6: “Trap and truck” experiment 49
  - 4.4.5 Results for Analysis 7 “Remove barriers” experiment 51
- 4.5 Statistical power analyses for example experiments 54
  - 4.5.1 Introduction 54
  - 4.5.2 Methods 55
  - 4.5.3 Results and discussion 56

5.0 Preliminary Conclusions and Recommendations 67
5.1 Conclusions from Literature Review 67
5.2 Conclusions from Preliminary Analyses 67
5.3 Conclusions from Experimental Analyses 68
5.4 Conclusions from Power Analyses 68

6.0 References 71

Appendix A: Information Requests Assigned at Hypothesis Workshop in October 2002 75

Appendix B: Detailed Model Results 79

Appendix C: OkSockeye Version History 85

List of Tables

Table 1-1: Process of model development and application. 3
Table 4-1: Descriptions of Impact Hypotheses for links shown in Figure 4-1. 20
Table 4-1a: Preliminary synopsis of Kokanee Lakes with *Mysis relicta* 22
Table 4-1b: Equilibrium abundance and body lengths for kokanee (without mysis). 28
Table 4-1c: Equilibrium abundance and body lengths for kokanee (with mysis). 29
Table 4-2: Conditions necessary to achieve 80,000 kokanee in Skaha Lake. 40
Table 4-3: Estimated broodstock (# females) required from the Osoyoos stock for different levels of hatchery fry input (#fry/ha) to Skaha Lake. 43
Table 4-4: Estimated broodstock (number of female spawners) required from the Osoyoos stock for different levels of natural fry input (#fry/ha) to Skaha Lake. 44
Table 4-5: Summary statistics and power results for the three example experiments. 57
Table 4-6: Okanagan basin kokanee spawner abundance data and summary statistics. 64
Table 4-7: Correlation of the Skaha Lake kokanee spawner abundance data with that of other Okanagan basin lakes 65
Table B-1: Summary of model runs for sockeye equilibrium analysis (Osoyoos Lake only). 79

List of Figures

Figure 1.1: Possible outcomes of sockeye re-introduction to Skaha Lake, and possible decisions arising from alternative outcomes 5

Figure 4-1: Revised impact hypothesis diagram from the October 15–17 workshop..... 19

Figure 4-2: Total Phosphorus concentrations in Osoyoos and Skaha Lakes, 1968-2001 21

Figure 4-3: Comparison of Wells escapement for the Osoyoos stock under conditions of equilibrium (Analysis 1), natural variability (Analysis 2a), and natural variability + mysis (Analysis 2b). 27

Figure 4.4. Comparison of adult escapement to Wells dam for the Osoyoos stock for various components of natural variability, all with mysis (Analysis 2c), to actual historical escapement from 1973 (Year 1) to 1997. 28

Figure 4-5: Comparison of simulated kokanee Age 3 and 4 abundance and mysis densities in Skaha lake under equilibrium conditions with no natural variability (left panels) and starting at equilibrium conditions, but with full natural variability added back in (right hand panels). 29

Figure 4-6: Relative sensitivity of kokanee and mysis survival and population level performance measures to variation in feeding rate..... 31

Figure 4-7: Sensitivity of survival rate performance measures to increasing rates of sockeye fry introduction. 32

Figure 4-8: Relative sensitivity of survival performance measures to species interactions for base case feeding rates and two levels of sockeye fry stocking rate (200 and 800 fry/ha). 33

Figure 4-9: Relative sensitivity of survival performance measures by species to uncertainty in feeding rates and two levels of fry stocking rate (200 and 800 fry/ha)..... 34

Figure 4-10: Partitioning of Lake productive capacity between sockeye, kokanee and mysis at fry introduction rates of 800 and 7500 fry/ha. These results are from the same runs used to produce the survival estimates shown in Figure 4-7. 36

Figure 4-11: Synthetic time series of deviations in Smolt-to-Adult return rate (SAR) (1944-1999) used for modelling. 37

Figure 4-12: Comparison of model results for Wells dam escapement of Osoyoos sockeye under conditions of variable and constant mean SAR. 38

Figure 4-13: Results for 80,000 Kokanee analysis. Scenarios described in Table 4-2..... 40

Figure 4-14: Results for a run that provided stable returns to Skaha Lake – 50% mysis harvest in both lakes, trap and truck..... 41

Figure 4-15: Comparison of sockeye fry introduction (#fry/ha) to Skaha Lake between hatchery incubation and adult introduction alternatives 45

Figure 4-16: Hatchery fry supplementation experiment (Analyses 5a and 5b)..... 46

Figure 4-17: Hatchery fry supplementation experiment with harvest of mysis (Analysis 5c)..... 48

Figure 4-18: Trap and transport experiment (Analysis 6a and 6b). 50

Figure 4-19: Remove barriers experiment (Analyses 7a and 7b)..... 52

Figure 4-20: Comparison of the number of spawners reaching Skaha Lake for the "Remove Barriers" experiment (Analysis 7). "7a no variability" is analysis 7a. "Analysis 7b full variability" is analysis 7b. 53

Figure 4-21: Comparison of kokanee fry-to-Age 0 survival rates and fry abundance for the experimental alternatives with and without natural variability. 3a and b are the results for Analysis 3. 5a and b are the results for the hatchery fry supplementation experiment (Analysis 5). 53

Figure 4-22: Probability distribution of kokanee egg to fry survival rates in Skaha Lake, given OkSockeye model assumptions about mean and standard deviation. 57

Figure 4-23: Power vs. effect size (% Change) for the three example experiments. 59

Figure 4-24: Power vs. effect size (% Change) for different levels of statistical significance (α = 0.05 and 0.2). 61

Figure 4-25: Power vs. effect size (%Change) for different levels of measurement error (0 and 30%). 63

Figure 4-26: Power vs. correlation in kokanee spawner abundance between treatment and control systems. 65

Acronyms

O2	Oxygen
AM	Adaptive Management
ATU	Accumulated Thermal Units
AUC	Area Under the Curve
BPA	Bonneville Power Administration
CCT	Colville Confederated Tribes
CRITFC	Columbia River Intertribal Fish Commission
DFO	Fisheries and Oceans Canada
FWMT	Fish Water Management Tools
KOK	Kokanee
LLKM	Large Lakes Kokanee Model
OBTWG	Okanagan Basin Technical Working Group
ONFC	Okanagan Nation Fisheries Commission
RST	Rotary Screw Trap
SK	Sockeye
TP	Total Phosphorus
WLAP	BC Ministry of Water Land and Air Protection

1.0 Background

1.1 Overview of the Overall Project

Historical records indicate that sockeye salmon were once found in most of the lakes in the Okanagan Basin. Currently, the only sockeye population within the Okanagan Basin is found in Osoyoos Lake. Abundance of this stock has declined significantly in the last fifty years. Tribes and First Nations in the U.S. and Canada have proposed re-introducing the species into Okanagan Lake, which has a large rearing capacity. However, assessing the potential benefits and risks associated with a re-introduction of sockeye salmon into Okanagan Lake is difficult because of uncertainties about factors that determine production of Okanagan sockeye, and potential interactions with other species in Okanagan Lake.

The Okanagan Nation Fisheries Commission (ONFC) hosted a 1997 workshop to discuss these issues (Peters et al. 1998). The participants recommended that sockeye be re-introduced to Skaha Lake as an experimental management strategy to resolve some of these uncertainties. In preparation for such an experiment, the ONFC and the Colville Confederated Tribes (CCT) jointly undertook a research project to identify and assess the risks and benefits of an experimental re-introduction of sockeye salmon into Skaha Lake. This research project was funded by the Bonneville Power Administration (BPA), with the assistance of Fisheries and Oceans Canada (DFO), the BC Ministry of Water Land and Air Protection (WLAP) and the Columbia River Intertribal Fish Commission (CRITFC). ESSA Technologies Ltd. has been closely involved in both the formulation of the BPA project and the implementation of some of its objectives. The overall project has six objectives:

1. assess the risk of disease transmission from re-introduced sockeye to resident species in Skaha Lake;
2. assess the risk of accidental introduction of exotic species to Skaha and Okanagan Lakes associated with the provision of fish ladders at downstream barriers, and investigate feasible methods for reducing or eliminating these risks;
3. determine whether sockeye spawning and incubation habitat is likely to be limiting, and whether the amount of habitat can be increased;
4. develop a life-cycle model of Okanagan sockeye to project the effects of re-introduction into Skaha Lake on overall life-cycle survival of sockeye, explore potential impacts on resident kokanee, and assist in the design of an adaptive management experiment and associated monitoring program;
5. evaluate the various ways that an experimental re-introduction could be implemented, and the various monitoring programs associated with the re-introduction; and
6. finalise a plan for experimental re-introduction of sockeye salmon into Skaha Lake and associated monitoring programs.

Work on these objectives has been carried out under guidance of members of the Okanagan Basin Technical Working Group (OBTWG). Concerns about disease transmission, introduction of exotic species and habitat limitations (Objectives 1 to 3) have been addressed through field assessments (ONFC 2002). ESSA's role in this project (and the focus of this report) has been on objectives 4 and 5, which are described in more detail in the subsequent section. The ONFC and members of the OBTWG will complete Objective 6.

1.2 Objectives of Modelling Work

The overall goal of the Skaha Lake sockeye reintroduction project is to assess the possible benefits and risks of an experimental reintroduction. Potential benefits include:

- learning more about the interactions between sockeye, kokanee and mysids;
- providing an 'insurance policy' for the Osoyoos Lake sockeye stock by establishing a quasi-independent centre of production; and eventually; and
- increasing returns and harvest of adult sockeye as a result of opening up new spawning and rearing habitat.

Potential risks include:

- disease transmission;
- introduction of exotic species to areas that are currently inaccessible to such species;
- negative impacts on resident populations of kokanee trout through the cumulative effects of competition from introduced sockeye and mysid shrimp; and
- if survival rates in Skaha Lake are inferior to Osoyoos Lake, negative impacts on the Osoyoos stock.

A rigorous *a priori* assessment of such risks is essential for determining whether an experimental reintroduction is worth doing, and for convincing the relevant regulatory bodies that such an introduction is a safe and useful experiment. Detailed field monitoring is the most reliable way to assess the risks of diseases and exotic species, and potential spawning and rearing habitat (Objectives 1-3 of the project). Such field studies have been a major part of the project to date (ONFC 2002). However, potential risks associated with sockeye-kokanee-mysid interactions cannot be directly observed because sockeye access to Skaha Lake is currently blocked. Assessment of these risks requires addressing two important questions:

1. What range of impacts due to interaction between sockeye, kokanee, and mysids are likely to occur if sockeye are allowed to return to Skaha Lake?
2. How should we design an experimental introduction and associated monitoring so that we are able to maximise potential benefits, minimise potential risks, detect potential impacts and reduce remaining uncertainties about sockeye-kokanee-mysid interactions?

To address these questions, and meet Objectives 4 and 5 of the overall project, ESSA developed and applied a life-cycle model for Skaha Lake sockeye, kokanee and mysid populations, as well as for Osoyoos Lake sockeye and mysid populations. Over the last year, this work has been undertaken through an iterative, interactive process with close involvement of all agencies (Table 1-1). This report is a continuing part of that process.

Table 1-1: Process of model development and application.

Period	Progress Made
Dec/2001– Feb/2002	Development of a draft design document by ESSA
Feb/2002	Review and revision of the draft design by scientists from ONFC, DFO, WLAP, and CCT at a *Design Review Workshop* at the ONFC
April 2002	Distribution of a substantially revised design document in, together with a spreadsheet version of the sockeye-kokanee-mysid competition submodel
June 2002	Distribution of Version 1.0.0 of the model, including submodels and a User Interface written in VisualBasic, an ACCESS database for all input data and parameters, and Excel spreadsheets for displaying the results of model runs
Sept-Oct/2002	Preliminary model testing and sensitivity analyses
Oct 2002	Demonstration and review of the model at a *Hypothesis Workshop*, attended by scientists from ONFC, DFO, WALP, and CCT. This meeting served also to identify and begin to evaluate alternative methods of sockeye reintroduction and associated monitoring
Nov-Dec 2002	Development of a list of action items from the workshop (Appendix A); substantial modifications to the model based on recommendations from the *Hypothesis Workshop*; model analyses to assess alternative methods of re-introduction and the implications of different combinations of sockeye, kokanee and mysids.
Dec-Jan 2003	Compilation of a draft of this report, in preparation for a report/model review and model training workshop on Jan 14-15th , 2003.
January 2003	Held a two-day workshop to review the draft report, review the model assumptions and outputs, and provide training on how to use the model to conduct analyses
Jan-Feb 2003	Finalisation of report and model.
February 2003	Distribution of Version 2.2 of the life-cycle model (including a revised design document and user's guide), and a Draft version of this report
May 2003	Distribution of the Final Version of this report.

1.3 Structure of this Report

This report summarises the results of discussions at the *Hypothesis Workshop* and subsequent data and simulation analyses that address the two key questions outlined above.

The remainder of this report presents:

- a review of the objectives of the re-introduction, precautionary principles agreed to by the group, and a qualitative evaluation of alternative methods of re-introduction, based on workshop discussions (Section 2);
- an overview of the proposed monitoring plan (Section 3);
- an evaluation of risks and benefits using available literature[1] (Section 4);
- a quantitative evaluation of risks and benefits using the model (Section 4);

[1] The literature synthesis is awaiting material from Kim Hyatt – see Appendix A.

- a demonstration of how to use the life cycle model to evaluate alternative methods of re-introduction (Section 4); and
- Conclusions and Recommendations (Section 5).

The content of the report includes:

- new information, concerns and objectives raised by workshop participants at the October 2002 *Hypothesis Workshop*;
- new data provided by OBTWG members subsequent to the October 14-15 workshop (see Appendix A for a listing of what information has been received to date);
- an evaluation of competition hypotheses using this new information and the results of model analyses;
- calibration of the model to ensure that it can reproduce the general level of sockeye abundance observed in Osoyoos Lake, and the general level of kokanee abundance of Skaha Lake (both historic and current levels); and
- model analyses of experimental alternatives using the life-cycle model (version 2.2).

1.4 Next Steps

This report concludes ESSA's work on the BPA contract. However, this work should feed into a set of future steps to be carried out by the ONFC and OBTWG, which were discussed at the *Hypothesis Workshop* in October 2002 and the model/report review meeting in January 2003:

- development of a Technical Implementation Plan proposal by the ONFC and CCT, with participation of OBTWG scientists;
- development of an Implementation Agreement by policy personnel in ONFC, CCT, WLAP, DFO and any other relevant agencies (e.g., Transplant Committee);
- application for funding (to BPA and possibly other agencies) for the Adaptive Management (AM) experiment to re-introduce sockeye to Skaha Lake;
- implementation of the AM experiment, including field monitoring, data analysis to test hypotheses and model improvements; and
- evaluation of the results of the AM experiment (Figure 1-1).

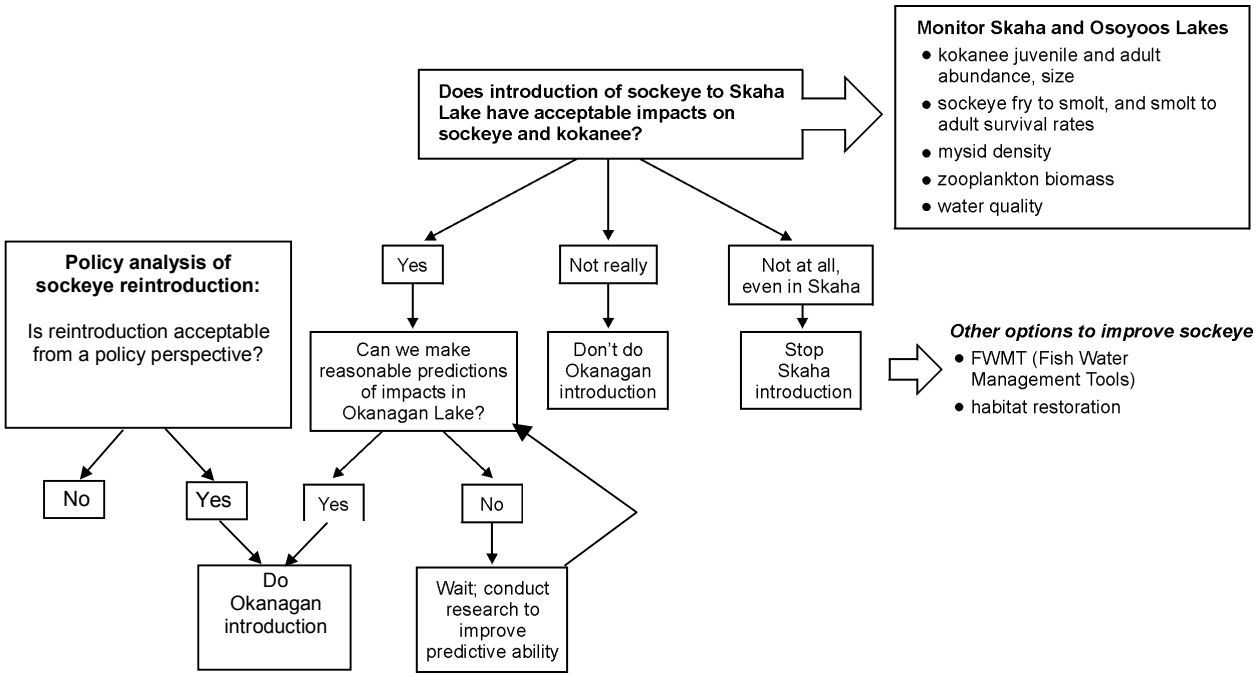


Figure 1.1: Possible outcomes of sockeye re-introduction to Skaha Lake, and possible decisions arising from alternative outcomes (based on discussions at workshops in October 2002 and January 2003).

2.0 Alternative Methods of Re-introduction

2.1 Objectives of Skaha Lake Reintroduction

At the October 15th-17th 2002 *Hypothesis Workshop*, the ONFC, WLAP, and DFO representatives agreed on the following objectives for the reintroduction:

- ***Learning***: Conduct a controlled Adaptive Management experiment to evaluate what level of sockeye can co-exist with kokanee and mysids, so as to better assess risks and alternative methods of introducing sockeye to Okanagan Lake. Use the life-cycle model to help design and interpret the results of experiments.
- ***Conservation***: Establish a quasi-independent centre of sockeye production with better temperature / oxygen conditions than in Osoyoos Lake, increasing the overall resilience of the populations. Maintain existing Osoyoos population, given potential changes in climate and other environmental factors. At the same time, conserve Skaha Lake kokanee populations.
- ***Increase Sockeye Production and Harvest***: This is a longer term objective.

The participants noted that the current objectives now differ somewhat from the original objectives considered at the 1997 workshop (Peters et al. 1998). In particular, the emphasis on conservation of sockeye has increased because of increases in the abundance of *Mysis* in Osoyoos Lake in recent years, and a deterioration of lake oxygen/temperature conditions suitable for sockeye rearing (Kim Hyatt, DFO, pers. comm.). These changes are expected to decrease the survival rates of Osoyoos Lake sockeye over the fry-to-smolt life stages, placing them at greater risk of extinction, and increasing the benefit of having a quasi- independent centre of sockeye production. Ultimately the critical issue for sockeye is whether the abundance and resilience of the Okanagan stock are increased or decreased as a result of the Skaha Lake re-introduction.

In general, monitoring the impacts on fry to smolt (sockeye) or fry to age 0 (kokanee) survival rates are related to learning objectives, while monitoring the impacts on adult sockeye and kokanee spawners are related to conservation and harvest objectives.

Concerns about sockeye should not supplant the need to also protect and conserve kokanee populations in Skaha Lake (Steve Matthews, WLAP, pers. Comm). Kokanee populations have generally been at low levels of abundance in Skaha Lake, and have been negatively impacted by habitat loss and mysid populations. Bearing in mind the multiple objectives of conserving both sockeye and kokanee, as well as learning more about competitive interactions, the group specified a set of precautionary principles to help guide the development and assessment of reintroduction methods (Box 2.1).

Box 2.1: Precautionary principles for guiding the development and evaluation of experimental sockeye reintroduction methods for Skaha Lake:

1. Collect adequate pre- and post-experimental data to evaluate impacts well.
2. Use reversible methods of sockeye reintroduction and ensure an acceptable level of impact (e.g., the loss of 1 year class of kokanee may be OK; losing 3 year classes is unacceptable).
3. Evaluate results each year and re-assess next steps.
4. Consider conservation risks to both sockeye and kokanee.
5. Recognise the need to balance the risks of acting too quickly (and making mistakes due to insufficient information) vs. the conservation risk to sockeye induced by acting too slowly.

Point #5 in Box 2.1 is a common tradeoff in adaptive management experiments (Walters and Green 1997). Longer experiments provide more precise testing of alternative hypotheses, but delay taking actions that may be required to meet ecological and socioeconomic objectives. Shorter experiments lead to faster long term decisions, but have a greater risk of error. This tradeoff exists for the issue of sockeye reintroductions to Skaha Lake. In particular, the years 2003 to 2005 are likely to have a large number of sockeye returning off of the 2000 brood year, which provides an ideal opportunity to re-introduce sockeye to Skaha Lake with a relatively small impact on the Osoyoos stock. On the other hand, having more years of baseline data would provide a stronger ability to evaluate the results of the experiment.

2.2 Possible Methods of Reintroduction

The OBTWG discussed three general methods of reintroduction at the October 15–17th workshop:

- removing all barriers to upstream migration of sockeye spawners from Osoyoos lake to Skaha Lake;
- trapping adult sockeye spawners below McIntyre Dam and transporting them to Skaha Lake; and
- trapping adult sockeye females below McIntyre Dam, incubating their eggs in a hatchery, and releasing fry to Skaha Lake.

Each of these methods is discussed below, and evaluated qualitatively against the three objectives listed in Section 2.1. This evaluation synthesises discussions at the *Hypothesis Workshop*. More detailed evaluations using available literature and the model are included in Section 4.

2.2.1 Remove all Barriers

This is the most direct and intuitively 'natural' method for reintroduction. Anecdotal information (observations of spawners at McIntyre Dam by native fishers and the dam operator) suggest that the early part of the Osoyoos sockeye run (July) will move upstream and spawn if the barriers are removed. There is however some uncertainty concerning the nature of early arrivals at McIntyre Dam. Some people consider the early arriving fish to represent the vestigial remnants of an historical Okanagan Lake sockeye run. Others believe that the arrival time at McIntyre dam is a function of temperature conditions in the Columbia.

Conservation:

Risk to Osoyoos sockeye: This method could place the Osoyoos stock at higher risk in two ways. First, natural migration could lead to lower net production from the Osoyoos stock. Returning adults tend to move as far upstream as temperature and time to spawning permit (Kim Hyatt, pers. comm.). This means they may not make it all the way to Skaha Lake and end up spawning in habitat that is of lower quality than what is currently available below McIntyre dam. In addition, migration from upstream spawning and rearing areas may also expose smolts to higher predation risk during migration (e.g., passage through Vaseaux Lake, a risk faced with all three methods of reintroduction). These factors could together lead to a lower rate of sockeye production from Skaha Lake than from Osoyoos Lake, which would lower overall sockeye production from the Okanagan Basin. Second, this is a passive method that relies on nature to generate the conditions that would allow sockeye to reach Skaha Lake, conditions which may not occur before rearing conditions in Osoyoos Lake deteriorate to the point where the Osoyoos stock is lost. These risks would make it difficult for DFO to justify just opening the barrier to upstream migration.

Risk to kokanee: Relatively few sockeye spawners are likely to reach Skaha Lake. Therefore the risk to Skaha lake kokanee from competition with sockeye is likely to be low. Sensitivity analyses using the life cycle model can illustrate the range of conditions under which competition with sockeye fry will become important. In general, these simulations show the kokanee population to be quite resilient to competition with sockeye, but affected more significantly by competition with mysids, which are already present in relatively high densities in Skaha Lake (Section 4.1.2).

Reversibility: This method is conceptually easy to reverse, as it would only require re-creating impassable barriers at McIntyre Dam. The cost of reversing this action depends on how it is implemented. It would be least costly to leave McIntyre dam in place, and selectively allow sockeye through the dam. This action would be easy to reverse, and would also prevent movement of any exotic species. Conversely, removing the dam entirely would require more time and money to reverse the action (i.e., construct a new barrier).

Learning:

The rate of learning about the strength of competition will be a function of the natural variability in fry abundance, measurement error associated with estimating fry abundance, the annual contrast in treatments (i.e., sockeye fry abundance), the degree of control over the number of fry introduced to the lake, and the sequence of introduction (e.g., high-low-high, etc). The passive nature of the “remove barriers” method will have a slow rate of learning because natural variability in fry abundance will be high (creating an inconsistent ‘treatment’), and sampling for sockeye fry abundance will add measurement error. The number of spawners returning to the lake (and, consequently, the number of sockeye fry introduced to Skaha Lake) will be a function of conditions beyond the control of researchers, such as survival rates in the Columbia River hydrosystem and ocean. However, the natural migration method will also provide information on the spatial distribution and habitat usage of sockeye spawners returning to the upper portion of the Okanagan River, which the other methods would not.

Increase sockeye production and harvest:

This method has the potential to directly address this long-term objective since sockeye will be free to establish in Skaha Lake. Because this method allows for natural migration behaviour, it would allow for natural selection and could therefore reduce the genetic risks associated with more artificial approaches to reintroducing sockeye to Skaha Lake. However, it could take a relatively long time before sockeye production from Skaha Lake is large enough to allow increased harvest.

2.2.2 Trap and Transport (Truck, or Lift)

For this method, sockeye spawners would be collected below McIntyre Dam, transported to Skaha Lake, and then released to spawn.

Conservation:

Risk to sockeye: There may be less risk to sockeye than in the "remove barriers" option because fish would only be collected when returns of Osoyoos Lake spawners are high. Fish could also be trucked to a preferred spawning location, reducing the risk of spawning in suboptimal habitats. Risks will also depend on the direct and indirect effects of trapping and transporting fish (e.g., increased stress could increase egg retention and lower overall egg production). These effects could be minimised by only collecting spawners in relatively good condition (e.g., collect earliest returning spawners, which will have shorter holding times in the Okanagan and Columbia Rivers).

Risk to kokanee: The risk to kokanee depends on how many sockeye are introduced, and the abundance of mysids (Section 4.1.2). Since this option could potentially introduce higher numbers of sockeye to Skaha Lake, it could result in a greater level of competition on the spawning grounds and in the lake than the "remove barriers" option. However, if kokanee production is carefully monitored, then negative effects on kokanee could trigger a halt in the trap and truck experiment.

Reversibility: This approach is easy to reverse; just stop collecting and transporting.

Learning:

This is a less passive method than "remove barriers" and thus provides the opportunity for an increased rate of learning. Because a known number of spawners would be introduced to Skaha Lake, there would be potentially better estimates of spawning success, the natural egg-to-fry survival rate, and the opportunity to observe sockeye spawning habitat selection.

However, the adult take will still be dependent on the condition of the Osoyoos stock and egg-to-fry survival will be dependent on natural conditions. Thus Skaha Lake sockeye fry production will still be highly variable, and sockeye fry abundance estimates will be uncertain. This means a relatively poor experimental control over the number of fry added to Skaha Lake to test competition hypotheses.

Increase sockeye production and harvest:

This method may cause a net increase in production of Okanagan sockeye, if Skaha spawners have higher spawner to spawner survival rates than Osoyoos spawners. However, returning progeny of Skaha spawners will be stopped by McIntyre Dam. Assuming that Skaha spawners will spawn and rear in habitats currently occupied by Osoyoos spawners and juveniles, this could increase intra-species competition for spawning and rearing habitat. Given temperature/oxygen constraints on rearing habitat in Osoyoos Lake, these competitive effects could be significant. The objective of increased production will only be fully achieved when barriers are removed and high spawner to smolt survival is established in Skaha Lake.

2.2.3 Egg Incubation and Fry Introduction Experiment

This method involves taking adults from the Osoyoos stock, then incubating their eggs to the fry stage in an existing hatchery adjacent to Skaha Lake. Thermal shock treatment is used to mark fry otoliths, the fry are then released to Skaha Lake in precisely known numbers. All barriers to upstream migration remain

in place. The overall method is described below in Box 2.2; example calculations of the number of adults required to produce particular fry density targets are provided in Section 4.4.

Box 2.2: A general structure for the fry incubation experimental introduction method.

Method:

- take about 200 to 300 returning sockeye females in late September / early October from below McIntyre Dam {bio-sampling already being done there for the FWMT project};
- fertilise and incubate eggs in Skaha Lake hatchery (may need to cool groundwater so that eggs don't hatch too soon; use FWMT model to get appropriate ATUs);
- place desired number of fry in Skaha Lake in spring;
- this general structure can accommodate different specific patterns of introduction. For example, the applying the same treatment 5 years in a row; varying treatments in 3-year blocks, concurrent harvesting of mysis, etc).

Conservation:

Risk to sockeye: Because a much higher egg-to-fry survival rate can be achieved in a hatchery setting than under natural conditions (e.g., 70% hatchery vs. approximately 10-20% natural), far fewer adults need to be taken from the Osoyoos stock to provide fry for Skaha Lake than the trap-and-truck method. Though this method would provide greater numbers of fry for a given number of adults than the "remove barriers" or "truck and transport" method, it could still be constrained by the number of available adults from the Osoyoos stock in years when adult returns are particularly low. Because barriers to upstream migration (McIntyre Dam) would be retained, returning adult progeny of fry stocked in Skaha Lake, and their progeny, would increase the density of spawners and juveniles using existing spawning and rearing habitat in and around Osoyoos Lake. These potential competitive effects, particularly in habitat-limited Osoyoos Lake, would have to be considered when deciding how many fry to release into Skaha Lake.

Reliance on artificial propagation could cause potential harmful genetic risks to both the Osoyoos and Skaha populations. For example, if the female broodstock removed from the Osoyoos stock was relatively genetically homogenous, this would result in a Skaha population that lacked the genetic diversity necessary to persist in variable environmental conditions. Genetic matching protocols would be necessary to ensure that genetic diversity in the Osoyoos broodstock was representative of the population as a whole.

Risk to kokanee: There would be no risk to kokanee from competition on the spawning ground because no adults would be released. With barriers in place, no adults will return. However, there is a potentially greater risk to kokanee fry and age 0 juveniles from competition than the trap-and-truck method because larger numbers of sockeye fry could be introduced. Kokanee populations will still need to be monitored to ensure that there are no deleterious impacts. One workshop participant raised the question of whether there was some potential for sockeye residualization (i.e., sockeye becoming kokanee), and whether this would be considered a genetic contamination of the Skaha kokanee stock. The converse situation (potential smoltification of kokanee juveniles) could pose similar risks to the sockeye stock. More information on the genetic differences between the two populations is needed to determine the importance of these potential risks.

Reversibility: This method is highly reversible, just stop introducing fry. Any residualization would dissipate over time, and the natural spawning kokanee would re-establish dominance.

Learning:

This method provides much greater flexibility and control over the number of fry introduced to the lake and the opportunity for greater contrast in competitive pressure. An additional advantage is that the number of fry introduced to Skaha Lake will be known precisely. The greater contrast in numbers introduced and greater precision in fry abundance estimates will allow more precise and timely estimation of competition effects.

Higher numbers of marked fish will allow improved detection of Skaha Lake smolts at Wells Dam (note however that smolts are currently not monitored at Wells Dam). This will provide the opportunity for better estimates of smolt production from Skaha Lake and better assessment of Osoyoos-Skaha differences in smolt to adult survival rates. If smolts are also monitored at McIntyre Dam, this approach would also provide a means of estimating predation rates between Skaha Lake and McIntyre Dam.

This method alone will not provide information on spawning habitat selection and quality, or spawning success. However such information could be gained through ancillary field work (e.g., use in-stream incubation boxes for data on *in situ* sockeye egg-to-fry survival rates (an index of spawning habitat quality); radio tagging/tracking of a few introduced adults to track habitat selection and behaviour, and competition for spawning sites between sockeye and kokanee).

Increase sockeye production and harvest:

This method would not directly address this objective in the near term, but would be a first step in a long-term reintroduction process. Although adults produced from the Skaha fry would return to McIntyre Dam, the full reintroduction process would not be complete until barriers were removed. If this method and other ancillary field work provides evidence that satisfactory egg to smolt survival rates could be achieved for sockeye in Skaha Lake without harming kokanee, then the next logical experiment could be a trap and truck experiment (Section 2.2.2), which if successful could in turn lead to removal of barriers (Section 2.2.1).

2.3 Considerations for an Overall Experimental Design

Because the three reintroduction methods address slightly different hypotheses, they are not mutually exclusive. One may want to perform these experiments in sequence so as to test alternative hypotheses sequentially in a logical and unconfounded manner. For example, one approach would be to implement the fry incubation and release strategy first to test hypotheses about interactions between sockeye fry, kokanee fry, and mysid shrimp. Next, the trap and truck approach could be implemented to test hypotheses about the quality and quantity of spawning habitat available around Skaha Lake. Finally, one could implement the remove barriers approach to test hypotheses about the effects of migration conditions in the Okanagan River on the spatial distribution of sockeye spawners between Osoyoos and Skaha Lake spawning areas.

Another consideration in the overall experimental design is the effects of mysis on sockeye and kokanee survival and growth rates. A mysid harvest experiment is currently being implemented in Okanagan Lake (Andrusak et al. 2002), which could be extended to Skaha and perhaps Osoyoos Lakes. Harvesting mysis in conjunction with the three reintroduction methods described above may improve both learning (by removing one potential confounding factor) and conservation objectives (by removing a potential

competitor for food from rearing lakes). Participants at the January 2003 workshop discussed two alternative strategies for implementing mysis harvest. One option would be to implement an experimental mysis harvest before implementing sockeye reintroduction. This would provide key information on mysis-nerkid interactions without introducing the costs and potential risks associated with sockeye reintroduction. However, such an approach would not be as appealing to various entities (e.g. ONA, DFO, BPA) primarily interested in sockeye, not kokanee, conservation and enhancement. The other approach would be implement mysis harvest and sockeye reintroduction concurrently. This approach would allow a more immediate assessment of hypotheses about sockeye-kokanee interactions and about relative fry survival rates in Skaha and Osoyoos Lakes, although such assessments may be complicated by the concurrent removal of mysis. It is a tradeoff between conservation and learning objectives. Simultaneously harvesting mysis and re-introducing sockeye helps sockeye conservation sooner, but sacrifices some clarity in learning because of changing two things at once.

3.0 Overview of the Proposed Monitoring Plan

This section summarises the baseline data required for assessing our ability to detect effects of interest during experimental reintroduction, the hypotheses that monitoring plans should be designed to address, and the components of those monitoring plans and model analyses used to explore some components of experimental introductions (e.g., simulated fry introductions).

3.1 Baseline Information Required to Detect Impacts of Reintroduction on Other Ecosystem Components

Baseline information (or "Before treatment" data) is necessary to empirically detect and assess changes in survival and growth rates due to competition. A list of information needs was compiled at the October 2002 *Hypothesis Workshop.*, and is summarised in Appendix A. The information below represents all of the information that has been received by February 11th, 2003.

Existing data for Skaha Lake include:

- mean size-at-age for Age 0, 1, 2, 3, 4 kokanee. (We have some data for Skaha Lake from Steve Matthews that provides rough estimates of Age 0, 1, 2, and 3 lengths);
- estimates of the within and between year variation in age-specific sizes;
- existing survival estimates of year classes of kokanee plus any new information from recent sampling;
- 15 years of kokanee spawning abundance and distribution (rough estimates received from Steve Matthews);
- five years of juvenile kokanee abundance estimates (Kim Hyatt);
- five years of mysis density estimates (Kim Hyatt);
- zooplankton abundance and species composition (Vic Jenson; Kim since 1997) – (Kim Hyatt and Howie Wright); and
- ancillary explanatory variables: TP, O2, temperature (Howie Wright).

Participants at the January 2003 review meeting pointed out that the large number of Skaha kokanee spawning in the fall of 2002 (around 100,000 spawners, which represents a 10-fold increase over recent abundances) provides a unique opportunity to collect data under high density conditions. These data could be used to test hypotheses about potential limiting factors for this population, or for testing the ability of current monitoring methods to detect large changes in abundance. For example, the acoustic trawl survey data of juvenile kokanee densities in Skaha Lake in the next few years should show a large pulse of juvenile density resulting from this year's large escapement. It will be critical to continue to monitor for such effects as part of the baseline monitoring described above.

3.2 Hypotheses to be Tested

The monitoring should be able to provide tests of the following hypotheses (from the October 15th-17th *Hypothesis Workshop*).

Hypothesis 1: Sockeye reintroduction will only cause a decline in kokanee growth / survival for certain combinations of sockeye, kokanee, and mysis densities.

> ***Alternative Hypothesis 1A:*** Increased sockeye returns will increase nutrient concentrations and improve kokanee growth in a subsequent year.[2]

Hypothesis 2: Sockeye fry to smolt and SAR survival is as good in Skaha as it is in Osoyoos.

Hypothesis 3: Sockeye egg to fry survival is as good in Skaha as it is in Osoyoos.

We could develop more explicit versions of Hypothesis 1 to test using the "pie slicing" assumptions of the life-cycle model and simulating the effects on kokanee of a variety of feasible combinations of sockeye and mysids in Skaha Lake. The model can be used to simulate different experiments and output key performance measures that reflect variables which would be measured in the field, with simulated measurement error included, to assess our ability to detect impacts of varying magnitude.

There are also some "mitigation hypotheses" of interest:

Hypothesis 4: Egg to fry survival in the Okanagan River above Skaha Lake can be improved to satisfactory levels by adding gravel, reducing milfoil, and/or making channel improvements.

Hypothesis 5: Sockeye fry to smolt survival rates and kokanee fry to age 0 survival rates will increase if mysids are removed, with benefits to both species.

> ***Alternative Hypothesis 5A:*** Removal of mysids will reduce growth of older age kokanee, neutralising the benefits of higher egg to age 0 survival rates.

Hypothesis 6: Early-returning adults that come back to McIntyre Dam and then fall back to Osoyoos Lake experience lower pre-spawning survival than later-returning fish because they have to spend a longer time exposed to increased temperature stress in Osoyoos Lake. Early-returning adults which were allowed to pass by McIntyre Dam would experience higher pre-spawning survival.

3.3 What to Measure: Where, When, Precision

The final implementation plan needs to address a number of monitoring questions:

- What components of the system are of interest or concern (e.g., sockeye egg-fry survival, kokanee survival)?
- What attributes of the system should be measured to address these interests and concerns (e.g., fry abundance, smolt abundance, fry size, smolt size, etc.)?

[2] Information to test this hypothesis may be available from Quesnel Lake, as well as from an ONFC literature review by Adrian Vedan, and a reference from the Bureau of Commercial Fisheries, Donaldson and Kern (Howard Smith to provide). Skaha Lake may already have sufficient TP, such that additional contributions from sockeye would not significantly change productivity.

- When should these attributes be measured and how often (e.g., spring, summer, fall; weekly or monthly)?
- How should the attribute be measured (e.g., sonar, rotary screw traps, trawl)?
- What is the expected precision based on historical information for the selected method (e.g., range of variation for fry abundance estimates using method X)?
- What is the desired precision (e.g., to provide statistical power of 80%)?
- Can the desired precision be achieved, given our assumptions about natural (uncontrollable) variability? (see Section 4.1.2)

The group addressed these questions to some extent during the October workshop, as summarised under the three headings below.

3.3.1 Skaha Lake Monitoring

Monitoring would include:

- three acoustic/trawl surveys (lake is small enough to survey the entire area): May, late fall / early winter; late Jan-Feb (pre-smolts, used as estimate of smolts);
- precision of acoustic surveys is estimated to be about ± 40% (± 20% with greater effort)}. More precise methods are possible (e.g., mark-recapture) but the increased precision may not merit the increased cost, and the change in methods from those used to collect baseline data may limit the usefulness of the data for illustrating before/after changes;
- O^2 and Temperature (weekly to biweekly during the Aug-Oct critical period for temperature / oxygen squeeze in Osoyoos Lake; can do monthly at other times); Total Phosphorus (TP) (weekly to monthly now in BPA project (more intensive in Osoyoos); spring and fall by WLAP);
- zooplankton (biweekly from Feb/April to June to catch cladoceran bloom and see if mysids delay it; monthly during July–November); save samples, analyse if necessary. Look at whether emergence time of KOK affects their survival due to hitting or missing bloom; and
- size at age information for kokanee (scale samples, otoliths).

3.3.2 Okanagan River Monitoring

Monitoring would include:

- smolt biosampling at McIntyre Dam (for length and timing);
- possible Vaseaux Lake predation study with tagging at Okanagan Falls and recovery at McIntyre Dam with RST;
- otolith samples from spawners to assess % of Skaha-origin vs. Osoyoos-origin, age distribution., sex distribution.(with the hatchery experiment, smolts could be temperature marked with an external mark as well)
- intensified escapement monitoring and biosampling of kokanee (AUC, daily or every second day, in a boat); and
- continued monitoring of sockeye escapement using current methods.
- boat counts of smolts in April in Osoyoos Lake staging area

3.3.3 Columbia River Monitoring

Monitoring would include:

- returning spawner count at Wells Dam {± 10%; include in observation submodel}, Zosel? (BPA proposal);
- smolt counts at Wells or Zosel (would need to be externally marked to distinguish between Skaha and Osoyoos-origin smolts);
- smolt counts at Rocky Reach (Kim Hyatt is talking to Chelan PUD about collecting 100–200 smolts for biosampling); and
- use PIT-tags to estimate survival rates in Okanagan River (between Skaha and Osoyoos lakes) and in Columbia River (Kim Hyatt will be talking to the Mid-Columbia Coordinating Committee).

3.3.4 Control Populations

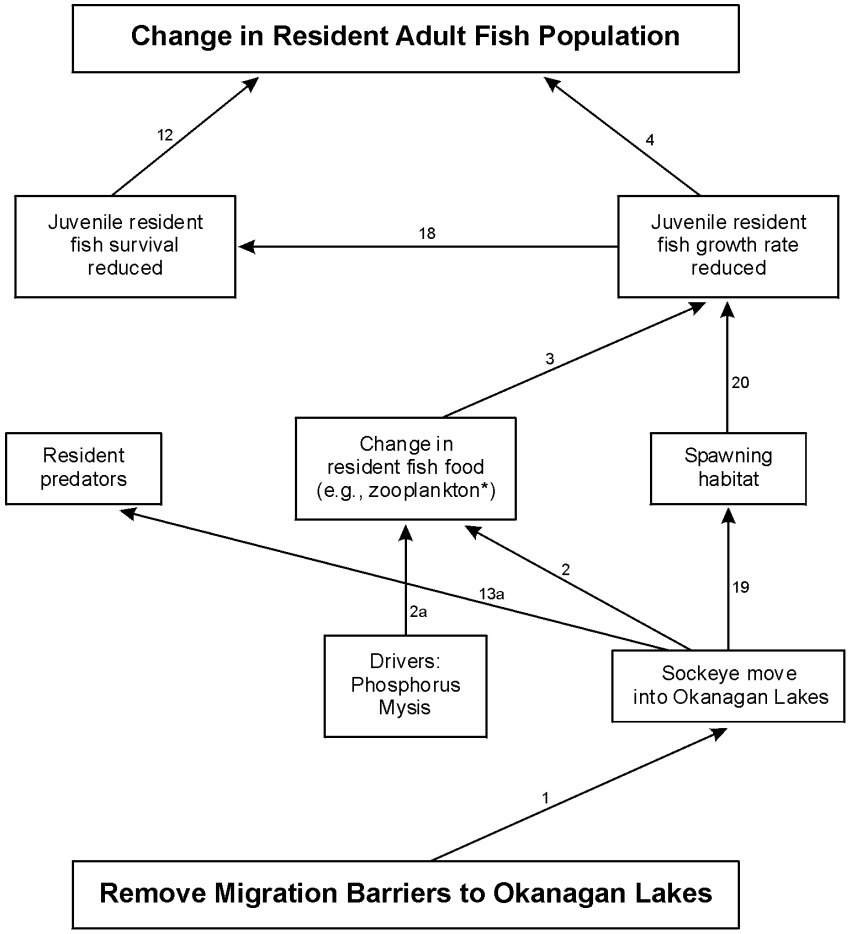
Control populations help to ensure that observed changes are not due to regional climatic factors, and can in fact be attributed to actions that affect freshwater habitat. For kokanee, it is important to continue to monitor Okanagan Lake and other nearby populations (e.g., Kalamalka Lake), although Steve Matthews noted that there are no long-term kokanee monitoring for lakes other than Okanagan, and that there are major differences in chemistry between Skaha and Okanagan lakes. There is a "Catch 22" with respect to the issue of finding control populations for kokanee. There are only weak correlations of spawner abundance between Skaha and other nearby lakes, which implies that these other lakes would not be good control populations (see Section 4.5.3). However, these correlations may be weak simply because of inadequate monitoring methods with substantial measurement error. Thus we don't have a strong rationale for monitoring control lakes precisely for kokanee until we monitor them more precisely to establish a higher correlation with Skaha. Catch 22!

For Skaha sockeye, it is important to continue to monitor Barkley Sound (for variations in large-scale ocean climate factors), Osoyoos sockeye (to control for local climatic and flow effects) and Wenatchee stocks (to control for Columbia River factors such as Columbia River flow, which would affect both upstream and downstream migration conditions. The Washington Department of Fish and Wildlife monitors Wenatchee abundance.

4.0 Results: Evaluation of Risks and Benefits / Refinement of Experimental Design

4.1 Overview of Impact Hypotheses

At the 1997 workshop, participants reviewed a number of hypotheses related to the potential impacts of sockeye re-introductions (Peters et al. 1998). Many of these hypotheses (e.g., effects of disease and exotics, availability of spawning habitat) have been addressed by other reports (ONFC 2002). Figure 4-1 and Table 4-1 shows a subset of some of the original hypotheses reviewed at the initial workshop. The key links of interest here are numbers 2, 2a, 3, and 18, which are best considered jointly. Section 4.1.1 evaluates these hypotheses based on existing literature; Section 4.1.2 evaluates them using the model.



*zooplankton represented implicitly in model, not explicitly

Figure 4-1: Revised impact hypothesis diagram from the October 15–17 workshop. These links will be explicitly evaluated in this report. The other links originally shown in Figure 4.7 of the 1997 workshop report are being addressed in other research projects.

Table 4-1: Descriptions of Impact Hypotheses for links shown in Figure 4-1.

Link	Link Description
1	Once migration barriers have been removed, anadromous sockeye will continue their upstream migration, entering Vaseaux Lake, Skaha Lake, and eventually Okanagan Lake.
2	Once inside the Okanagan lakes, anadromous sockeye will compete with resident fish for food organisms, such as zooplankton, thereby effectively reducing the abundance of available food.
2a	Concentrations of phosphorus and *Mysis* are the two main "drivers" influencing species composition and abundance within the Okanagan Lake zooplankton community.
3	A reduction in food abundance will reduce growth rates for resident fish.
4	Reduced growth rates for resident fish will lead to decreased numbers and biomass of adult populations of these fish species.
12	Reduced survival rates for resident fish will lead to decreased numbers and biomass of adult populations of these fish species.
13a	Re-introduction of sockeye will provide another prey source for resident predators.
18	Reducing growth rates in juvenile resident fish could cause reduced survival of these fish.
19	Once anadromous sockeye adults arrive at Vaseaux, Skaha, and Okanagan lakes, they will seek spawning habitats in either lakeshore or river / tributary stream environments.
20	Competition for spawning sites could result in reduced growth rates for juvenile resident fish.

4.2 Results of Literature Review

Synoptic observations from lake-to-lake comparisons can be very informative. At the workshop, Kim Hyatt provided a verbal summary of competition between kokanee and sockeye (quantitative data on TP levels and species abundances from different lakes were unavailable for this report). In low productivity coastal lakes with TP < 5 ug/l, sockeye outcompete kokanee. Sockeye have larger eggs, which provide an energetic advantage, particularly in years with a late plankton bloom. In these lakes, older age classes of kokanee have difficulty finding food. In interior lakes with greater productivity (TP > 10 ug/l), sockeye and kokanee are able to co-exist (e.g. Quesnel, Horsefly, Shuswap). For lakes with a TP of 5 to 10 ug/l, the outcome of competition is "a toss-up". TP estimates for Osoyoos and Skaha Lakes are shown in Figure 4-2. TP in both lakes has declined since 1990. Recent values of TP suggest that coexistence of sockeye and kokanee is likely in Osoyoos Lake (TP around 15 ug/l), but less certain in Skaha Lake (TP around 10 ug/1).

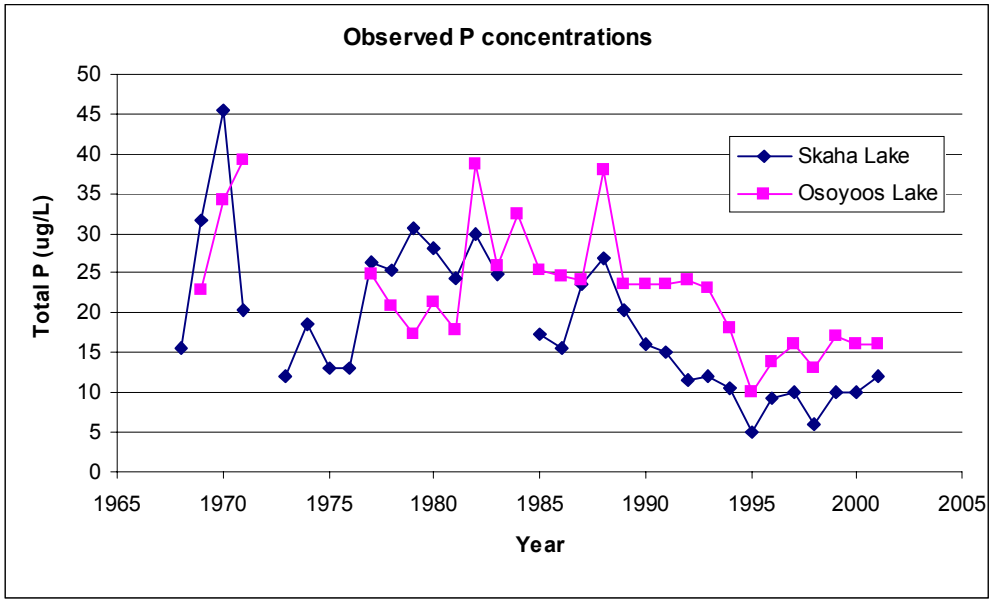


Figure 4-2: Total Phosphorus concentrations in Osoyoos and Skaha Lakes, 1968-2001. Data provided by G. Huggins, WLAP.

Lake-to-lake comparisons can also provide insights on the ability of nerkids and mysids to co-exist, and can form the basis for hypothesising about the factors that determine whether co-existence is likely (Table 4-1a). For example, in Wood Lake, mysids have yet to establish despite high productivity (>15 ug/L of total phosphorus). One reason for this may be the relative shallowness of the lake, which limits the amount of vertical refuge for mysis from kokanee predation. Another interesting example is Kalamalka Lake, where mysids have established at relatively high densities while kokanee populations have remained stable. This lake is of average depth and productivity, although it is not as shallow as other lakes where kokanee are declining. This suggests that something other than productivity and depth may be the primary factor for allowing mysids and kokanee to coexist in this lake. Possibilities include higher alkalinity of Kalamalka Lake, and differences in emergence timing in Kalamalka Lake such that kokanee fry enter the lake after mysid densities peak. In Lake Tahoe, mysid densities are high but kokanee are stable, perhaps because cultural eutrophication provides enough nutrients to allow co-existence.

While such comparisons are informative, there are many confounding factors that need to be considered when drawing conclusions. Other factors in addition to mysids have played a role in kokanee population declines in virtually all of the lakes in which such declines have been observed. For example, Lake Pend Oreille has very high mysid densities, but other factors such as predation, hatcheries, and dams have also affected kokanee populations. Changes in habitat conditions have played a role in many of the lakes listed in Table 4-1a. Trends in lake productivity have also likely affected observed patterns in kokanee populations. Increasing eutrophication in the Arrow Lakes and Kootenay Lake, and increasing oligotrophication in Okanagan lake, have likely influenced the relative balance between kokanee and mysid populations. Such factors make it difficult to ascribe observed declines in kokanee populations directly to mysids. Still, a more in-depth assessment and comparison of the physical and biological information in lakes with different species compositions would be a useful approach for further exploration of nerkid-mysid interactions.

Table 4-1a: Preliminary synopsis of Kokanee Lakes with *Mysis relicta* (compiled by Howie Wright, ONFC).

Lake	Study Years	Physical Properties						Chemical Properties	Mysis relicta		Kokanee depressed	Other Factors for Decline (y/n)	Ref. (2)	Comments
		Trophic Status (1)	Trend	Mean depth (m)	Max Depth (m)	Lake residency (years)	Surface Area (km^2)	TP (ug/L)	Year Introduced	Current Density ($no./m^2$)				
Wood		M	Stable	22	34	30	9.3	> 15	1960s?	-	n	y	1	some stream habitat degradation, water flow issues
Kalamalka	1996-1998	O	Stable	59	142	65	25.9	5 to 15	1960s?	418	n		1,2,3	stream habitat loss, water flow
Okanagan	1996-1998	O	Oligo-troph	76	242	60	348	8	1966	300	y	y	1,3,4	stream habitat loss, water flow
Skaha	2001, 2002	O-M	Stable	26	57	1.2	20.1	12 (2001); 8 (2002)	1966-1972	130 (2001); 83 (2002)	y	y	1,5	stream habitat loss and water flow, River channelization
Osoyoos (North Basin only)	2001, 2002	M	Stable	21	63	0.7	9.91	22	after 1992	50 (2001); 93 (2002)	y	y	1,5,6	stream habitat loss and water flow, River channelization
Upper Arrow	1997-present	O	Fertiliz.	101	287	<1	275	3 to 5	1968 and 1974	32 (1997); 71 (1998)	y	y	7,8,9, 10	dam construction, impoundment, loss of trib habitat, fert has resulted in larger mysids with increased fecundity with no increase in density
Lower Arrow	1997-present	O	Fertiliz.	57	194	<1	190	3 to 5	1968 and 1974	63 (1997); 99 (1998)	y	y	7,8,9, 10	dam construction, impoundment, loss of trib habitat
Slocan	2000-2001	O	Stable	171	298	7	69	4.6	1973	111	y	n	11	thought to be in decline, little knowledge though
Kootenay	1993-present	O	Fertiliz.	94	154	1.5	390	5 to 10	1949 and 1950	98-288	y	y	12,13	dam construction, impoundment, loss of trib habitat, nutrient loading that lead to overfishing, then oligotrophication
Pend Oreille	19	O	Cultural eutroph	164	351	3.2	383	assume <10	1966-1970, 1st sampled 1972	2148	y	y	14,15	popular sport fishery from 1940s - 1970s. Lake trout predation, hatchery supplemented and mysis introduction
Flathead	1986	O-M	Cultural eutroph	32.5	113	3.4	510	5.9 (2000)	1st detected 1981	peaked at 130, now b/w 16 and 68	y	y	16	kokanee introduced in 1916, initial decline in 1970s due to hydroelectric development with persistence of fishery (200,000 fish/yr), declining rapidly since 1985

Lake	Study Years	Physical Properties						Chemical Properties	Mysis relicta		Kokanee depressed	Other Factors for Decline (y/n)	Ref. (2)	Comments
		Trophic Status (1)	Trend	Mean depth (m)	Max Depth (m)	Lake residency (years)	Surface Area (km^2)	TP (ug/L)	Year Introduced	Current Density (no./m^2)				
Tahoe	1966-1991	O	Cultural eutroph	313	505	700	501	6.3 (1992)	1963 to 1965	>300 in 1970 (peaked and most likely lower now)	n	n	17,18	Kokanee introduced (1940s) prior to mysid introduction, documented collapse of cladocerans due to mysid and kokanee cropping. Affected kokanee size of spawning but not numbers. Clouded by cultural eutrophication

1. M = mesotrophic; O = oligotrophic; O-M = oligo-mesotrophic
2. (1) Pinsent et al. 1974; (2) Ashley et al. 1998, MS; (3) Ashley et al. 1999a, MS; (4) Andrusak et al. 2001a MS; (5) Wright 2001; (6) Hyatt & Rankin 1999; (7) Pieters et al. 1998 MS; (8) Pieters et al. 1999, MS; (9) Lasenby et al. 1986; (10) Ashley et al. 1999b, MS; (11) Andrusak et al. 2001b, MS; (12) Ashley & Thompson 1993, MS; (13) Northcote 1973; (14) Clarke & Bennett 2002; (15) Bowles et al. 1991; (16) Beattie & Clancey 1991; (17) Richards et al. 1991; (18) Northcote 1991.

4.3 Results of Model Analyses (Preliminary analyses)

We completed a number of analyses for this report. We found it necessary to first conduct a set of preliminary analyses in order to determine base case model settings, demonstrate that the model could reproduce the behaviour of the Osoyoos stock for reasonable parameter assumptions, illustrate the effects of natural variability on model results, explore competition effects, and answer some specific questions raised at the October 2002 workshop. We then applied what we learned from our preliminary analyses to develop a framework for modelling and comparing the three alternative introduction methods. We present these analyses in the *Experimental Analyses* section.

We used the upgraded version of the life-cycle model (V2. 2; see Appendix C for a version history of the model), began each simulation in water year 1973, and simulated over 25 years.[3] Run definitions and output for the model runs presented here are archived in the database "OkSockeye(Report).mdb," which is being distributed with version 2.2 of the OkSockeye life-cycle model (available from the Okanagan Nation Fisheries Commission).

4.3.1 Overview of Preliminary Analyses

Analysis 1:

Our objective in this analysis was to produce equilibrium Osoyoos sockeye Wells dam escapements similar to the geometric mean of historical Wells dam escapements from 1973 to 1996 (about 20,000). We did this first by removing all sources of natural variability as well as competition with mysis.

We chose to adjust only the smolt-to-adult survival rate to achieve this objective because our earlier analysis (from June 2002 and at the October 2002 workshop) demonstrated that the persistence of the Osoyoos stock was very sensitive to this parameter. Additionally, the default egg-to-fry survival rate (about 20%) is at the upper bound of those reported for sockeye by Bradford (1995) (about 20%) and the fry-to-smolt survival rate realised during modelling (about 30%) also tends to be quite high. So, while setting these rates higher would improve overall survival, such increases would be less likely to occur naturally.

By "removing all sources of natural variability", we mean no random variation in the natural component of the egg-to-fry survival rate, a constant age structure, a constant smolt-to-adult recovery rate (SAR), a constant per project survival, and constant stock composition, flow, and total phosphorous. For all factors except SAR, we set these constant values to the long-term average (e.g. the constant age structure was the average proportion at each age over the seven years of data available).

[3] Results reported in the Jan 8 2003 Draft of this report used version 2.1.2 of the model. Results in this report used v.2.2 of the model (the difference between the two versions is described in Appendix C). Sensitivity analyses showed that the two versions produce results that are identical, except when very large numbers of fry are introduced into Skaha Lake. Results for these preliminary analyses were unchanged.

Analysis 2:

Our objective in this analysis was to explore the effects of various sources of natural variability on overall equilibrium model results. Factors in the model that include a component of natural variability are:

- sockeye egg to fry survival rate;
- sockeye age structure (proportion at each age class);
- mean, maximum, and minimum flows in the Okanagan River during sockeye spawning and incubation;
- smolt-adult survival rate (SAR);
- sockeye upstream survival rate;
- proportion of Okanagan/Wenatchee sockeye (this is used in the model to determine total Okanagan + Wenatchee returns to the Columbia River mouth, which determines commercial harvest rates in the Lower Columbia River); and
- total phosphorus concentrations.

Analysis 2a:

Starting with the equilibrium parameter values for the Osoyoos stock from Analysis 1, we added all natural variability back in to illustrate the impact on the equilibrium result.

Analysis 2b:

Starting with the equilibrium values determined in Analysis 1, we added all natural variability back in as well as competition with mysis. Note that this run is essentially a "base case", because it includes all sources of variability, and includes mysis competition.

Analysis 2c:

Starting with the equilibrium values determined in Analysis 1, we then added the components of natural variability back in one by one:

2c0 – Analysis 1 + Added competition with mysis

2c1 – Analysis 2c0 + Added variability in sockeye egg to fry survival rate

2c2 – Analysis 2c1 + Added variability in age structure

2c3 – Analysis 2c2 + Added variability in annual mean, maximum flows during sockeye spawning and incubation

2c4 – Analysis 2c3 + Added year to year variability in SAR

2c5 – Analysis 2c4 + Added variability in upstream survival rate

2c6 – Analysis 2c5 + Added variability in Okanagan/Wenatchee proportions

2c7 – Analysis 2c6 + Added variability in Total Phosphorus concentrations

Analysis 3:

Determine equilibrium settings for Skaha Lake kokanee and mysis.

Analysis 4a:

Starting with the equilibrium settings determined in Analysis 3, we explored the strength of the competitive interactions between kokanee and mysis by varying the feeding rate for each species 0.5, 1 (base), and 1.5 times its base-case value.

Analysis 4b:

Starting with the equilibrium settings determined in Analysis 3, we explored strength of competitive interactions at between kokanee and mysis and sockeye fry at different levels of sockeye fry supplementation to Skaha Lake. We varied the competitive ability the same way as in Analysis 4a.

Answers to questions raised at the October 15th-17th workshop: While the analyses above were crucial to our understanding of model behaviour, there were several specific questions raised at the October workshop. We used the results from the preliminary analyses and some additional model runs to address the following questions:

- How does variable SAR affect Osoyoos results? We compared results for constant and variable SAR time series.
- What conditions are required to support 80,000 kokanee spawners in Skaha Lake?
- What conditions are required for sockeye to establish in Skaha Lake?
- How do sockeye, kokanee, and mysis impact one another?
- How many fry can be introduced before there is an impact on kokanee?

4.3.2 Results for Analysis 1: Equilibrium settings for sockeye in Osoyoos Lake

Without natural variability or mysis, an SAR of 2.65% gives an equilibrium of 20,000 adults at Wells (Figure 4-3). This is considerably higher than the default value derived from Fryer (1995) of 0.4% (see Peters and Marmorek. 2003), but still less than the mean of 6.2% reported in Bradford (1995) for 12 sockeye stocks. An SAR of 2.65%, therefore, does not seem unreasonable given the negative impact of passage through the Columbia hydrosystem and the effects of poor ocean conditions during recent decades for many Columbia River chinook stocks (e.g. Deriso et al. 2001).

4.3.3 Results for Analyses 2a-c:Effects of variability

When natural variability was added back in (Analysis 2a), Wells escapement varied about the equilibrium value until the last few years of the simulation when it dropped well below the equilibrium value (Figure 4-3). When both natural variability and mysis were added back in, the pattern of variation was similar to natural variability only, but the escapement values were lower (Figure 4-3).

Figure 4-4 summarises the impact of different components of natural variability on adult escapement to Wells dam (Analysis 2c). It is interesting to note the overall trend with no variability and with mysis (run 2c0), compared to no variability and no mysis (equilibrium, Figure 4-3). Increasing the density of mysis from 6/m^2 to about 130/m^2 (the simulated mysis density in Osoyoos Lake after 25 years) reduces the equilibrium number of sockeye spawners from 20,000 to 6,000 fish.

Figure 4-4 also shows the results of scenarios with sources of natural variability added in one by one. Variability in some factors, such as egg-fry survival have an overall positive (upward) effect on escapement while others, such as spawning and incubation flows, have an overall negative effect. Finally, Figure 4-4 also shows the observed number of adult sockeye at Wells Dam from 1973 to 1998. The year-to-year trends don't track exactly between the modelled and actual data, probably because the random number sequence used to generate egg-to-fry survival does not reflect natural variations in egg-to-fry survival, but the simulated overall range of adult returns is similar to the actual range over the 1973-1997 time period, and the overall downward trend in simulated escapement is consistent with the overall trend seen in the observed values. This suggests to us that the model is doing a reasonable job of capturing the major factors that affect long-term production of Okanagan sockeye.

Descriptions of each of the Analysis 2c scenarios, further summary graphs for fry and smolts, and additional graphs showing various combinations of natural variability components can be found in Appendix B.

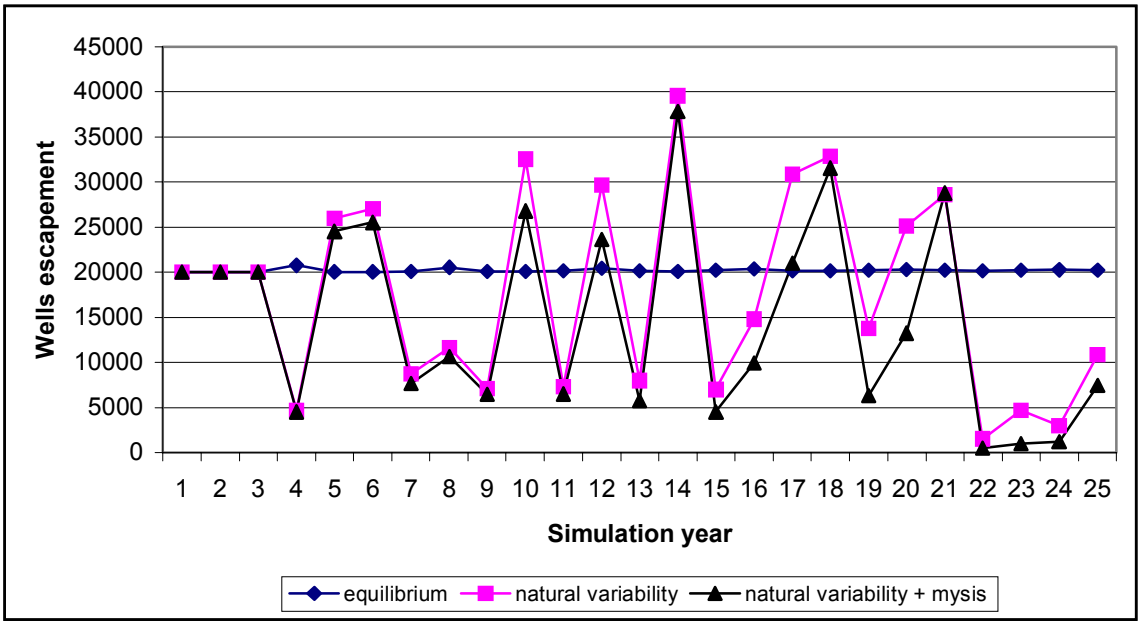


Figure 4-3: Comparison of Wells escapement for the Osoyoos stock under conditions of equilibrium (Analysis 1), natural variability (Analysis 2a), and natural variability + mysis (Analysis 2b).

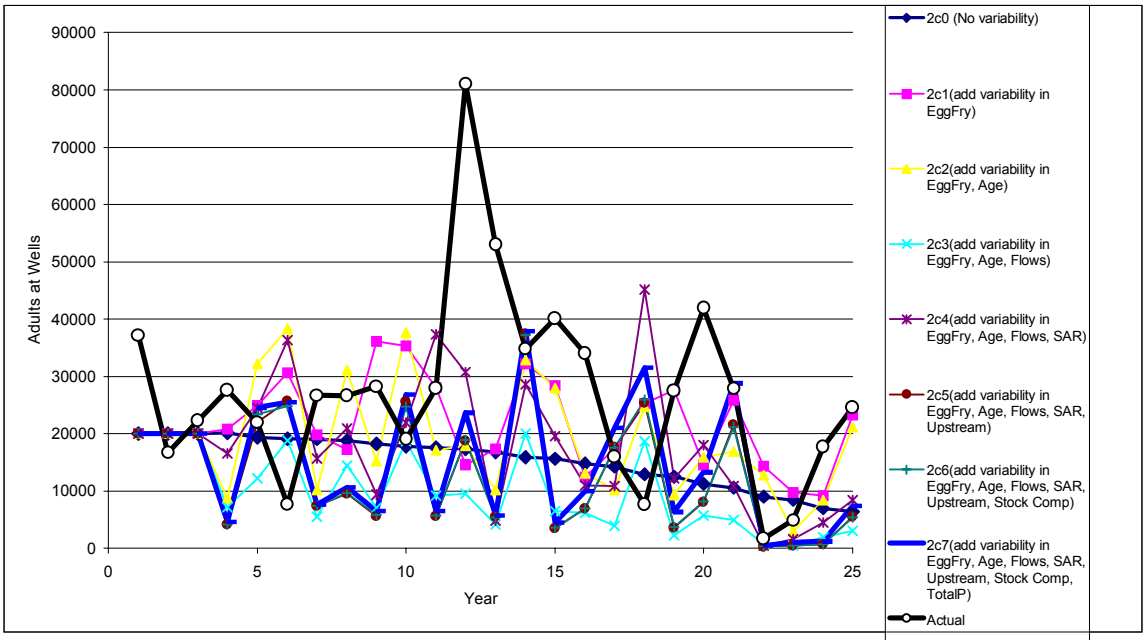


Figure 4.4. Comparison of adult escapement to Wells dam for the Osoyoos stock for various components of natural variability, all with mysis (Analysis 2c), to actual historical escapement from 1973 (Year 1) to 1997.

4.3.4 Results for Analysis 3: Equilibrium values for kokanee and mysis in Skaha Lake

Kokanee equilibrium (age-specific abundance, length-at-age) without mysis and no variability

Without mysis competition and with no variability in egg-to-fry survival or other components of natural variation, kokanee equilibrated at the following age-specific abundance and length-at-age:

Table 4-1b: Equilibrium abundance and body lengths for kokanee (without mysis).

Age	Abundance	Length (mm)
0	121799	n/a, constant at 55
1	48665	189
2	29153	250
3	20361	277
4	2785	289

Mysis equilibrium (immature and mature density) with no kokanee

Without kokanee and with no variability in total phosphorous, mysis immature and mature densities equilibrated at approximately 110 and 40 respectively.

Kokanee and mysis equilibrium with both together (no variability in kokanee egg-to-fry survival rate, plus no variability in other factors as for the Osoyoos sockeye in Analysis 2). We conducted this analysis to provide a stable starting point for the experimental analyses. Starting from equilibrium values would remove as much as possible the influence of trend on comparison of results "Before" and "After" treatment. There was little change in the mysis equilibrium densities (immature densities = 114/m^2, mature densities = 41.5/m^2), but the age-specific equilibrium values for kokanee changed considerably (table below). When we added natural variability back in and started a simulation with the new equilibrium values, both kokanee abundance and mysis density ranged above their equilibrium values (Figure 4-5).

Table 4-1c: Equilibrium abundance and body lengths for kokanee (with mysis).

Age	Abundance	Length (mm)
0	8054	n/a, constant at 55
1	3263	193
2	1965	256
3	1357	282
4	142	295

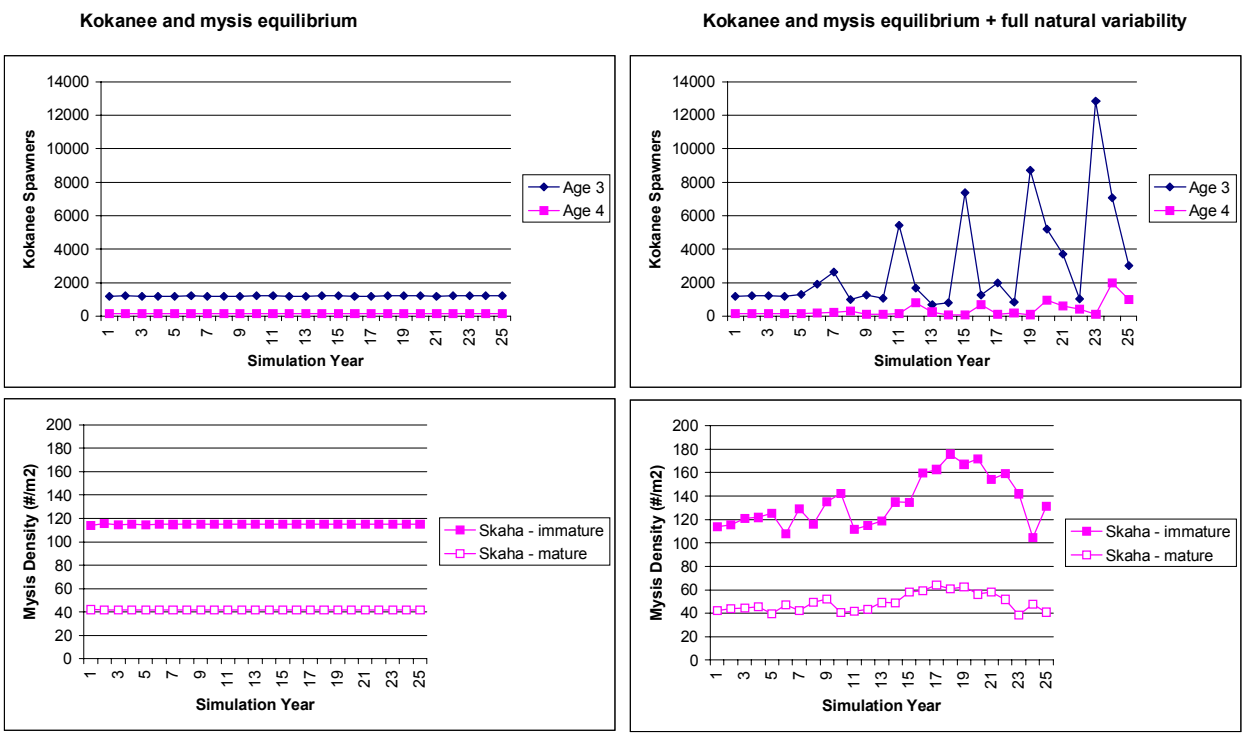


Figure 4-5: Comparison of simulated kokanee Age 3 and 4 abundance and mysis densities in Skaha lake under equilibrium conditions with no natural variability (left panels) and starting at equilibrium conditions, but with full natural variability added back in (right hand panels).

4.3.5 Results for Analysis 4: Explore strength of competitive interactions at different levels of fry supplementation to Skaha Lake

The purpose of this analysis is to explore the strength of the competitive interactions between sockeye, kokanee and mysis in the life-cycle model.

We started with the equilibrium, no variability, scenarios developed in Analyses 1-3 and then varied the feeding rates from their base values (for sockeye, kokanee, and mysis) and the level of sockeye fry supplementation (200 and 800 fry/ha). We maintained a constant rate of fry supplementation (e.g., 200 fry/ha) in each year of a simulation, as long as the number of female Osoyoos sockeye was above the threshold where take for hatchery broodstock was allowed (we assumed a threshold of 5,000 spawners). To maintain a constant level of supplementation we blocked the return of model Skaha adults to Skaha Lake by setting the thermal barrier between Osoyoos and Skaha Lake to 0. Each simulation began in water year 1973 and was 25 years long.

Note that for our base case simulations, realised kokanee fry/ha ranged from about 60-75 fry/ha over the 5-year index period. Therefore, a sockeye fry supplementation rate of 200 sockeye fry/ha roughly quadrupled the total fry density in Skaha Lake (kokanee + sockeye fry).

We used the following performance measures, calculated over simulation years 5-9:

- sockeye – average fry-to-smolt survival;
- kokanee – average fry-to-Age 0 survival, average number of spawners;
- mysis – average immature-to-mature survival, average density of immature and mature mysis.

We started at year five to minimise initialisation effects and averaged over five years to reduce the influence of trends (e.g., a trend in fry-smolt survival may arise due to changes in fry production resulting from changes in spawner abundance, which can arise from factors other than in-lake competition).

Kokanee and mysis:

We first explored the competitive interactions between kokanee and mysis in Skaha Lake without sockeye fry supplementation to provide a baseline for comparison (Figure 4-6). Note that for base case parameter settings, the equilibrium density values (#/m^2) for immature and mature mysis were about 114 and 41.5 respectively. This is slightly below recent estimates of immature mysis densities in Skaha Lake of 150-250/m^2 (K. Hyatt, DFO, pers. comm.)

The main result is that kokanee performance measures are much more sensitive to uncertainty in the kokanee and mysis feeding rate than mysis as demonstrated by the relative spacing and steepness of the lines in the top panels of Figure 4-6. For example, if the kokanee feeding rate is held at its base-case value (i.e. 1X), increasing the mysis feeding rate by 1.5X decreases the kokanee fry-to-Age 0 survival rate from 0.4 to 0.32 (Figure 4-6, top left panel). However, holding the mysis feeding rate constant at its base value (1X) and increasing the kokanee feeding rate by 1.5X results in only a 1% decrease in the mysis immature-to-mature survival rate (Figure 4-6, top right panel).

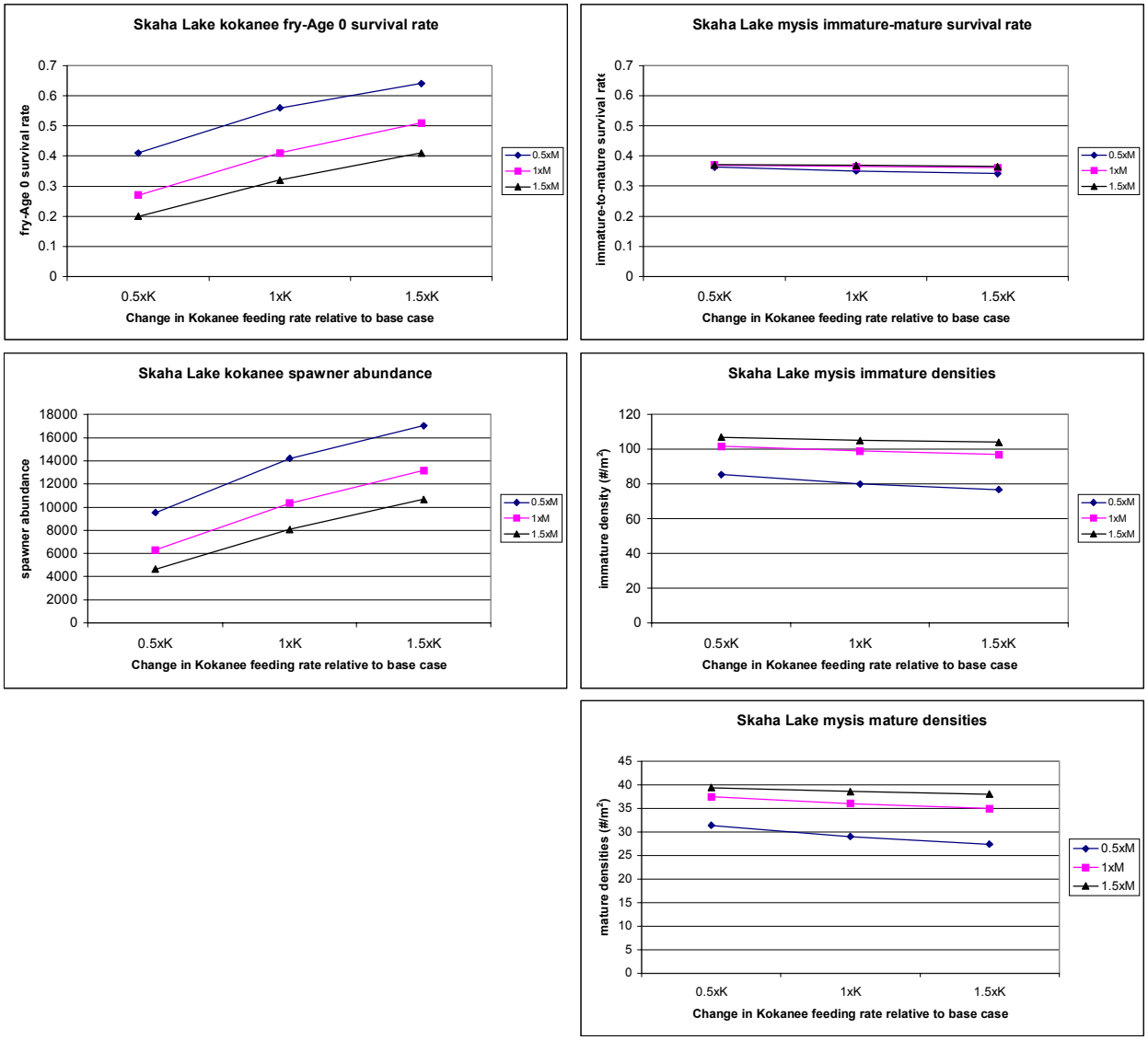


Figure 4-6: Relative sensitivity of kokanee and mysis survival and population level performance measures to variation in feeding rate. The top left panel shows the response of kokanee fry-to-Age 0 survival rate to changes in the kokanee feeding rate. The top right panel shows the response of the mysis immature-to-mature survival rate to changes in the kokanee and mysis feeding rate. Each line represents a different mysis feeding rate, while each point on a line represents a different kokanee feeding rate (shown on the x-axis).

Sockeye, kokanee, and mysis

Next we included fry supplementation at levels that ranged from 200 to 7500 fry/ha, while varying the mysis feeding rate as before and varying the sockeye feeding rate relative to a constant kokanee feeding rate (at the base case value of 8.5 kg/kg). We assumed that the kokanee feeding rate was more certain than the sockeye feeding rate which was merely set equal to the base case kokanee rate as a default. In comparison, the geometric mean fry/ha for Osoyoos Lake (1972-2001) is 5,426 fry/ha, (max: 19,610; min: 403) based on the observed escapement to Wells dam (1972-2001) and assuming an 87% pre-

spawning survival rate, a female ratio of 52%, a weighted fecundity of 2674 eggs/female, an egg-to-fry survival rate of 20%, and an area of 1000 ha for the north basin of Osoyoos Lake.

We found that the survival performance measures were insensitive to stocking densities up to 1000 fry/ha, but showed greater sensitivity for levels above 1000 fry/ha with the kokanee and mysis survival rates gradually declining and the sockeye rates more rapidly increasing (Figure 4-7). The sockeye fry-to-smolt survival rate increased up to 5000 fry/ha and then began to decline.

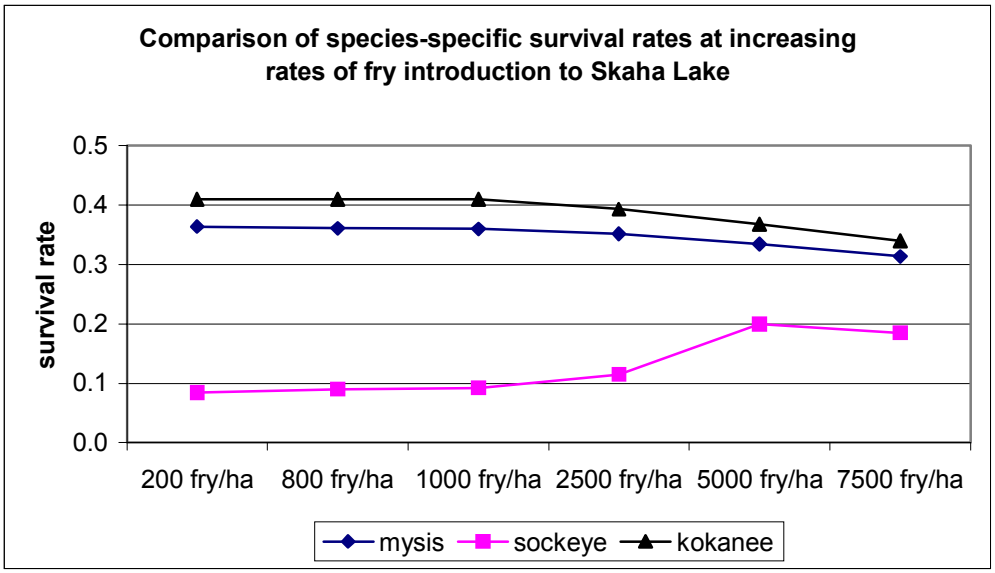


Figure 4-7: Sensitivity of survival rate performance measures to increasing rates of sockeye fry introduction.

We explored interactions for various species combinations and levels of fry introduction (Figure 4-8). Kokanee are sensitive to mysis, but not sockeye. Sockeye are sensitive to both kokanee and mysis, but more sensitive to mysis. Mysis are insensitive to either sockeye or kokanee. These results are insensitive to sockeye fry stocking rates of up to 800 fry/ha.

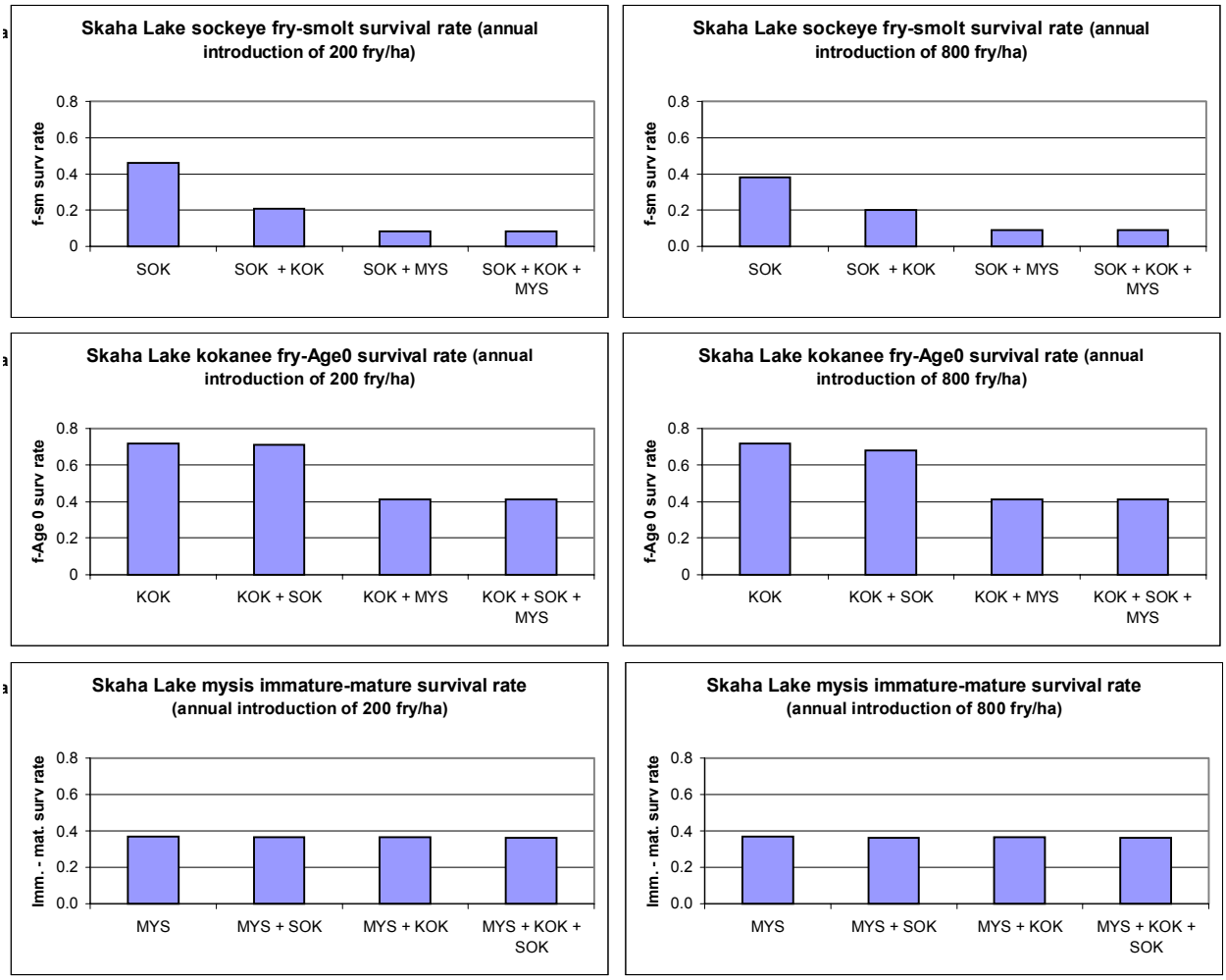


Figure 4-8: Relative sensitivity of survival performance measures to species interactions for base case feeding rates and two levels of sockeye fry stocking rate (200 and 800 fry/ha). The x-axis labels indicate the species combination for each scenario (e.g., MYS + SOK means mysis and kokanee only).

We then explored the competitive interactions between the species in more detail over different levels of feeding rates (Figure 4-9). These results show that sockeye are somewhat sensitive to uncertainty in mysis and sockeye feeding rates (top left panel), but the magnitude of this response is insensitive to the fry stocking rate up to 800 fry/ha (compare the top left and right panels). Kokanee are insensitive to uncertainty in the sockeye fry feeding rate (middle left panel) and the fry stocking rate (compare the middle left and right panels); however, as shown previously, they are sensitive to uncertainty in the mysis feeding rate. Mysis are insensitive to uncertainty in the sockeye feeding rate (bottom left panel), though they do show a very slight decline in survival at the highest sockeye feeding rate under the highest fry stocking rate (bottom right panel).

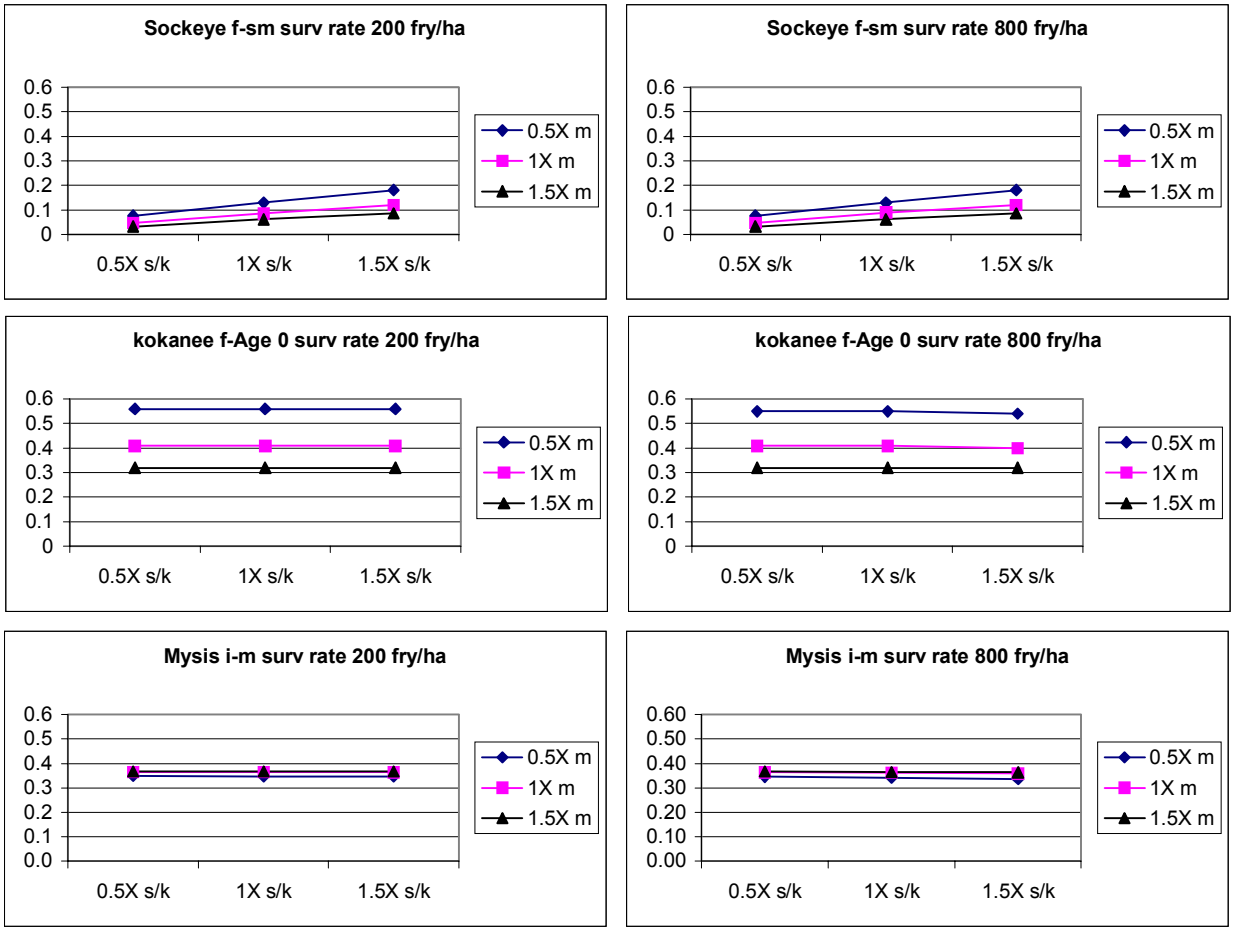


Figure 4-9: Relative sensitivity of survival performance measures by species to uncertainty in feeding rates and two levels of fry stocking rate (200 and 800 fry/ha). The ratio of the sockeye to the kokanee feeding rate in on the x-axis, the mysis feeding rate is the legend. Survival rate is on the y-axis.

These results arise from both biomass and conversion efficiency effects. In a given simulation year, the partitioning of available total lake capacity by species is a function of each species' production. For each species, production is a function of its abundance (or density in the case of mysis), average weight (biomass), and the production-to-biomass (P:B) ratio, which is in turn a function of the species-specific feeding rate and conversion efficiency (e.g., see Design Document equations, 4-12, 4-13 and 5-3). Sockeye require a portion of the available total lake capacity for smolt production (affects fry-to-smolt survival rate), while kokanee require a portion of lake capacity for Age 0 production (affects fry-toAge0 survival rate) as well as production in older, heavier, age-classes. Mysis require a portion of total lake capacity for production in both the immature and mature stages (affects immature-to-mature survival rate). The sockeye and kokanee have default feeding rates of 8.5 Kg/Kg for the fry stages while kokanee have default feeding rates of 3.7 Kg/Kg for ages 0 to 4. Both sockeye and kokanee use the same equation for conversion efficiency. The mysis have a feeding rate of 18 and 25 Kg/Kg for the mature and immature life stages respectively (default parameter values for feeding rates are from Kay 2002)

Conversion efficiency effects dominate results under a given fry stocking rate (e.g., Figure 4-8, left column). For these analyses, the observed effects are a function of conversion efficiency because initial

abundances/densities, age-specific weights, and conversion efficiency equation parameters are held constant. Adjusting the feeding rate can be interpreted as a proxy for adjusting conversion efficiency because the P:B ratio is the product of feeding rate and conversion efficiency.

Biomass effects dominate when comparing results between fry stocking rates (e.g., Figure 4-7). The relatively high initial biomass of mysis (function of initial density and weight) and their high feeding rates means they appropriate the largest share of the available lake productive capacity (Figure 4-10, top panel), which explains their strong effect on sockeye and kokanee (e.g., Figures 4-8, 4-9). For the initial condition used in these analyses, the starting biomass of sockeye fry, kokanee (all age classes), and mysis (both stages) under the 800 fry/ha introduction rate is 0.2, 8.3 and 10.8 kg/ha respectively; sockeye biomass is only about 1.9% that of mysis. Kokanee are able to obtain a medium level of capacity due to their relatively higher biomass, which is also why they have a stronger impact on sockeye than sockeye do on them. The largest share goes to the older kokanee age classes. As the biomass of sockeye increases, they obtain a larger share of the available lake capacity and have a stronger impact on mysis and kokanee (Figure 4-10, bottom panel). At a stocking rate of 7500 fry/ha, the biomass of sockeye fry increases to 1.5 kg/ha, about 14% of the initial mysis biomass.

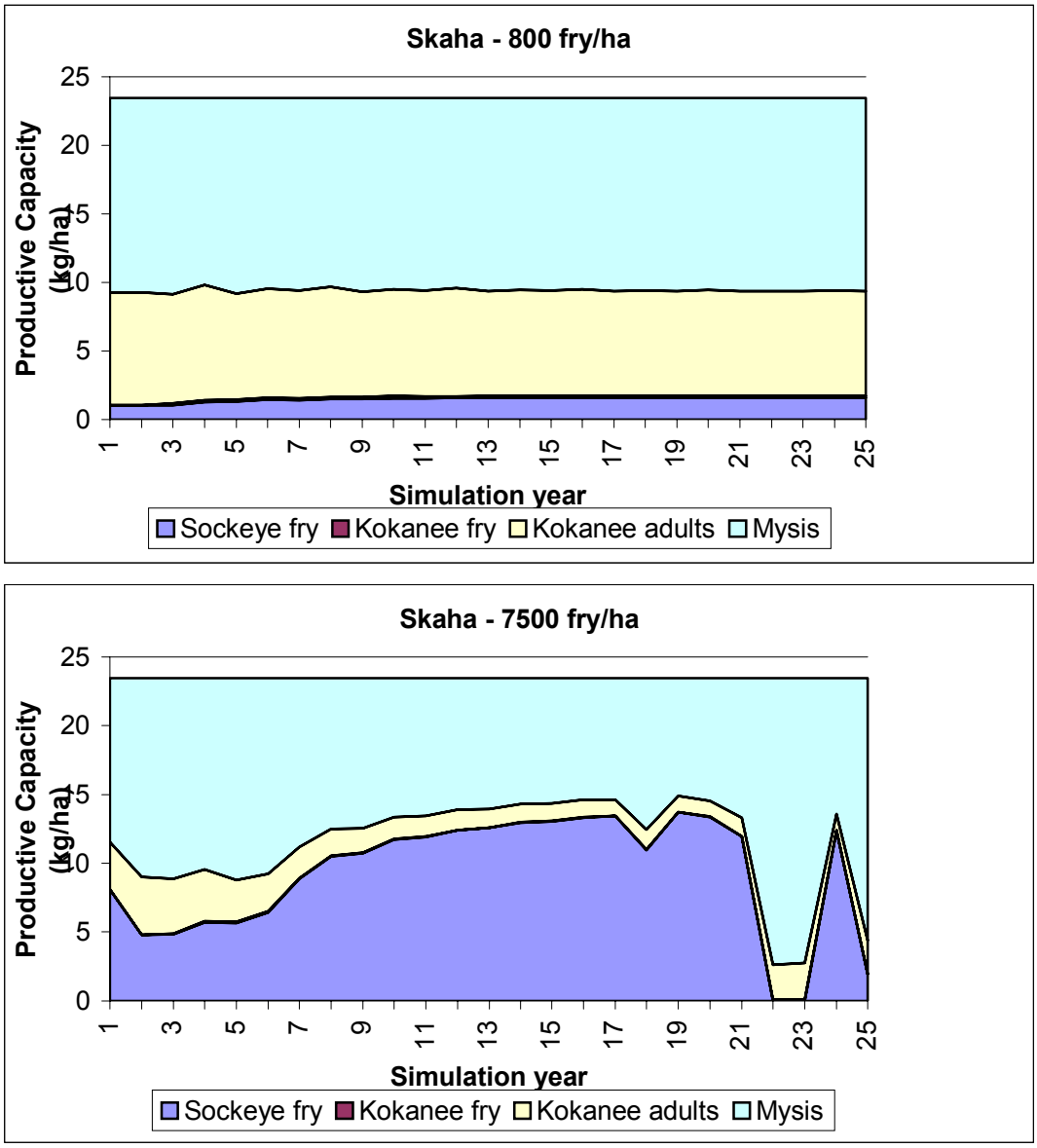


Figure 4-10: Partitioning of Lake productive capacity between sockeye, kokanee and mysis at fry introduction rates of 800 and 7500 fry/ha. These results are from the same runs used to produce the survival estimates shown in Figure 4-7.

4.3.6 Answers to specific questions

We used the results from the above analyses plus some additional model runs to address specific questions raised at the October 15-17 2002 and January 14-15 2003 workshops.

Compare results for constant and variable SAR time series:

For preliminary runs of the life-cycle model (V1.0, June 19, 2002) it was necessary to increase the mean smolt-to-adult recovery rate (SAR) to 2.5% for the Osoyoos and Skaha sockeye stocks to persist for at

least 20 years. This is about 6.25 times higher than the derived base case value of 0.4% (Peters and Marmorek 2003). In this model version, the mean SAR is constant; a question raised at the October 15-17 workshop was how year-to-year variation in SAR might affect simulation results. It might be that despite a low mean SAR periodically high SAR values would allow the Osoyoos sockeye population to persist.

We explored this possibility by modifying the life-cycle model code to use year-to-year variability in the modelled SAR time series. We then derived a time series of SAR deviations from the geometric mean of Barkley Sound coho SAR data (1973 to 1997) (data provided by Kim Hyatt, DFO) under the assumption that Osoyoos sockeye SAR deviations would show a similar pattern. The Barkley sound time-series is not as long as the data series used by the model (1944-1999), so we increased its length by assuming the derived SAR deviations repeated over time, an assumption that is probably overly pessimistic for SAR conditions prior to 1973 (Figure 4-11). The deviations are used as multipliers to the assumed mean SAR entered in the model interface. Independent estimates of a mean SAR for Osoyoos were not available to us at the time of this analysis.

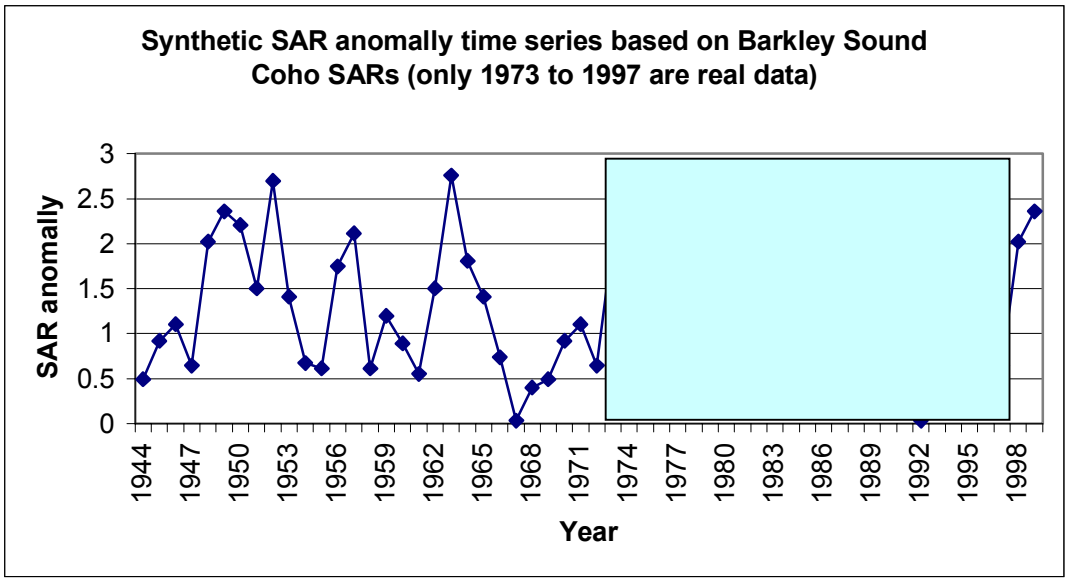


Figure 4-11: Synthetic time series of deviations in Smolt-to-Adult return rate (SAR) (1944-1999) used for modelling. The shaded area indicates the time series of deviations (1973-1997) derived from the Barkely Sound coho SAR data provided by Kim Hyatt, DFO.

We compared the results of a simulation with all components of natural variability (Analysis 2a) to those for a run with all components of variability except variable SARs (Figure 4-12). Including variability in SARs improved the performance of the modelled Osoyoos stock, in terms of Wells dam escapement. Escapements were generally higher over the length of the simulation. So, in general, it is possible for periodically high SAR values to increase the persistence of the Osoyoos stock. However, these results are for only one version of the SAR time series, based on a coastal coho stock from the West Coast of Vancouver Island. It would be useful to explore a wider range of SAR time-series based more closely on the Columbia River/Ocean conditions that interior Osoyoos sockeye might experience.

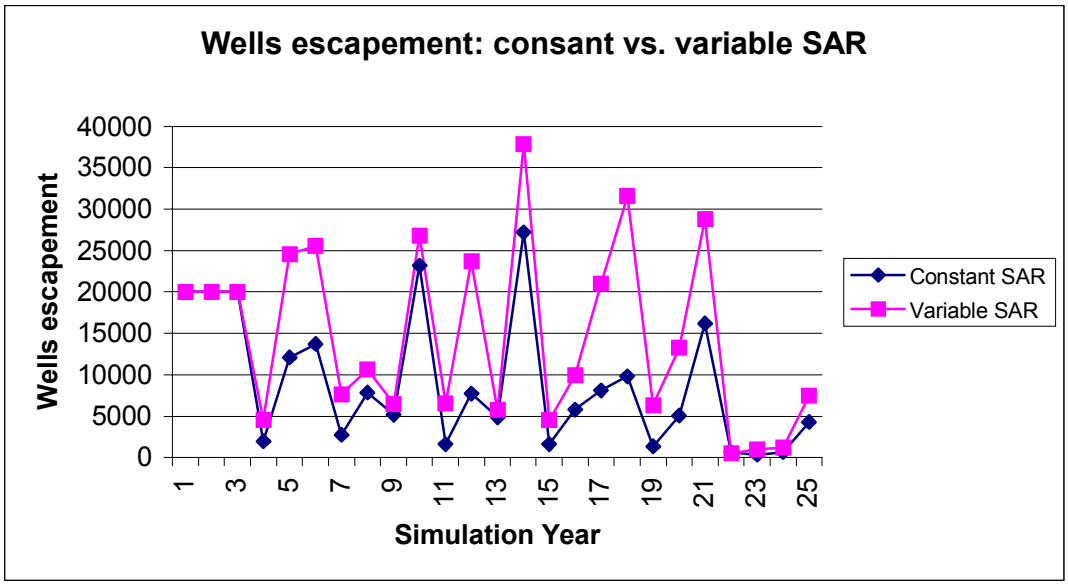


Figure 4-12: Comparison of model results for Wells dam escapement of Osoyoos sockeye under conditions of variable and constant mean SAR.

What conditions are required to support 80,000 kokanee spawners in Skaha Lake?

At the October 2002 workshop it was noted that in the late 1960s, hatchery egg recovery records indicate that Skaha Lake supported an adult population of approximately 100,000 kokanee. However, model kokanee abundance produced using the default (base case) parameter settings for version 1.0 of the life-cycle model had a geometric mean of about 9774 adults (ages 3 + 4) over a 20 year simulation. This raised the question, "Under what conditions would the model produce a Skaha Lake adult kokanee population of 80,000-100,000?"

We addressed this question through a series of simulations starting from base case parameter setting for kokanee. We considered the following scenarios as examples of the factors that have likely most affected the kokanee population since late 1960s.

- Increased competition with mysis (affects fry-Age 0 survival rate): In the late 1960s there may not have been mysis in Skaha Lake. During base model runs, mysis are initiated at set densities and then increase over time. We compared base case results with mysis competition to a scenario without mysis.
- Decrease in competitive ability (feeding rate, kg consumed per kg of biomass). This is represents a hypothesis that there have been changes in kokanee competitive ability apart from competing with increased abundance of mysis over time, perhaps through impaired feeding ability under conditions of increased milfoil weed.
- Decrease in area of kokanee spawning habitat (m2) (decrease in habitat quantity). In the late 1960s there may have been a greater quantity of spawning habitat for kokanee.
- Decrease in kokanee egg-to-fry survival rate (decreased habitat quality). In the late 1960s there may have been better quality spawning habitat for kokanee.

The impact of changing total phosphorous levels over time (affects fry-Age 0 survival rate) may also be worth exploring. Lake productivity has declined since the 1960s as a result of implementation tertiary sewage treatment in Okanagan cities.

Our performance measures were the average kokanee egg-to-fry survival, average kokanee fry-to-Age 0 survival and average kokanee Age3 and 4 abundance over the last five years of a twenty-year simulation starting water year 1985, there was no sockeye supplementation. We used version 1.0 of the life-cycle model, but explore the effects of using the most recent version (v. 2.1.2).

Our results show that the model parameters can be adjusted in combination to produce adult kokanee abundance (Age 3 + 4 spawners) in the range of 80,000 adults (Table 4-2). For example, removing competition (no mysis, no sockeye), doubling egg-to-fry survival rates (improved habitat quality) and tripling habitat area (m2) (increased habitat quantity) achieved an average of 78,258 adults. Just removing mysis, or increasing habitat area alone could not achieve this result. Scenarios with average spawners less than 80,000 achieved more than 80,000 in some years (Figure 4-13).

Note that because we used version 1.0 of the life-cycle model for the bulk of this analysis, results will be different using version 2.1.2, but our general conclusions will be unchanged. For example, the numbers in yellow highlight in the right hand column of Table 4-2 were derived using V2.1.2 with the equilibrium form of the kokanee model (Analysis 3) and no variability. They show the same pattern of increasing average abundance as first mysis are removed, then habitat is increased, then egg-to-fry survival is doubled, although the actual values are lower than for the V1.0 results. This is due to the exclusion of variability. When variability is added back in, the values increase, shown by the number in red highlight, which was derived using the V2.1.2 scenario with variability added back in. It is much larger than the V1.0 result because the model is initiated using equilibrium values for kokanee abundance and length-at-age.

Table 4-2: Conditions necessary to achieve 80,000 kokanee in Skaha Lake. Results were calculated using V1.0 of the life-cycle model (June 19, 2002). For comparison, the yellow highlighted results were calculated using V2.1.2 and the equilibrium kokanee model with no variability (Analysis 3). The red highlighted number was obtained using V2.1.2 and equilibrium kokanee model with full variability added back in.

Scenario	Egg-to-fry survival rate	Fry-to-Age 0 survival rate	Avg. Age 3-4 abundance over years 16-20
Base case	0.057	0.46	7950
No mysis	0.057	0.72	20706 (19,929)
Double habitat, no mysis	0.057	0.67	29872 (27,773)
Triple habitat, no mysis	0.057	0.64	36003
Double feeding rate, no mysis, base habitat	0.057	0.81	25281
Double egg-to-fry survival, no mysis, base habitat, base feeding rate	0.115	0.59	44800 (41,951)
Double egg-to-fry survival, double habitat	0.115	0.53	64601 (58,892)
Double egg-to-fry survival, triple habitat	0.115	0.50	78258
Double egg-to-fry survival rate, double habitat, double feeding rate	0.115	0.62	85231 (79,897) (118,159)

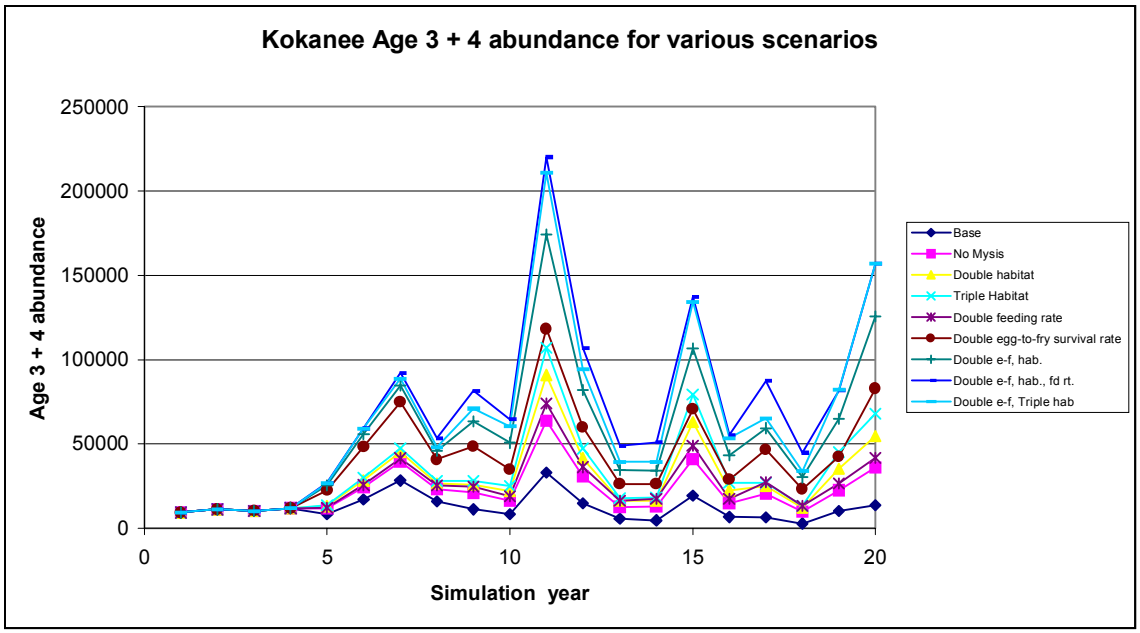


Figure 4-13: Results for 80,000 Kokanee analysis. Scenarios described in Table 4-2. Results were calculated using V1.0 of the life-cycle model (June 19, 2002).

What conditions are required for sockeye to establish in Skaha Lake?

At the January 14-15 workshop, the group explored conditions necessary to establish a new sockeye stock Skaha Lake. The most promising results were found for removing barriers in combination with trapping and placing adults into Skaha Lake along with mysis harvest in both Osoyoos and Skaha Lake (at a constant 50% harvest rate) (Figure 4-14).

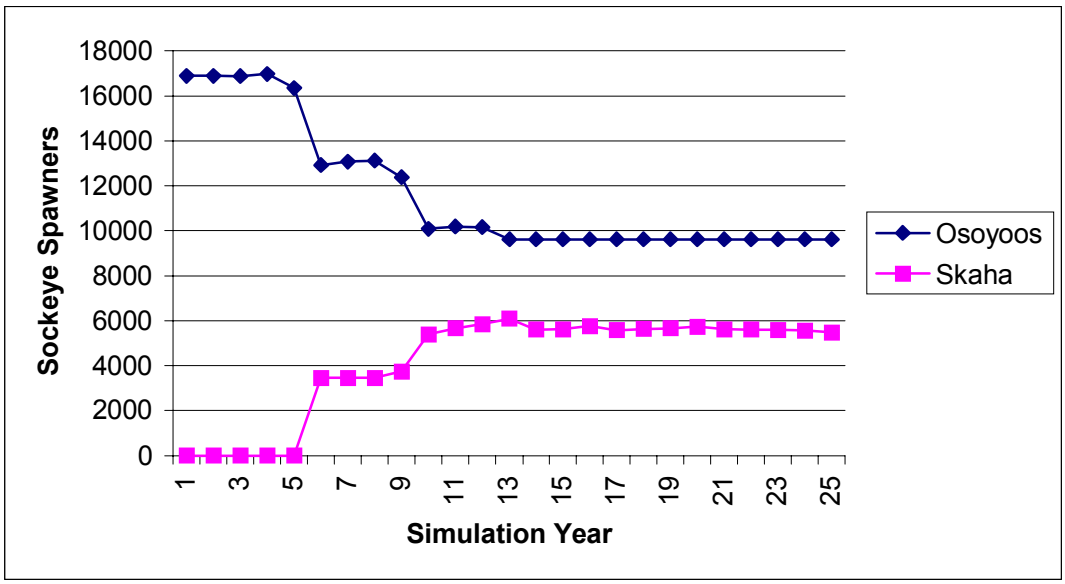


Figure 4-14: Results for a run that provided stable returns to Skaha Lake – 50% mysis harvest in both lakes, trap and truck.

How do sockeye, kokanee, and mysis impact one another?

For the base case parameter settings, sockeye fry have relatively little impact on kokanee, or mysis (Figures 4-8 and 4-9). This results holds even when their competitive ability (feeding rate) and abundance are set much higher than base case levels. Kokanee have some impact on sockeye, but little impact on mysis (Figures 4-7 and 4-8). Mysis have a large impact on both sockeye and kokanee (Figures 4-7, 4-8 and 4-9).

How many fry can be introduced before there is an impact on kokanee?

For the base case parameter settings, kokanee are insensitive to sockeye fry up to levels of 1000 sockeye fry/ha (Figure 4-7). For levels above this, there is a gradual decline in the kokanee fry-to-Age 0 survival rate from about 41% to about 35%.

4.4 Results of Model Analyses (Experimental analyses)

We built a framework for simulating examples of the three alternative methods of sockeye introduction discussed at the October 2002 workshop. For each analysis we calculated the results without variability to see the "true" impact on a performance measure and then added variability back in to simulates an

estimating the "true" change in the presence of "natural" variability. There are many possible experimental variations; for brevity, we chose to provide a single example in each of the three categories:

Analysis 5a: Hatchery fry supplementation experiment without natural variability.
Analysis 5b: Hatchery fry supplementation with natural variability.
Analysis 5c: Hatchery fry supplementation without natural variability with mysis harvest.

Analysis 6a: "Trap and transport" experiment without natural variability.
Analysis 6b: "Trap and transport" experiment with natural variability.

Analysis 7a: "Remove barriers" experiment without natural variability.
Analysis 7b: "Remove barriers" experiment with natural variability.

4.4.1 Advantages of hatchery incubation for fry introduction experiments

An important point raised at the October 2002 workshop was that hatchery fry introduction experiments would provide faster tests of competitive interactions between sockeye fry and kokanee in Skaha Lake. An added benefit is that the higher egg-to-fry survival in a hatchery would mean that less broodstock would be required from the Osoyoos stock to provide fry for Skaha Lake. To demonstrate this and to help determine the number of spawners required for different levels of fry seeding for the Analysis 5 and 6, we calculated the relative production of fry from hatchery broodstock (Table 4-3) and natural spawning (Table 4-4).

The geometric mean escapement for the observed Wells dam escapement from 1973 to 1997 is approximately 20,000. Using the life-cycle model's base case values for the Wells-to-Osoyoos spawning ground survival rate and the sockeye female ratio (0.87 and 0.52 respectively), this level of escapement yields an average of 9000 female spawners each year from which to draw hatchery broodstock for Skaha Lake. For hatchery conditions (assuming 70% egg-to-fry survival), 100 sockeye females would produce a fry abundance per hectare that more than doubles the 60-75 kokanee fry per hectare produced from an average kokanee spawning run (Table 4-3). In comparison, under conditions of natural egg-to-fry survival, it would take 800–900 females reaching Skaha Lake and successfully spawning to produce a similar sockeye fry density in Skaha Lake) (Table 4-4). Hatchery production of fry would therefore provide the opportunity for a greater range of fry stocking densities to Skaha Lake for a given impact to the Osoyoos stock (Figure 4-15).

Table 4-3: Estimated broodstock (# females) required from the Osoyoos stock for different levels of hatchery fry input (#fry/ha) to Skaha Lake. "% of expected number female in Osoyoos stock" presents the number in the far left column as a percent of the 1973-1997 geometric mean escapement to Wells dam. "Average fecundity" is the age-frequency weighted average fecundity. "% increase in total fry population" is the proportional increase in total fry (sockeye + kokanee) for given number of female sockeye relative to an average annual kokanee fry production of 75 fry/ha.

Osoyoos Females collected	% of expected number female in Osoyoos stock	Avg. fecundity	Assumed hatchery egg-to-fry survival	#Fry (x 10^6)	#Fry/ha (area of Skaha Lk is 2010 Ha)	% Increase in total fry population (assuming avg. kokanee fry production of 75/ha)
100	1.1%	2768	0.7	193752	96	129%
200	2.2%	2768	0.7	387504	193	257%
300	3.3%	2768	0.7	581256	289	386%
400	4.4%	2768	0.7	775008	386	514%
500	5.5%	2768	0.7	968760	482	643%
600	6.6%	2768	0.7	1162512	578	771%
700	7.7%	2768	0.7	1356264	675	900%
800	8.8%	2768	0.7	1550016	771	1028%
900	9.9%	2768	0.7	1743768	868	1157%
1000	11.1%	2768	0.7	1937520	964	1285%

Table 4-4: Estimated broodstock (number of female spawners) required from the Osoyoos stock for different levels of natural fry input (#fry/ha) to Skaha Lake.

Females spawning in Skaha Lake	% of expected number female in Osoyoos stock	Avg. fecundity	Assumed natural egg-to-fry survival	#Fry (x 10^6)	#Fry/ha (area of Skaha Lk is 2010 Ha)	% Increase in total fry population (assuming avg. kokanee fry production of 75/ha)
100	1.1%	2768	0.08	22143	11	15%
200	2.2%	2768	0.08	44286	22	29%
300	3.3%	2768	0.08	66429	33	44%
400	4.4%	2768	0.08	88572	44	59%
500	5.5%	2768	0.08	110715	55	73%
600	6.6%	2768	0.08	132859	66	88%
700	7.7%	2768	0.08	155002	77	103%
800	8.8%	2768	0.08	177145	88	118%
900	9.9%	2768	0.08	199288	99	132%
1000	11.1%	2768	0.08	221431	110	147%
1100	12.2%	2768	0.08	243574	121	162%
1200	13.3%	2768	0.08	265717	132	176%
1300	14.4%	2768	0.08	287860	143	191%
1400	15.5%	2768	0.08	310003	154	206%
1500	16.6%	2768	0.08	332146	165	220%
1600	17.7%	2768	0.08	354289	176	235%
1700	18.8%	2768	0.08	376433	187	250%
1800	19.9%	2768	0.08	398576	198	264%
1900	21.0%	2768	0.08	420719	209	279%
2000	22.1%	2768	0.08	442862	220	294%
2100	23.2%	2768	0.08	465005	231	308%
2200	24.3%	2768	0.08	487148	242	323%
2300	25.4%	2768	0.08	509291	253	338%

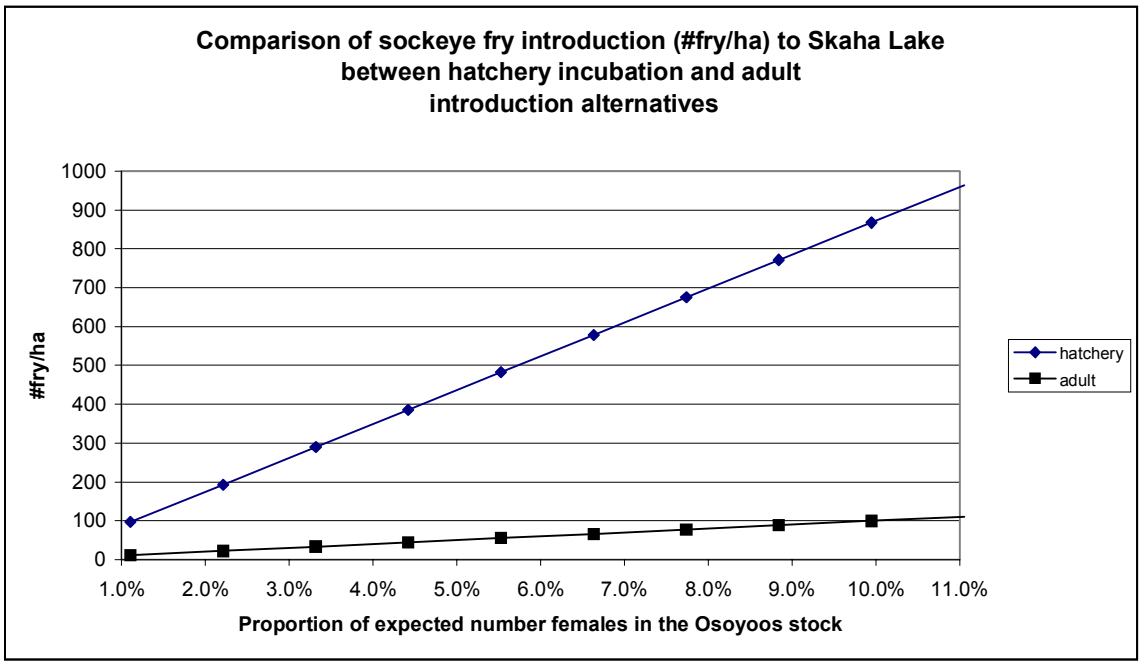


Figure 4-15: Comparison of sockeye fry introduction (#fry/ha) to Skaha Lake between hatchery incubation and adult introduction alternatives. Based on data in Tables 4-3 and 4-4.

4.4.2 Results for Analysis 5: Hatchery fry supplementation experiment

For this analysis, we started with the equilibrium Osoyoos stock settings determined in Analysis 1 and the equilibrium Skaha kokanee/mysis settings determined in Analysis 3. To simulate the existing barrier to returning Skaha adults we set the model's thermal barrier to 0 °C for both the Osoyoos and Skaha stocks.

We selected this simple experimental design:

- Five years of Before monitoring followed by five years of treatment and After monitoring.
- The treatment was 200 sockeye fry/ha added to Skaha Lake in each of the five treatment years. This required a take of approximately 385 Osoyoos spawners (females producing 200 fry/ha from Table 4-3, divided by female proportion of 0.52 to expand to total spawners required).
- The treatment was implemented in years 6 to 10 of the simulation.

We simulated this experiment without natural variability (Analysis 5a) and with natural variability added back in (Analysis 5b) to simulate process error in the "measured" indices (Figure 4-16).

Stocking sockeye fry at a rate of 200/ha over five years did not have any noticeable impact on kokanee or mysis under equilibrium conditions (Figure 4-16, left hand column of panels). Adding natural variability back in masked the downward trend in sockeye fry and spawner abundance, improved kokanee spawner abundance, and increased mysis densities (Figure 4-16, right hand column of panels). Sockeye fry-to-smolt survival over the 5-year treatment period was 0.083 and 0.093 for conditions of no variability and variability respectively. Kokanee fry-to-Age 0 survival over the 5-year treatment period was 0.41 and 0.45 for conditions of no variability and variability respectively.

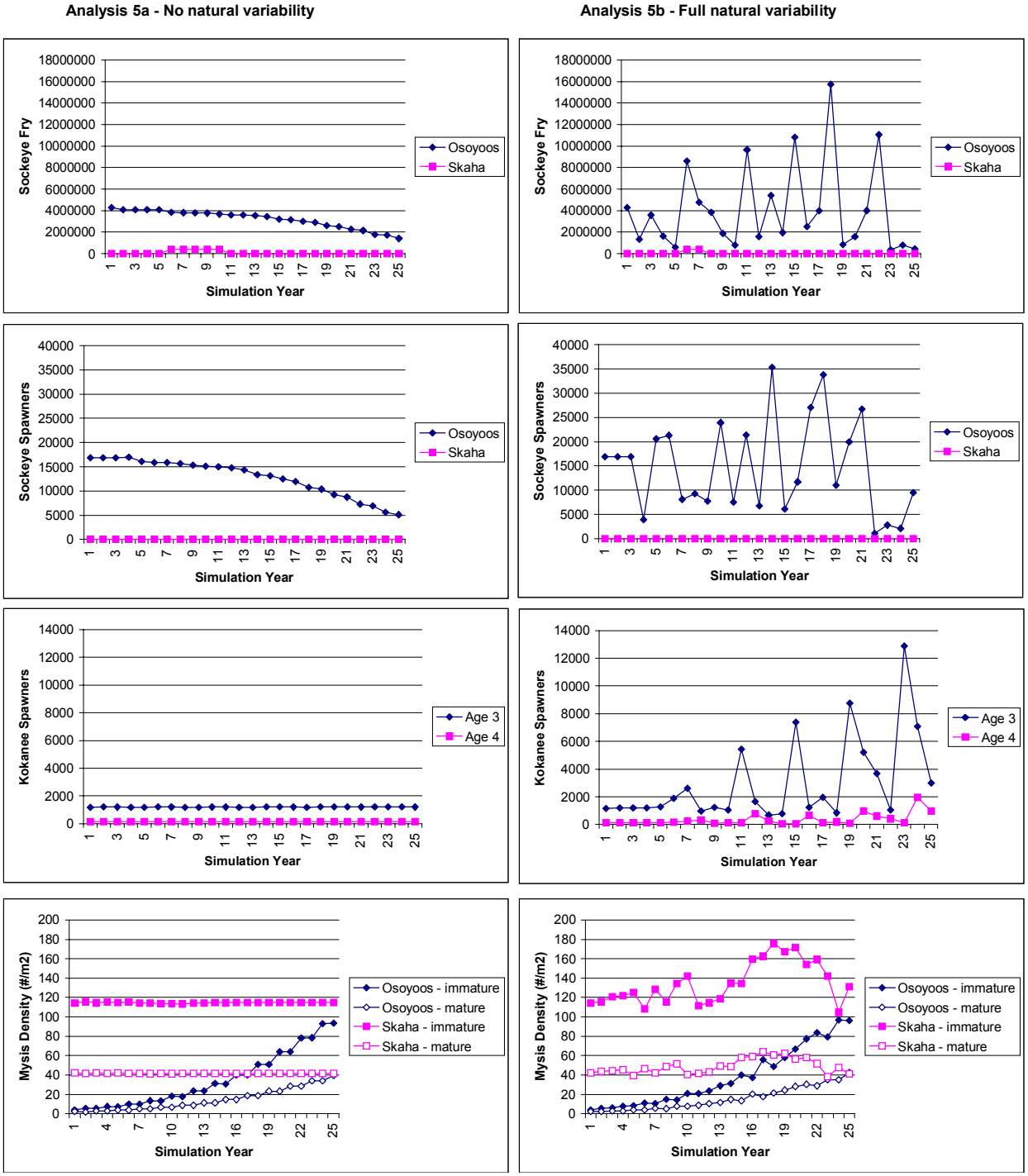


Figure 4-16: Hatchery fry supplementation experiment (Analyses 5a and 5b). The panels in this figure compare the fry supplementation impacts on sockeye fry, sockeye spawners, kokanee spawners, and mysis densities under conditions of no natural variability (left hand column of panels) and full natural variability (right hand column of panels). Sockeye fry supplementation treatment of 200 fry/ha was applied in simulation years 6-10.

4.4.3 Results for Analysis 5c: Hatchery fry supplementation experiment with mysis harvest

We modified Analysis 5a to run with an annual harvest of 50% of the mysis in Skaha Lake to explore how this might benefit sockeye and kokanee (Figure 4-17). Harvesting mysis had a beneficial effect for both kokanee fry and sockeye fry, probably by reducing the strong competitive effect mysis have on the survival rates of both (as shown in Figure 4-8). Under mysis harvest, the average sockeye fry-to-smolt survival increased from 0.083 to 0.33 over the five years of treatment (Analysis 5a compared to 5c) and increased the kokanee fry-to-Age 0 survival rate from 0.41 to 0.86 (Analysis 5a compared to Analysis 5c, Figure 4-21). This large increase in the kokanee survival rate is reflected by the steep increase in kokanee spawner abundance (Figure 4-17), right hand kokanee panel). Another, interesting results is the benefit to the Osoyoos stock that results from the improved sockeye fry-to-smolt survival in Skaha Lake. Returning Skaha spawners boost the abundance of Osoyoos spawners starting in year 9 because they cannot return to Skaha Lake (compare the sockeye spawner panels in Figure 4-17), which in turn boosts Osoyoos fry production and helps temporarily offset the steady decline of the Osoyoos stock (compare the left and right hand sockeye fry panels in Figure 4-17). Additionally, under the constant annual 50% harvest rate, Skaha mysis were driven to extinction.

These results indicate that mysis harvest could benefit Skaha kokanee and help to offset competition impacts associated with sockeye fry introduction. However, this example does account for competition between sockeye and kokanee on the spawning grounds, which should be explored through additional simulations.

Note that with natural variability, adults could only be taken in two of the five years of the treatment period (Figure 4-16, right hand sockeye fry graph).

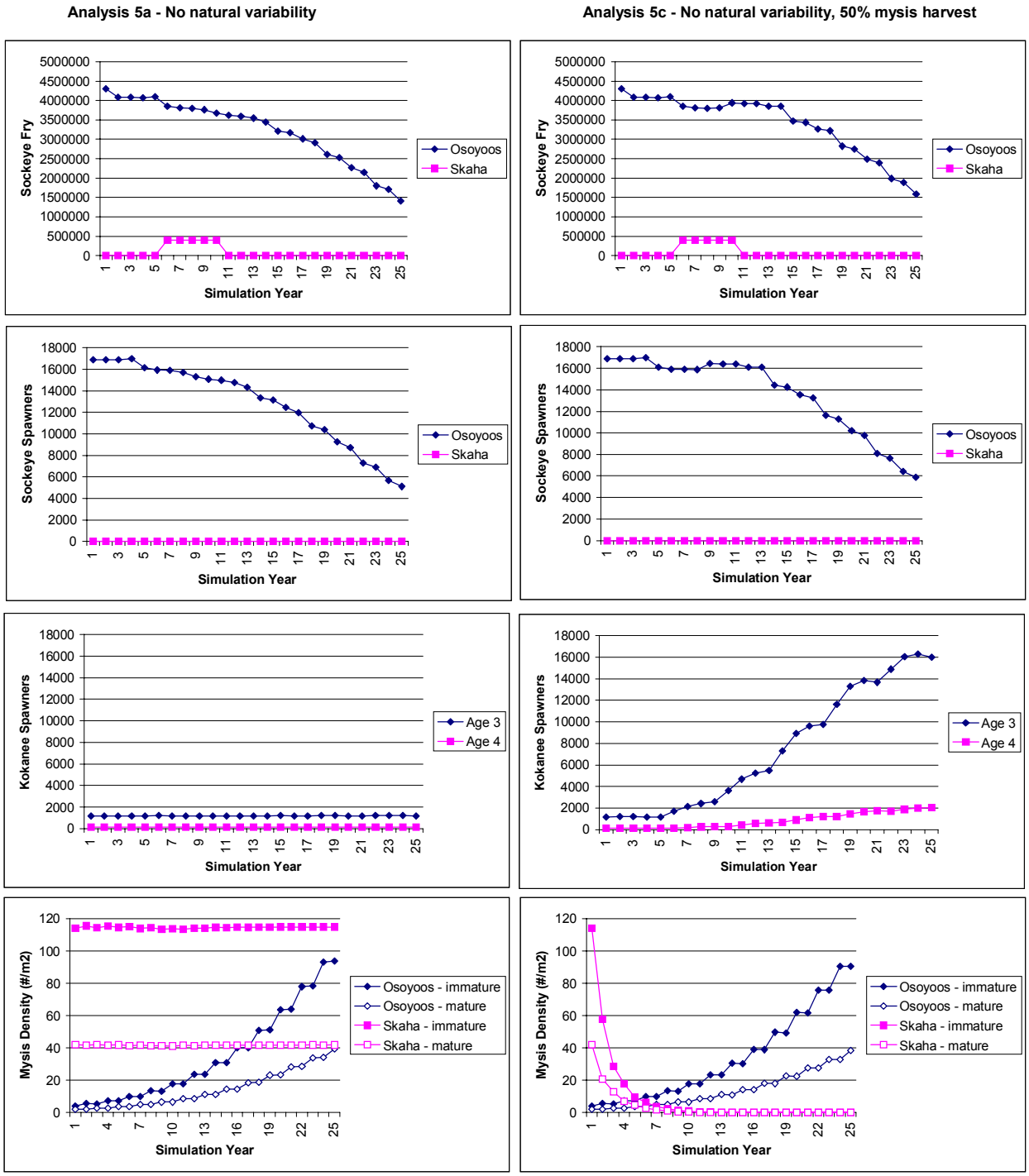


Figure 4-17: Hatchery fry supplementation experiment with harvest of mysis (Analysis 5c). The panels in this figure compare the fry supplementation impacts on sockeye fry, sockeye spawners, kokanee spawners, and mysis densities under conditions of no natural variability (left hand column of panels) and full natural variability (right hand column of panels). Sockeye fry supplementation treatment of 200 fry/ha was applied in simulation years 6-10. A 50% harvest rate was applied to mysis in Skaha Lake in every year of the simulation.

4.4.4 Results for Analysis 6: "Trap and truck" experiment

For this analysis, we started with the equilibrium Osoyoos stock settings determined in Analysis 1 and the equilibrium Skaha kokanee/mysis settings determined in Analysis 3. To maintain the existing barrier to returning Skaha adults we kept the model's thermal barrier at 0 °C for both the Osoyoos and Skaha stocks as in Analysis 5.

We selected this simple experimental design:

- Five years of Before monitoring followed by five years of treatment and After monitoring.
- The treatment was adding enough Osoyoos spawners to add about 200 sockeye fry/ha to Skaha Lake in each of the five treatment years. This required about 3454 spawners (read number of females required from Table 4-4 and then divide by the female proportion of 0.52 to expand to total spawners required).
- The treatment was implemented in years 6 to 10 of the simulation.

We simulated this experiment without (Analysis 6a) and with (Analysis 6b) natural variability added back in (Figure 4-18).

More adults were required from the Osyoos stock to meet the fry abundance target for this analysis than for Analysis 5 (3454 vs. 385). This requirement negatively impacted the Osoyoos stock, causing it to decline more quickly over the simulation period (compare left side of Figures 4-18 and 4-16).

Average sockeye fry-to-smolt survival over the treatment period went from 0.083 with no variability to 0.096 with variability. This result is similar to that for Analysis 5 (Figure 4-21). Average kokanee fry-to-Age 0 survival over the treatment period went from 0.41 with no variability to 0.45 with variability. This result is the same as that for Analysis 5 (Figure 4-21).

There was an impact on the kokanee fry abundance (Figure 4-21, top left panel), but this effect was small and was masked when natural variability was included (Figure 4-21, bottom left panel).

Note that with natural variability, adults could only be taken in two of the five years of the treatment period (Figure 4-18, right hand spawner graph).

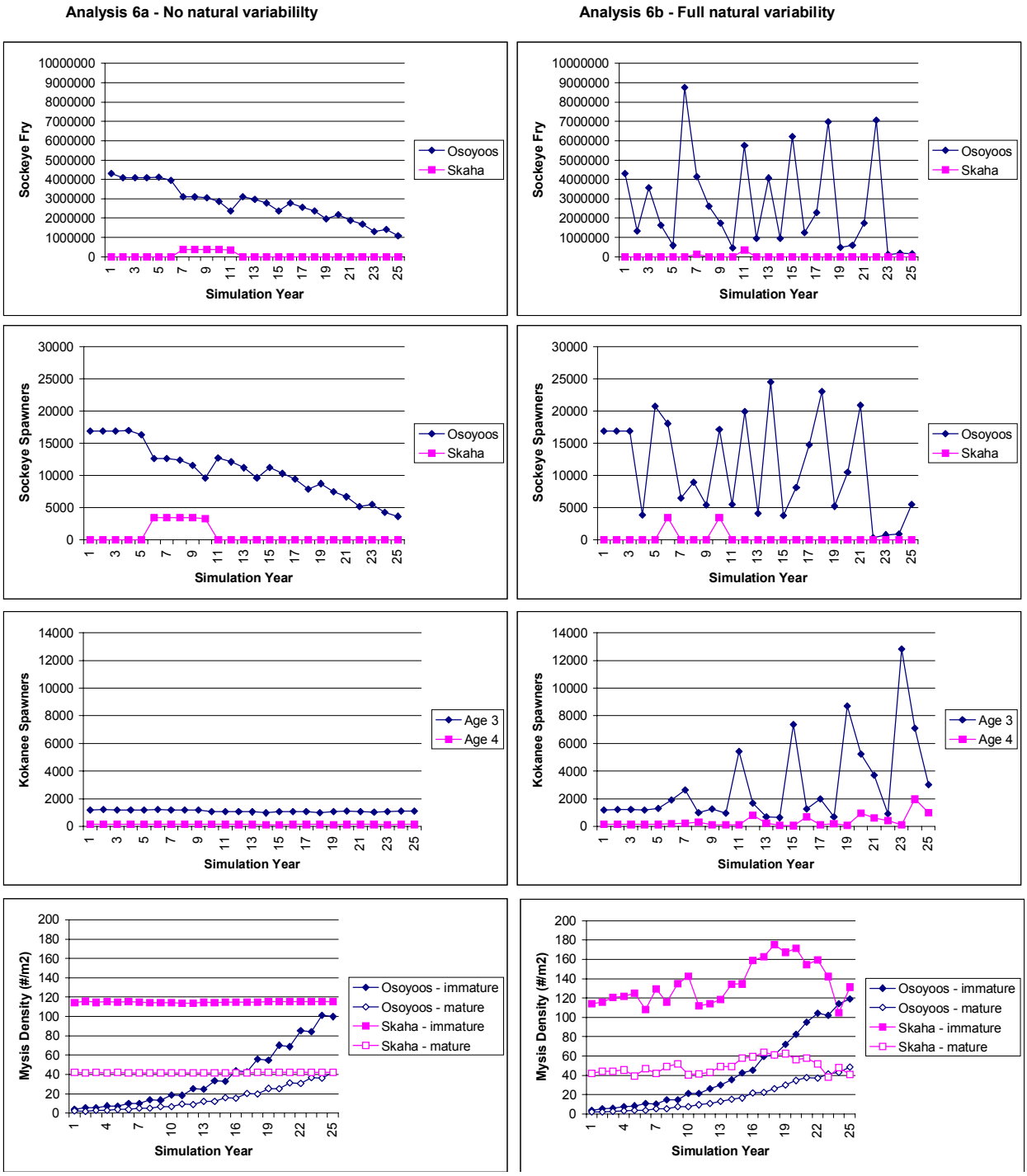


Figure 4-18: Trap and transport experiment (Analysis 6a and 6b). The panels in this figure compare the fry supplementation impacts on sockeye fry, sockeye spawners, kokanee spawners, and mysis densities under conditions of no natural variability (left hand column of panels) and full natural variability (right hand column of panels). Sockeye adults were selected from the Osoyoos stock in years 6-10 of the simulation. Enough adults were taken to stock 200 fry/ha (approximately 3454 adults).

4.4.5 Results for Analysis 7 "Remove barriers" experiment

This is the simplest of the three alternatives to simulate. We again started with the equilibrium Osoyoos stock settings determined in Analysis 1 and the equilibrium Skaha kokanee/mysis settings determined in Analysis 3. We simulated removal of the barriers to migration above Osoyoos Lake by setting the model's thermal barrier to 15 °C for both the Osoyoos and Skaha stocks. 15 °C is the base value assumed for Skaha, but Osoyoos is set to zero under base conditions to prevent them from migrating upstream. Setting this temperature barrier higher (e.g., 25 °C) would allow more spawners to return or stray to Skaha Lake, which could be explored in an analysis subsequent to this one. At the January 14–15 workshop, Kim Hyatt noted that a default upstream temperature barrier of 21 °C is more realistic than 15 °C.

As for Analyses 5 and 6, we simulated this experiment without (Analysis 7a) and with (Analysis 7b) natural variability added back in (Figure 4-19).

The results are very similar to those for Analysis 5 (Figure 4-16). This is probably because in both cases very few spawners are "taken" from the Osoyoos stock, either deliberately as in Analysis 5, or serendipitously as conditions permit as in Analysis 7 (Figure 4-20). Therefore there is little impact on Osoyoos stock production and few sockeye fry in Skaha Lake to compete with kokanee fry and few sockeye adults to compete with kokanee adults for spawning habitat.

Average sockeye fry-to-smolt survival over the same years as the treatment period for Analyses 5 and 6 went from 0.083 with no variability to 0.092 with variability. This result is similar to those for analysis 5 and 6 (Figure 4-21). Average kokanee fry-to-Age 0 survival over this same 5-year period went from 0.41 with no variability to 0.45 with variability. This result is the same as those for Analysis 5 and 6 (Figure 4-21).

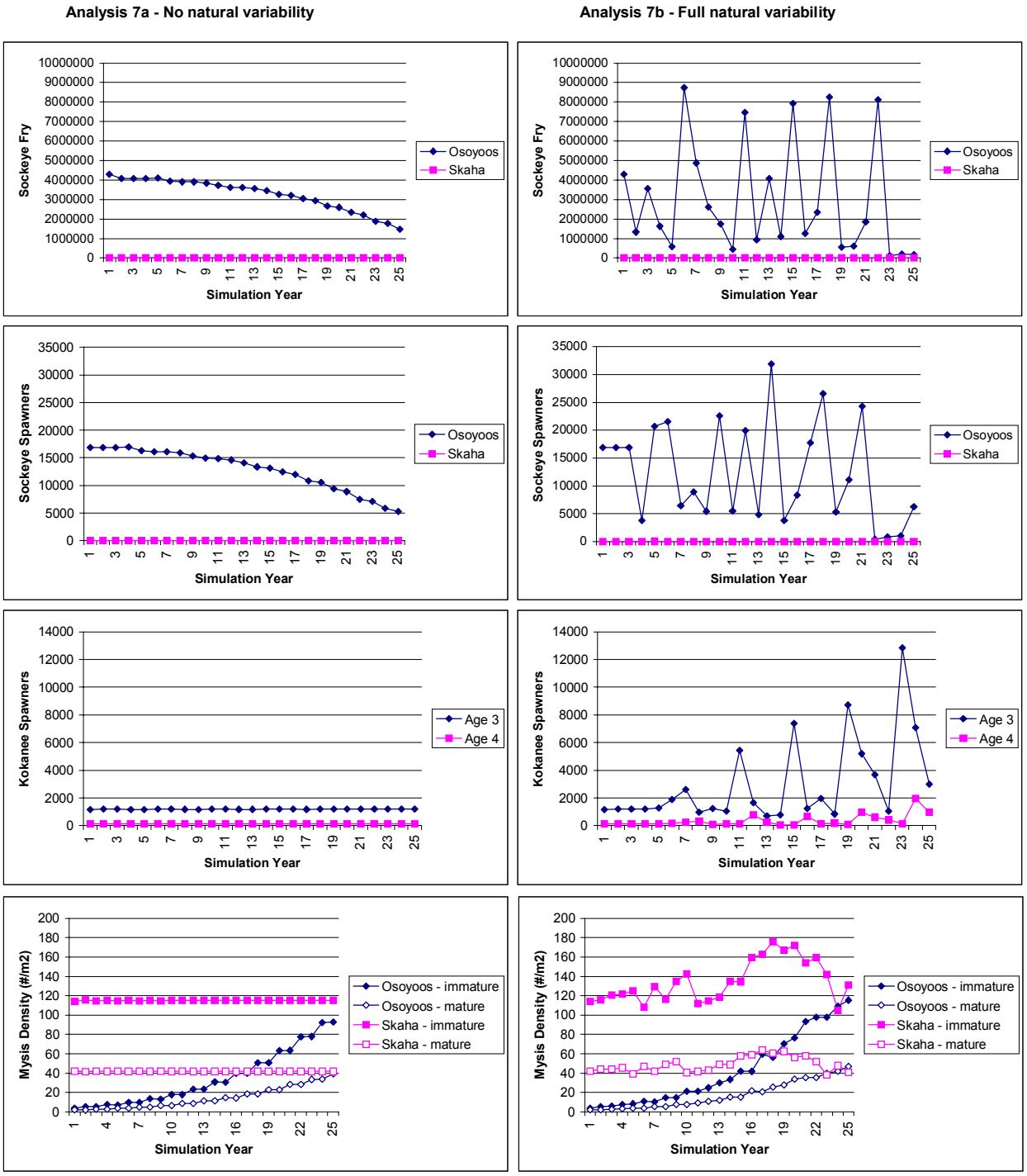


Figure 4-19: Remove barriers experiment (Analyses 7a and 7b). The panels in this figure compare the fry supplementation impacts on sockeye fry, sockeye spawners, kokanee spawners, and mysis densities under conditions of no natural variability (left hand column of panels) and full natural variability (right hand column of panels). All temperature barriers to upstream migration above Osoyoos lake were removed to simulate the removal of physical barriers.

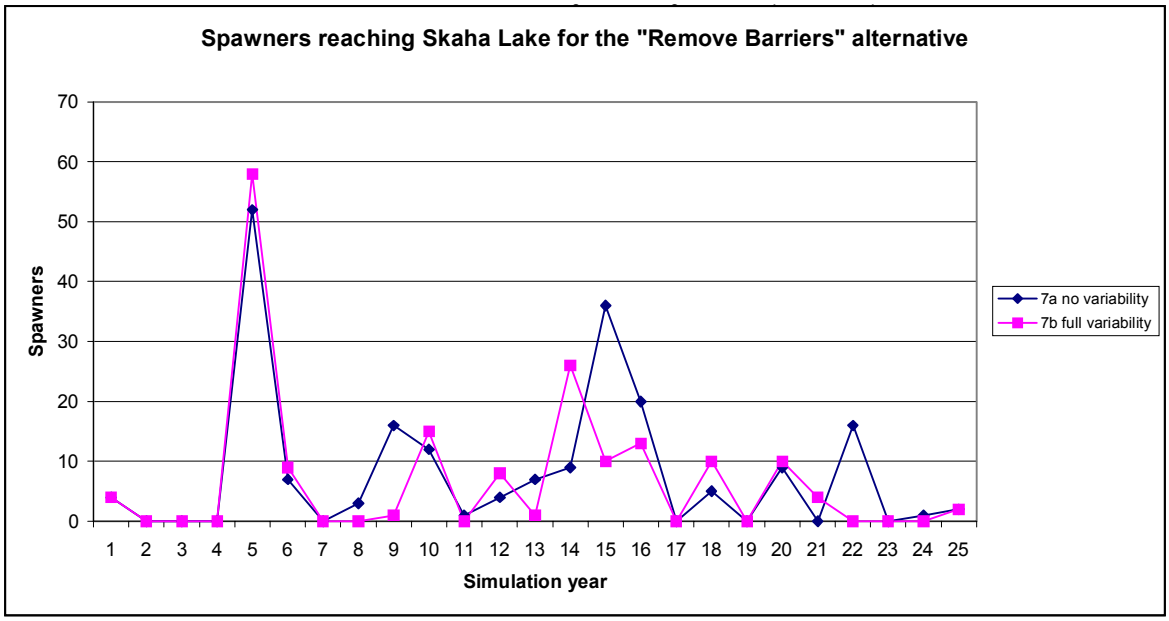


Figure 4-20: Comparison of the number of spawners reaching Skaha Lake for the "Remove Barriers" experiment (Analysis 7). "7a no variability" is analysis 7a. "Analysis 7b full variability" is analysis 7b.

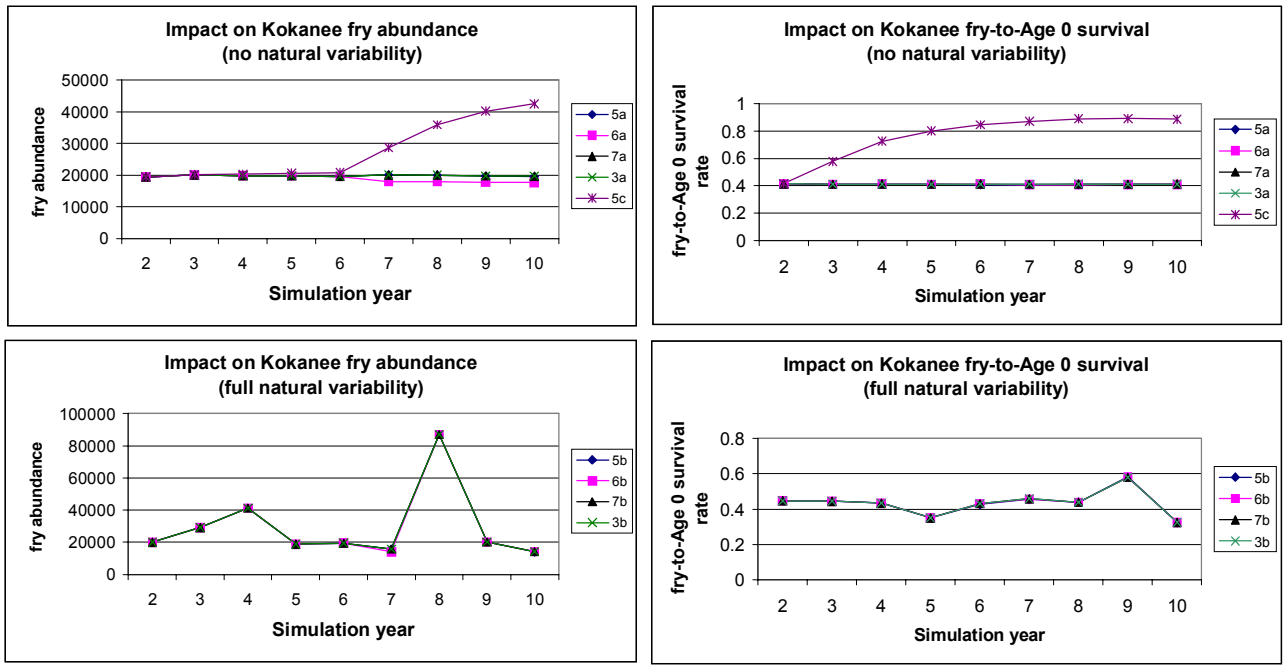


Figure 4-21: Comparison of kokanee fry-to-Age 0 survival rates and fry abundance for the experimental alternatives with and without natural variability. 3a and b are the results for Analysis 3. 5a and b are the results for the hatchery fry supplementation experiment (Analysis 5). 6a and b are the results for the trap and transport experiment (Analysis 6). 7a and b are the results for the remove barriers experiment (Analysis 7).

4.5 Statistical power analyses for example experiments

4.5.1 Introduction

The tests of significance commonly used to assess experimental results are subject to Type I and II errors in inference. A Type I error is the probability of failing to accept a true null hypothesis of no effect. An example of a Type I error would be that the sockeye re-introduction actually has no effect on kokanee, but we mistakenly conclude (due to imprecise measurements and/or natural variability) that an effect did occur, either a positive or negative effect. The acceptable magnitude of this error (α) is typically selected by the researcher, but 0.05 is often used in controlled experiments. A Type II error (β) is the probability of failing to reject a false null hypothesis, or missing a true effect. An example of a Type II error in the Skaha situation is that the sockeye re-introduction positively or negatively affected kokanee, but our measurements were unable to detect this effect. The converse of type II error ($1-\beta$) is statistical power, or the probability of detecting a true effect. While the Type II error rate is not usually set by the researcher, experiments should be designed to keep β as low as possible and therefore keep power as high as possible. This is done using *a priori* (before the experiment) statistical power analysis (e.g., Cohen 1988, Peterman 1990).

A priori power analysis involves estimating statistical power over different combinations of the four basic components of experimental design:

- the level of statistical significance (Type I error rate, or α);
- the effect size, or change, important to be able to detect;
- sample size (n); and
- sample variance (s^2).

This can help to answer important inferential and logistical questions that arise during the design of management experiments (e.g., how many years to monitor?, will adding a control system help?, what size of effect can be detected with high power?). Thus *a priori* statistical power analysis is an important tool for experimental design and evaluation.

In this section we use *a priori* power analyses to further evaluate the example sockeye introduction experiments in Section 4.4, in the context of specific questions raised during workshop discussion of monitoring requirements:

- What is the expected precision based on historical information for the selected method (e.g., range of variation for fry abundance estimates using method X)?
    - acoustic abundance estimates may have measurement error of 20-40%;
    - kokanee spawner abundance estimates, in early years may have error up to +/-100%, more recently +/-50%, plus bias associated with density, bank walks (wetted width) etc., used expansion factors based on a fence count.
- What is the desired precision (e.g., to provide statistical power of 80%)?

- Can the desired precision be achieved, given our assumptions about natural (uncontrollable) variability?
- What's the power to detect different effect sizes within a given time period?

To address these questions, we calculated the statistical power to detect the observed effects under each of the three example experiments on three indices of system performance: kokanee fry-to-Age 0 survival, kokanee fry abundance, and kokanee spawner abundance. Additionally, we explored a wider range of effect sizes, sample sizes, and variance as well as the potential benefits, in terms of statistical power, of including a control system. These analyses are provided as an example of the types of analyses that should be done prior to any large-scale experiments in order to maximise both the learning and conservation benefits of such experiments.

4.5.2 Methods

We used the OkSockeye model to simulate the trend in kokanee abundance for the example experiments presented in Section 4.1.3. The example experiments are simple balanced "Before-After" (abbreviated as "B-A") designs with 5 consecutive years of monitoring in each period. Each experiment is run without natural variability (runs 5a, 6a, 7a, as described in Section 4.1.2) and with natural variability added back in (runs 5b, 6b, 7b). For each index, the "true" effect of treatment is the difference between the "Before" and "After" period means from the experiment run without natural variability. The size of the true effect is determined by the rules and data incorporated in the model. We estimated the natural variability (process error) around the means from the experimental run that included natural variability.

We calculated power in the context of a two-way t-test (Cohen 1988, Parnell 2002). A two-way test is appropriate since the direction of change is unknown. Power estimates would be higher if calculated for a one-way t-test. We calculated power for two levels of statistical significance ($\alpha = 0.05$ and 0.2) to explore the tradeoffs, in terms of statistical power, between learning and conservation objectives. We assumed that the minimum desired level of power ($1-\beta$) for an experiment was 0.8 (i.e. a 0.2 chance of a Type II error). We also calculated power over a range of effect sizes (changes from the Before period mean) for each index (+/- 50% for fry-to-Age 0 survival rate, +/-100% for fry and spawner abundance) and for a range of Before and After sample sizes (2-10 years) around the base sample sizes. All power calculations were done using an Excel spreadsheet (Parnell 2002).

Kokanee spawner abundance may show the effects of interactions with sockeye several years after treatment begins, so we also calculated power assuming that the 5-year After period for spawner abundance began 4 years after treatment (i.e. a 4 –year lag due to the maturation time of kokanee).

The low level of fry introduction over three experiments (maximum of 200 fry/ha) had little impact on kokanee indices (Table 4-5), as expected from our preliminary analyses of sockeye-kokanee-mysis interactions in Section 4.2. Therefore, we explored an extreme variation of the hatchery fry supplementation experiment with an introduction of 5000 sockeye fry/ha to estimate the effect on kokanee indices under this much higher level of competition.

As mentioned above, sample variance is composed of both natural variation (process error) and measurement error. We assumed that managers could not reduce process error in a simple B-A experiment, but that they could reduce measurement error. During the workshop discussions, it was noted that acoustic estimates of fry abundance have measurement error in the range of 20-40%, while kokanee spawner abundance estimates using recent methods may have measurement error in the range of 50%

(historically, it may have been as high as 100%). To explore the impact of measurement error, we also calculated statistical power for each index by adding a measurement error of 30% to the process error.

We then explored the potential statistical advantage of adding a control system (a Before-After-Control-Impact, or BACIP design, Stewart-Oaten et al. 1986) for reducing process error (i.e. filtering out natural variation that is common to both treated and control systems) and thereby increasing statistical power. We did this by explicitly including the effect of covariance between a treatment and control system in our power calculation model. We explored the results over a wide range of correlation in spawner abundance and grounded our results using estimates of correlation in kokanee spawner abundance between Skaha Lake and several Okanagan lakes.

4.5.3 Results and discussion

Base results

There was virtually no probability of detecting the observed "true" effects of the three sockeye re-introduction experiments, because their magnitude was so small (Table 4-5). The base power results were essentially identical for all three experiments.

The largest effects were seen for the Trap and Truck experiment where the fry abundance and spawner abundance indices decreased by 8.15% and 1.45% respectively from their "Before" period means. Variance generally increased for all indices in the "After" period. The fry-to-Age 0 index had the lowest variance of the three indices (CV ranged from 0.11 to 0.22) and showed the least increase between the Before and After periods.

The kokanee fry abundance index had the highest CV (CV ranged from 0.53 to 1.73). In the Skaha simulation model, we use the standard assumption (Bradford 1995) that egg to fry survival has a lognormal distribution (mean 0.05; SD 0.5; Figure 4-22). This assumption can generate quite a large natural year-to-year variation in the egg-fry survival rate, making it difficult to detect the effects of an experimental treatment (e.g., either sockeye re-introduction or mysid removal) on kokanee fry abundance. The change in variance between the "Before" and "After" periods for fry is just a random result due to the particular sequence of random numbers that emerged in this single example simulation. If many simulations were run (say 1000), and there wasn't a major change in kokanee abundance, then the variances in fry abundance in the "Before" and "After" periods would be similar. Other factors in the model (e.g. the time series of Total Phosphorus measurements, flow, temperatures) also affect the amount of variation in kokanee fry abundance for each period. Of course in nature you get the cards you're dealt, which could very well result in changes in variance from the Before period to the After period.

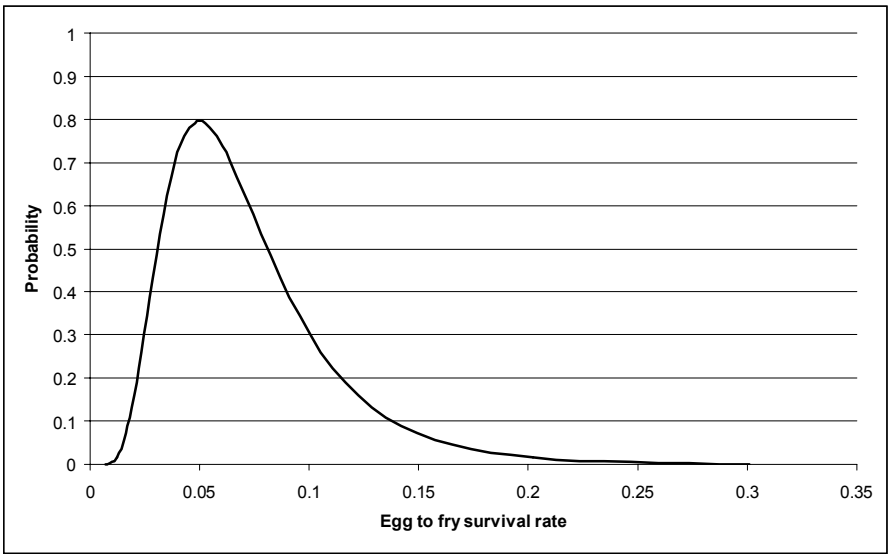


Figure 4-22: Probability distribution of kokanee egg to fry survival rates in Skaha Lake, given OkSockeye model assumptions about mean and standard deviation.

Table 4-5: Summary statistics and power results for the three example experiments. 'n' is the number of years in the Before and After periods. 'SD' is standard deviation. 'Mean' is the mean of the index over the Before and After periods. 'CV' is the coefficient of variation (SD/Mean). '% Change' is the percent change from the Before period mean, or the "True" effect size. 'Power' is the statistical power to detect the observed '% Change'. Power is calculated for $\alpha = 0.05$.

	Hatchery Fry Supp.		**Trap and Truck**		**Remove Barriers**	
Expt combo	5a, 5b		6a, 6b		7a, 7b	
	Before	**After**	**Before**	**After**	**Before**	**After**
Kokanee fry-to-Age 0 survival rate						
n	4	5	4	5	4	5
SD	0.046	0.092	0.046	0.091	0.046	0.091
Mean	0.411	0.408	0.411	0.409	0.411	0.411
CV	0.111	0.224	0.111	0.223	0.111	0.222
% Change		-0.76%		-0.60%		-0.06%
Power		0.028		0.028		0.025
Kokanee Fry Abundance						
n	4	5	4	5	4	5
SD	10397	31296	10397	31491	10398	31289
Mean	19776	19816	19776	18164	19775	19826
CV	0.53	1.58	0.53	1.73	0.53	1.58
% Change		0.21%		-8.15%		0.26%
Power		0.025		0.030		0.025
Kokanee Spawner Abundance						
n	5	5	5	5	5	5
SD	42	713	42	733	42	710
Mean	1328	1331	1328	1308	1327	1335
CV	0.03	0.54	0.03	0.56	0.03	0.53
% Change		0.23%		-1.45%		0.60%
Power		0.026		0.028		0.026

Varying Effect Size

To explore the effect of different effect sizes on statistical power, we calculated power over a range of effect sizes (changes from the "Before" period mean) using the base sample size and variance for each of the three indices of kokanee abundance (Figure 4-23). For each index, the results were essentially identical across the alternative experiments. The fry-to-Age 0 index, with the lowest range of variability, achieved a power of 0.8 for approximately a +/- 40% change in survival. The fry abundance index, with the highest range of variability, could not achieve power of 0.8 for even a +/- 100% change in abundance. The spawner abundance index, with the middle range of variability, achieved power of 0.8 for an approximate +/- 80% change in mean abundance.

It is interesting to note that the modelled range of variability for spawner abundance (CV ranges from 0.03 to 0.54) is lower than the observed range of variability for real spawner data (CVs range from 0.49 to 0.96, Table 4-6). This is a useful result for two reasons. First, it's comforting that the modelled error is lower than the real error because the model error does not include measurement error while the real data do. Second, the difference between the model and real CVs provides a crude estimate of the measurement error on spawner abundance estimates for consideration in this analysis (about 42–46%).

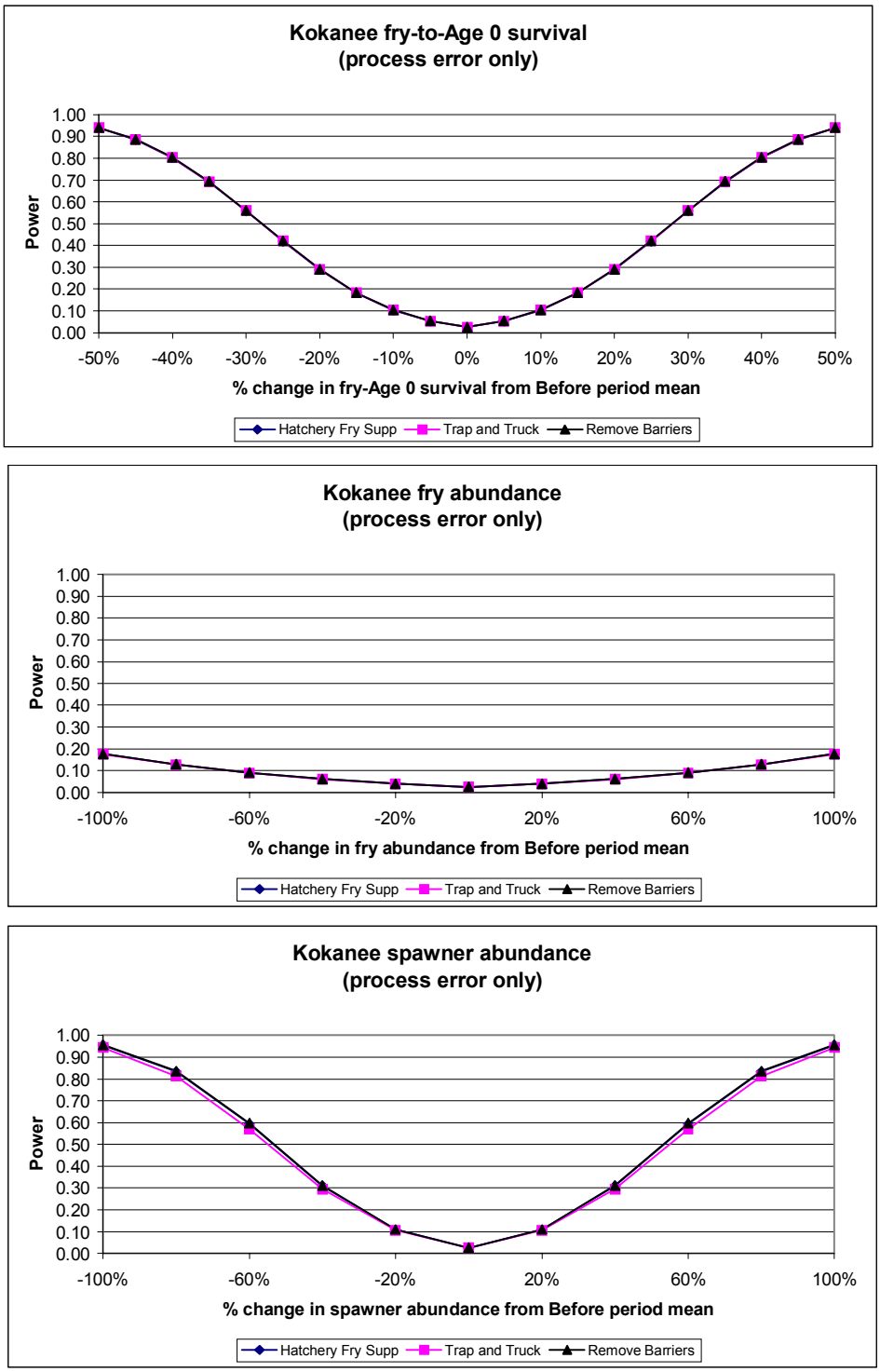


Figure 4-23: Power vs. effect size (% Change) for the three example experiments. % Change is the percent change from the Before period mean. Power is calculated using base n and SD values presented in Table 4-5, and $\alpha = 0.05$.

Varying Sample Size

Increasing sample size by increasing the length of the "Before" period, "After" period, or both periods did not appreciably increase power; power over all combinations of sample sizes ranging from 2-10 years in both the Before and After period was similar to the base results for each experiment and index.

This occurs because the degree by which increasing sample size will reduce sample variation depends in part on the relative magnitude of the variance in the Before and After periods, as well as in which period the increase in sample size takes place. For a given effect size, when total variation is much greater in the After period than the Before period, then increasing After sampling has much less impact on power than increasing Before sampling. Increasing sample sizes in the Before period did have a bigger impact on power than increasing the After sample size, but the effect was still small.

Varying the level of statistical significance

Increasing the level of statistical significance from 0.05 to 0.2 increased the level of statistical power (Figure 4-24). For example, the kokanee spawner abundance index went from being able to detect an 80% decline with a power of 0.8 to being able to detect a 55% decline with a power of 0.8. Thus, it may be worth increasing the risk of falsely detecting a change in kokanee indices when no change actually occurred (type I error or α) so as to ensure that you do detect an actual change. This would be consistent with the precautionary principles outlined in Section 2, and is commonly done for situations of this nature.[4]

We also calculated these results for a 1-tail test (α =0.05) to show how power increases for the test of a directional hypothesis (Figure 4-24, middle line). Such a test may be preferred from a conservation perspective where it's much more important to detect a decrease in kokanee abundance than an increase, particularly since a sockeye introduction is introducing a potential mortality factor, not removing one.

[4] Wilson (in Appendix C of ESSA Technologies Ltd. 2002a) summarizes recent literature on the relative risks of these errors and their implications for monitoring endangered species. Lindley et al. (2000) suggest that standard methods, which control for the Type I error rate and accept the resulting Type II error rate are inappropriate when monitoring endangered species. They believe a more logical and precautionary approach is to set the Type II error rate at an acceptably small value that yields a reasonable Type I error rate. Shrader-Frechette and McCoy (1992) note that Type II error leads to possible harm or loss of benefit, respectively. In endangered species recovery activities, if a Type II error is committed, a population could be on its way to extinction before the decline is detected and preventative action is taken. Conversely, if the population is monitored after initiating recovery actions, and the population is actually increasing, a Type II error would lead to the mistaken inference that the actions are not having the desired effect, perhaps jeopardizing continuance of those actions.

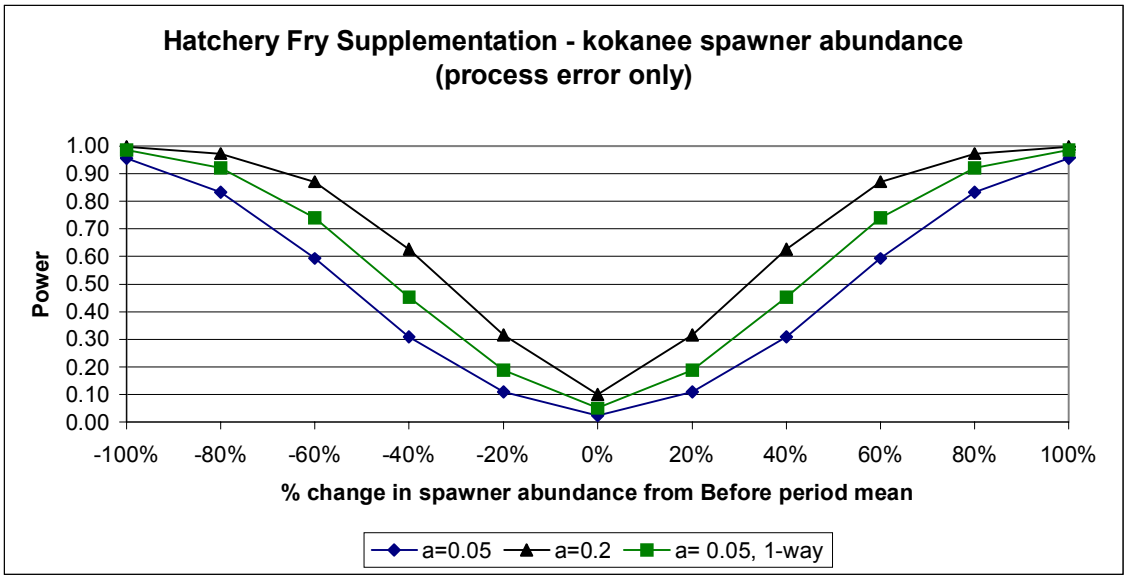


Figure 4-24: Power vs. effect size (% Change) for different levels of statistical significance (α = 0.05 and 0.2). For comparison, power results are also presented for a 1-way t-test (middle line) at α = 0.05. Power is calculated for the Hatchery Fry Supplementation experiment only. Calculations use base sample size (n) and variance (SD) results from Table 4-5.

Lag in Spawner Abundance

The fry-to-Age 0 survival rate and fry abundance indices will reflect impacts from the first year that treatment is initiated. However, there could be a lag-effect for the spawner abundance index depending on the hypothesised mechanism of impacts. For example, the impact to spawner abundance could begin in the first year of treatment if the number of spawners declines due to decreased growth arising from increased grazing pressure from additional fry. Alternatively, the impact may not appear until several years after treatment begins if decreased survival at fry-to-Age 0 stage from competition in year t reduces number of spawners in year t+4.

We estimated the "true" effect size for the spawner abundance index for the five years beginning in year 4 after treatment to capture the lagged effects of competition in the fry-to-Age 0 lifestage on spawner abundance. There was only a small change for the Hatchery Fry Supplementation experiment (%Change decreased from 0.23% to 0.l2%). There was a large change for the Trap and Truck experiment (%Change decreased from –1.45% to –11.47%), but this change would have only a minimal impact on power (see Figure 4-23, power only increases to about 0.06).

Contrast with 5000 fry/ha hatchery fry supplementation experiment:

While the 5000 fry/ha supplementation rate did have a larger impact on the three indices, statistical power did not substantially increase. The %Change for fry-to-Age0 survival rate was a 12.2% decrease, for fry abundance was a 1.9% decrease, and for spawner abundance was a 4.8% decrease, which yielded power of about 0.14, 0.03, and 0.04 respectively. Power for these changes can also be approximated from Figure 4-23.

Varying sample variance/precision

Adding measurement error: While increasing precision of estimates will decrease sample variance and increase power, we assumed that process error could not be reduced for the simple Before-After design modelled here; only the measurement error component of sample variance can be controlled through improved sampling methodology. Because we ran our bases results with process error only, adding measurement error will only decrease precision and thus power.

Adding 30% measurement error, a magnitude comparable to that observed for acoustic fry abundance estimates (20–40%) and that estimated above based on differences between variance of modelled and observed spawner abundance (42-46%), reduced power relative to the base results, as expected. For example, with process error only (i.e., 0% measurement error), the fry-to-Age 0 index achieved a power of 0.8 at about a 40% change. With 30% measurement error, this index achieved a power of point 0.8 at 50% change (Figure 4-25). The results for spawner abundance could be worse given the estimate above of approximately 45% measurement error.

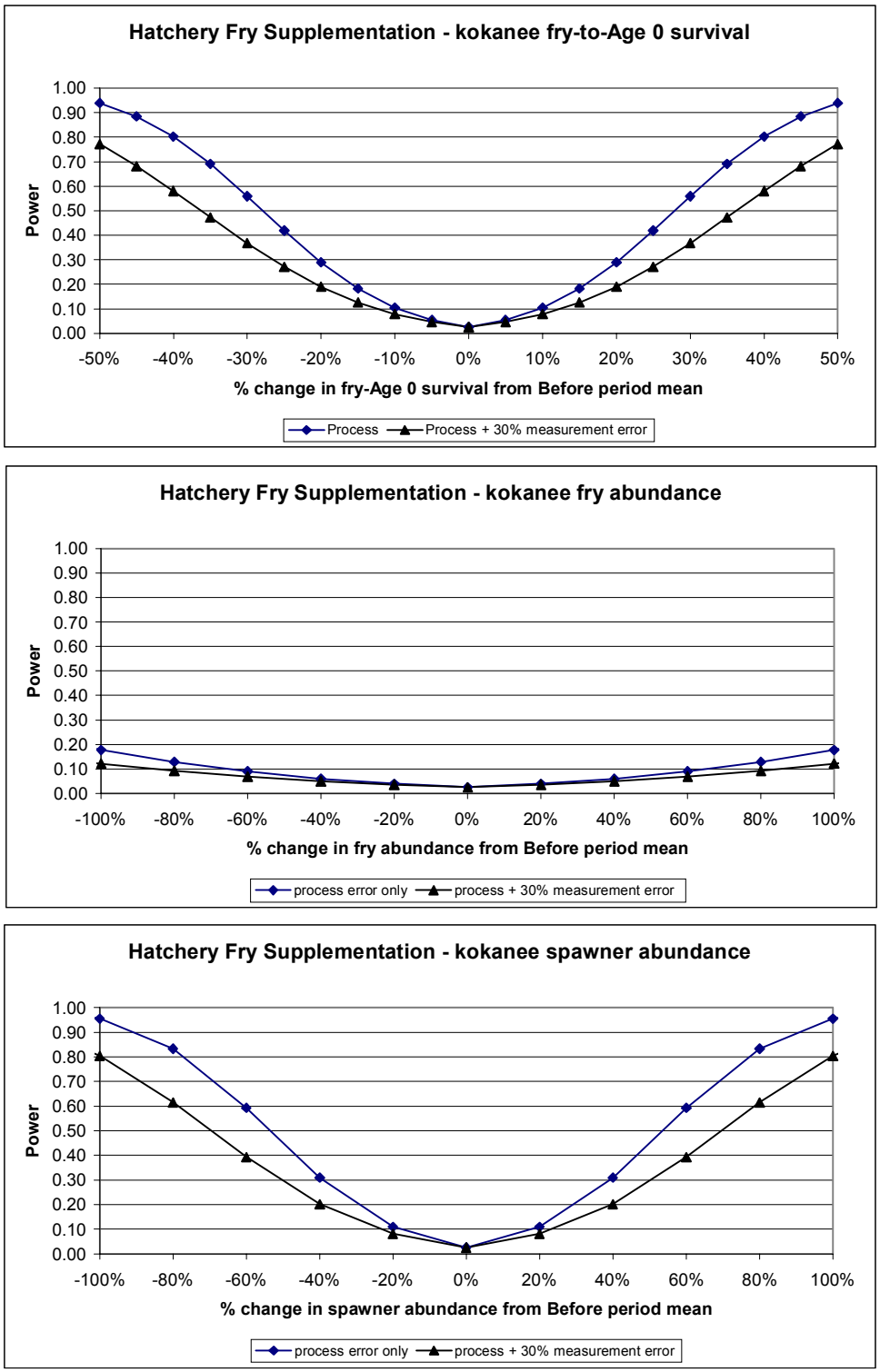


Figure 4-25: Power vs. effect size (%Change) for different levels of measurement error (0 and 30%). Power is calculated for the Hatchery Fry Supplementation experiment only. Calculations use base sample size (n) and variance (SD) results from Table 4-5 and α =0.05.

Benefit of including a control system for reducing process error: Managers may be able to decrease the effect of process error and increase statistical power by including a control system (e.g., in a BACIP design). We explored the effect of using control stocks to reduce process error and found that adding a single control system would only improve power if the correlation between indices was significantly greater than 0.5 (Figure 4-26). A correlation of 0.5 would produce the same variance and statistical power as the simple Before-After design. For correlations < 0.5, power decreases because BACIP sample variance increases.

We calculated correlations between spawner abundance of Skaha kokanee and other kokanee populations in the Okanagan region (Table 4-6). The highest correlation of 0.41 occurred between Skaha Lake and Wood Lake (Table 4-7). The low correlation is not really surprising given comments by Steve Matthews that historical measurements have been very imprecise. Therefore based on historical data and sampling methods it is unlikely that including a control system will benefit inference based on spawner abundance. It would be worth exploring juvenile and adult datasets for other interior kokanee stocks to see if stronger correlations exist, or if improvements in the precision of spawning counts could be made, which would likely increase correlations. Note that the advantage of correlations between treated and control systems increases more quickly above 0.5 as effect size increases. The results in Figure 4-26 are for the base "true" effect size, which is very small (Table 4-5).

Table 4-6: Okanagan basin kokanee spawner abundance data and summary statistics. Source: Skaha, Wood, Kalamalka: B.C. Ministry of Water, Land, and Air Protection. 2002. Okanagan Kokanee Spawning Summary for 2001; Okanagan Lake: Andrusak et al. 2002 (OLAP Year 6 Report).

	Skaha	Kalamalka	Wood	Okanagan - Mission Creek	Okanagan - stream + channel
1991	2200	55700	1200	11765	75522
1992	3300	26600	3200	25541	64630
1993	2400	13000	2700	9003	30653
1994	16000	39300	5700	3881	16566
1995	7300	28200	12500	6021	10304
1996	9900	24200	17000	7030	22630
1997	800	24800	8200	3422	11935
1998	10600	23300	9900	708	1735
1999	9700	9200	22300	322	1613
2000	12000	19000	12100	7357	24420
2001	11900	20000	7000	4659	38847
Var	24756182	161172727	41254727	48310103	584693667
SD	4976	12695	6423	6951	24180
Mean	7827	25755	9255	7246	27169
CV	0.64	0.49	0.69	0.96	0.89

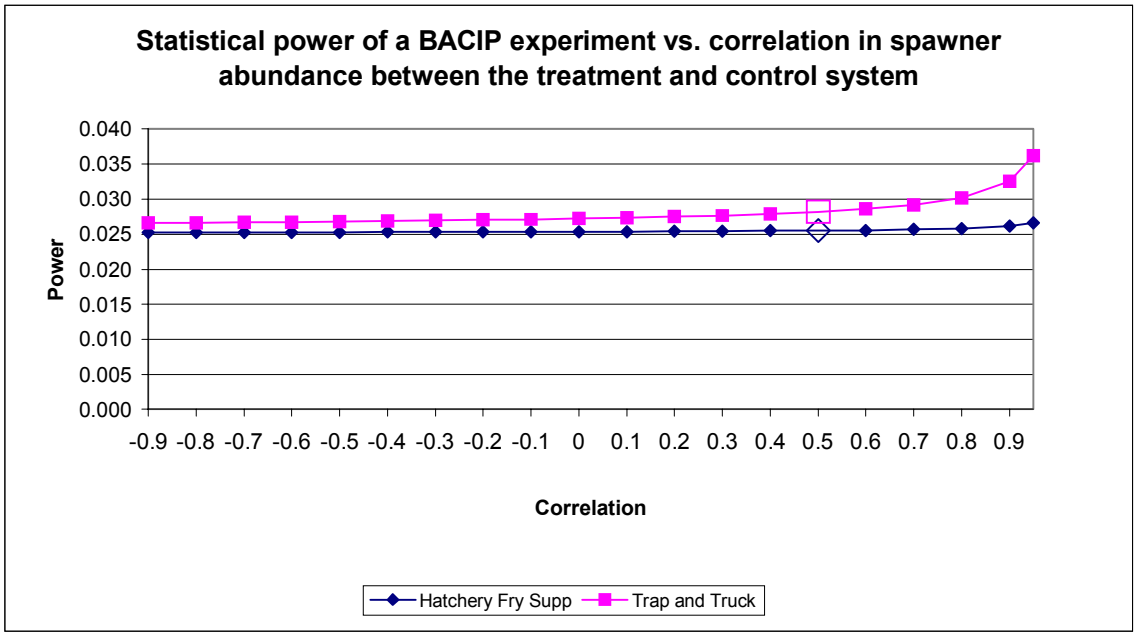


Figure 4-26: Power vs. correlation in kokanee spawner abundance between treatment and control systems. Power is calculated for the Hatchery Fry Supplementation and Trap and Truck experiments. Calculations use the base sample size (n) for spawner abundance and adjust the base variance (SD) results from Table 4-5. $\alpha = 0.05$. Open symbols indicate the base power results from Table 4-5, which occur when the correlation between systems is 0.5.

Table 4-7: Correlation of the Skaha Lake kokanee spawner abundance data with that of other Okanagan basin lakes. Data are presented in Table 4-6.

	Skaha	*Kalamalka*	*Wood*	*Okanagan - Mission Creek*
Kalamalka	-0.13			
Wood	0.41	-0.54		
Okanagan - Mission Creek	-0.46	0.26	-0.53	
Okanagan - stream + channel	-0.43	0.56	-0.68	0.80

5.0 Preliminary Conclusions and Recommendations

5.1 Conclusions from Literature Review

Lake-to-lake comparisons can provide insights on the ability of nerkids and mysids to co-exist, and can form the basis for hypothesising about the factors that determine whether co-existence is likely. While such comparisons are informative, however, there are many confounding factors that need to be considered when drawing conclusions. Examples include habitat alterations and loss, hatchery effects, and changes in lake productivity. Such factors make it difficult to ascribe observed declines in kokanee populations directly to mysids. Still, a more in-depth assessment and comparison of the physical and biological information in lakes with different species compositions would be a useful approach for further exploration of nerkid-mysid interactions.

5.2 Conclusions from Preliminary Analyses

1. The model is able to reproduce the observed geometric mean abundance of Osoyoos Lake sockeye (around 20,000 spawners), though to do so required a relatively high SAR of 2.6%. With mysids present, the Osoyoos population is expected to gradually decline over time.
2. Increasing the density of mysis from $6/m^2$ to about $130/m^2$ (the simulated mysis density in Osoyoos Lake after 25 years) reduces the equilibrium number of sockeye spawners from 20,000 to 6,000 fish.
3. Without mysids present, kokanee in Skaha Lake have an equilibrium population of about 23,000 spawners (age 3 and 4 fish); with mysids, the equilibrium population of kokanee is only 1,500.
4. The modelled fry-to-Age 0 survival rate and adult abundance of kokanee are sensitive to the assumed feeding rate.
5. For kokanee and mysis alone, kokanee performance measures are much more sensitive to uncertainty in the kokanee and mysis feeding rate than mysis.
6. Kokanee are insensitive to high levels of sockeye fry stocking. For simulations including kokanee, sockeye and mysis in combination, survival rate performance measures for all three species were insensitive to the level of fry stocking for densities that ranged from 200-1000 fry/ha.
7. For simulations including kokanee, sockeye and mysis in combination, kokanee were sensitive to mysis, but not sockeye, sockeye were sensitive to both kokanee and mysis, but most sensitive to mysis, mysis were insensitive to both sockeye or kokanee.
8. A variable SAR can improve the performance of the Osoyoos stock relative to its performance under a constant SAR.
9. Skaha Lake can support 80,000 adults kokanee for particular combinations of kokanee habitat area (habitat quantity), egg-to-fry survival rate (habitat quality), and feeding rate (competitive ability). It is believed that Skaha Lake historically supported a population greater than 80,000 adults (e.g., in the late 1960s).
10. Preliminary exploration of the conditions necessary to establish a sockeye stock in Skaha Lake showed that it required a combination of actions including the removal of barriers to upstream migration, the concurrent harvest of mysis in both Osoyoos and Skaha Lake, and a program to trap adults on the Osoyoos spawning grounds and transport them to Skaha Lake.

5.3 Conclusions from Experimental Analyses

1. Hatchery fry supplementation experiment: There was no impact to kokanee or mysis for sockeye fry stocking densities of 200/ha, which effectively quadrupled total fry densities (kokanee + sockeye fry). This is consistent with the results of the preliminary analyses.
2. Hatchery fry supplementation plus mysis harvest: Harvesting mysis in combination with fry supplementation is beneficial for kokanee and sockeye by reducing the strong negative impact mysis competition has on their fry-to-Age 0 and fry-to-smolt survival rates. This allowed the kokanee population to increase and substantially benefited the Osoyoos stock by supplementing it with returning Skaha spawners that could not move upstream to Skaha Lake. The subsequent increase in Osoyoos fry production helped offset the steady decline of the Osoyoos stock over the simulation, more than compensating for earlier broodstock removal.
3. Trap and transport experiment: More adults were required from the Osyoos stock to meet the fry stocking target for this analysis than for the hatchery fry supplementation analysis (3454 vs. 385). This caused the Osoyoos stock to decline more quickly over the simulation period than under hatchery fry supplementation. There was also small decrease in kokanee fry abundance over the treatment period, which may have been due to competition between sockeye and kokanee for spawning habitat.
4. Remove barriers experiment: Results for this analysis were very similar to those for the hatchery fry supplementation experiment. This is probably because in both cases very few spawners were removed from the Osoyoos stock, either deliberately for hatchery broodstock, or by migration to Skaha Lake as conditions permitted.

These results suggests that mysis harvest in combination with hatchery fry supplementation would benefit the Skaha kokanee population, offset sockeye competition impacts, and also benefit the Osoyoos stock. Note that these results do not account for competition between sockeye and kokanee on the spawning grounds (see point 3), which should be explored through additional simulations.

5.4 Conclusions from Power Analyses

Based on the results of our example statistical power analyses, we conclude that:

1. The simple “Before-After” designs we have explored thus far yield statistical power of much less than the commonly applied standard of 0.8. Increasing the experimental period (up to a total of 20 years) cannot rectify this due to the small “true” impact and the asymmetry of the variance in the “Before” and “After” periods. Similar analyses should be done for other, more complicated experiments (e.g., designs that create more temporal contrasts in effects by alternating between different treatments). These example power analyses need to be supplemented by more thorough analyses that simulate the experimental re-introduction many times, to reflect the possible range of natural variation. That would give a more accurate estimate of statistical power.
2. Increasing the level of statistical significance (alpha) will increase power, but will also increase the potential for falsely detecting an effect. The relative costs of falsely detecting a non-existent effect (high alpha, high power) and failing to detect a real effect (low alpha, low power) must be considered when setting alpha levels. The first case is like having a smoke detector that occasionally goes off for no reason; the second case is like having a smoke detector not go off during a real fire.
3. Because we calculated the base results without measurement error (maximum precision), these example estimates of statistical power are likely overestimates. This means that even if monitoring

methods were improved and measurement error decreased (increased precision), it is unlikely that statistical power would attain the 0.8 level. Therefore, if a large-scale lake sockeye re-introduction experiment is to be pursued, it is crucial that managers explore ways to reduce both measurement and process error. While one can't actually reduce the process error of raw indices (it's *natural* variation), one can 'filter it out' with an adequate (i.e. well correlated) control system, and/or by explicitly modelling relationships between driving factors and indices (e.g., density dependent egg-to-fry survival).

4. While the low level of correlation in spawner abundance between Skaha Lake and other Okanagan lakes found here suggests no statistical benefit from including a control lake, kokanee spawner abundance estimates for these systems are highly uncertain. Therefore, it may be worth exploring further the degree to which kokanee spawner abundance is correlated between systems by both looking over a wider range of lakes and also modelling in detail the way that process and measurement error enter into abundance estimates. With more precise measurement methods, it may well be possible to attain correlations greater than 0.5. Additionally, covariation in kokanee survival rates and fry abundance should be evaluated, especially since the kokanee fry-to-Age 0 index had the lower variation of the three explored in this analysis. Finally, while a control lake may not help from a statistical perspective, it can support subjective interpretation of observed changes by controlling for possible confounding from other factors (e.g., unusually dry conditions everywhere that reduce kokanee survival rates and unfortunately coincide with the sockeye re-introduction experiment).
5. Our analysis also suggests that it may be worth evaluating the costs and benefits of pursuing a large-scale experiment relative to directing research efforts on interactions between kokanee, sockeye, and mysis towards smaller scale experiments, where it is possible to exert greater control over variance and confounding (e.g., lake enclosure experiments, Budy et al. 1998). Such experiments, however, also create uncertainty about extrapolating those results to the larger lake system, and generally can only be run for a single season.
6. In general, these example analyses suggest that a well-developed statistical design is needed to ensure that an experimental re-introduction of sockeye salmon will satisfy both learning and conservation objectives. Part of this design will require a more comprehensive statistical power analyses, which would include:
    - an exploration of more complex experimental designs than the simple Before/After design shown here (e.g., an OFF-ON-OFF type design);
    - strategies for reducing process and measurement error (e.g., through alternative monitoring designs);
    - a discussion of an acceptable trade-off between alpha and statistical power;
    - a more comprehensive survey of data for other interior kokanee populations to identify potential control stocks, and an exploration of the potential for improving correlations through better monitoring;
    - an assessment of the feasibility of directed, smaller-scale experiments that could complement the experimental reintroduction; and
    - power analyses for all indices under consideration for sockeye, kokanee, and mysis.

It is worth expanding on this last bullet. Our example power analyses focused on detecting changes in kokanee, but the proper design of the sampling methodology for estimating the SAR for Skaha sockeye will require a similar analysis, which simulates the natural variability in SARs, and the optimal tradeoff between precision of SAR estimates and cost. For example, using external tags on Skaha hatchery raised fry would increase initial costs, but save money later by making the identification of returning Skaha

spawners easier and so reducing the number of spawners that need be taken for otolith analysis. A key question, then, is how many Skaha spawners need to be counted in different years to get sufficiently precise SAR estimates?

Finally, it is important to remember that different design questions need to be answered depending on the purpose of monitoring a particular index. For example, in our example hatchery experiment, estimating the sockeye fry-to-smolt survival rate is a precision question: how intensive should sampling be to produce sufficiently precise estimates of the survival rate? For kokanee fry-to-Age 0, it is an impact question: what level of sampling will allow detection of a change of a particular magnitude with high power? For other types of experiments, the questions may change. For example, when combining fry introduction with mysis harvest in a sequential experiment (e.g., before monitoring of current system, followed by sockeye fry introduction for X years, then mysis harvest and fry introduction for Y years), it also becomes important to be able to detect changes in the sockeye fry-to-smolt survival rate. Although precision and power are related (increased precision increases power) the precision sufficient for estimating survival may not be sufficient for powerful tests of hypotheses.

6.0 References

Andrusak, H., S. Matthews, I. McGregor, K. Ashley, G. Wilson, D. Sebastion, G. Scholten, L. Vidmanic, J. Stockner, K. Hall, G. Andrusak, J. Sawada, D. Cassidy, and J. Webster. 2001a. Okanagan Lake Action Plan Year 5 (2000). Fisheries Project Report RD 89. Fisheries Management Branch, Ministry of Water, Land and Air Protection, Province of British Columbia, Victoria.

Andrusak, H., S. Matthews, I. McGregor, K. Ashley, G. Wilson, L. Vidmanic, J. Stockner, D. Sebastian G. Scholten, P. Woodruff, D. Cassidy, J. Webster, K. Rood, A. Kay. 2002. Okanagan Lake Action Plan Year 6 (2001) Report with reference to results from 1996-2001. B.C. Ministry of Water, Land, and Air Protection. Fisheries Project Report No. RD 96.

Andrusak, H., R. Pieters, A. Eskooch, S. Harris, G. Wilson, D. Dolecki, D. Sebastion, G. Scholten, P. Woodruff, B. Lindsay, and M. Young. 2001b. Slocan Lake Limnology and Trophic Status (2000/2001) Year 1 Report, Draft. Redfish Consulting Ltd., Nelson.

Ashley, K., I. McGregor, B. G. Shepherd, D. Sebastion, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P. Troffe, C. Wong, G. Scholten, M. P. Zimmerman, P. Epp, V. Jensen, and R. Finnegan. 1999a. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. RD 78. Fisheries Branch, Ministry of Environment, Lands and Parks, Province of British Columbia.

Ashley, K., B. G. Shepherd, D. Sebastion, L. Thompson, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, R. Nordin, D. Lasenby, J. Quirt, J. Whall, P. Dill, E. Taylor, S. Pollard, C. Wong, J. den Dulk, and G. Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98). Fisheries Project Report RD 73. Fisheries Branch, Ministry of Environment, Lands and Parks, Province of British Columbia, Victoria.

Ashley, K., and L. Thompson. 1993. Kootenay Lake Fertilization Experiment - Year 1 (1992/93) Report. Fisheries Project Report No. RD 32. Fisheries Branch, Ministry of Environment, Lands and Parks, Province of British Columbia.

Ashley, K., L. Thompson, D. Lombard, Y. Ying-Rong, F. Pick, P. Hamilton, D. Lasenby, K. E. Smokorowski, D. Sebastion, and G. Scholten. 1999b. Kootenay Lake Fertilization Experiment - Year 5 (1996/97) Report. Fisheries Project Report No. RD 65. Fisheries Branch, Ministry of Environment, Lands and Parks, Province of British Columbia.

Beattie, W. D., and P. T. Clancey. 1991. Effects of Mysis relicta on the Zooplankton Community and Kokanee Population of Flathead Lake, Montana. Pages 39-48 in T. P. Nesler, and E. P. Bergersen, editors. Mysids in Fisheries: Hard lessons from headlong introductions. American Fisheries Society Symposium 9.

Bowles, E. C., B. E. Rieman, G. R. Mauser, and D. H. Bennett. 1991. Effects of Introduction of Mysis relicta on Fisheries in Northern Idaho. Pages 65-74 in T. P. Nesler, and E. P. Bergersen, editors. Mysids in Fisheries: Hardlong Lessons From Headlong Introductions. American Fisheries Society Symposium 9.

Bradford, M.J. 1995. Comparative review of Pacific salmon survival rates. Can. J. Fish. Aquat. Sci. 52: 1327-1338.

Budy, P., C. Luecke and W.A. Wurtsbaugh. 1998. Adding nutrients to enhance the growth of endangered sockeye salmon: trophic transfer in an oligotrophic lake. Transactions of the American Fisheries Society 127(1): 19-34.

Clarke, L.R. and D.H. Bennett. 2002. Newly Emerged Kokanee Growth and Survival in an Oligotrophic Lake with Mysis relicta. Transactions of the American Fisheries Society 131:176-185.

Cohen, J. 1988. Statistical power analysis for the behavioural sciences. 2nd Edition., Lawrence Erlbaum Associates., Hillsdale, N.J.

Cooper, K. 1988. Interactions among Neomysis mercedis populations, zooplankton community structure, and lake fertilization. Page 132. Biological Sciences. Simon Fraser University, Burnaby.

Deriso, R.B., D.R. Marmorek, and I.J. Parnell. 2001. Retrospective Patterns of Differential Mortality and Common Year Effects Experienced by Spring Chinook of the Columbia River. Can. J. Fish. Aquat. Sci. 58(12) 2419-2430

ESSA Technologies Ltd. 2002a. USFWS Bull Trout Workshop; Oct. 31 2001 to Nov. 1 2001; Welches, OR http://pacific.fws.gov/crfpo/pdfdocs/conservation/BullTroutWorkshopReport.pdf

Fryer, K.K. 1995. Columbia Basin Sockeye Salmon: Causes of their past decline, factors contributing to their present low abundance, and the future outlook. Ph.D. Thesis, university of Washington.

Hyatt, K. D., and D. P. Rankin. 1999. A Habitat Based Evaluation of Okanagan Sockeye Salmon Escapement Objectives. Canadian Stock Assessment Secretariat 99:59pp.

Kay, A.S. 2002. Mysis relicta and kokanee salmon (Oncorhynchus nerka) in Okanagan Lake, British Columbia: From 1970 and into the future. M.Sc. Thesis, University of British Columbia.

Lasenby, D., T. Northcote, and M. Furst. 1986. Theory, practice and effects of Mysis relicta introductions to North American and Scandinavian lakes. Canadian Journal of Fisheries and Aquatic Sciences 43:1277-1284.

Lindley, S.T., M. Mohr, and M. H. Prager. 2000. Monitoring protocol for Sacramento River winter chinook salmon, *Oncorhynchus tshawytscha*: Application of statistical power analysis to recovery of an endangered species. Fishery Bulletin (Seattle) 98(4): 759-766.

Mauchline, J. 1980. The biology of mysids and euphausids. Advances in Marine Biology 18.

Northcote, T. 1973. Some Impacts of Man on Kootenay Lake and its Salmonids. Great Lakes Fishery Commission Technical Report No. 25.

Northcote, T. 1991. Success, Problems, and Control of Introduced Mysid Population in Lakes and Reservoirs. Pages 5-16 in T. P. Nesler, and E. P. Bergersen, editors. Mysids in Fisheries: Hard lessons from headlong introductions. American Fisheries Society Symposium 9.

Okanagan Nation Fisheries Commission. 2002. Evaluation of an Experimental Reintroduction of sockeye salmon into Skaha Lake (Year 2 of 3) Draft Reports. Prepared by Okanagan Nation Fisheries Commission. February 28, 2002.

Parnell, I.J. 2002. Use of decision analysis to design a habitat restoration experiment. Master's Thesis. School of Resource and Environmental Management, Simon Fraser University, Burnaby B.C. 65 pp.

Peterman, R. M. 1990. Statistical power analysis can improve fisheries research and management. Can. J. Fish. Aquat Sci. 47: 2-15.

Peters, C.N., D.P. Bernard and D.R. Marmorek. 1998. Should sockeye be re-introduced to Okanagan Lake? An exploration of potential benefits, impacts and uncertainties. Prepared by ESSA Technologies Ltd., Vancouver, BC for Participants of the Okanagan Sockeye Workshop (hosted by the Okanagan Nation Fisheries Commission). 50pp.

Peters, C.N. and D.R. Marmorek. 2003. OkSockeye: A Simple Life-cycle Model of Okanagan Basin Sockeye Salmon Version 2.2 Design Document February 14, 2003

Pieters, R., L. Thompson, L. Vidmanic, S. Pond, J. Stockner, P. Hamblin, M. Young, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastion, G. Scholten, and D. Lombard. 1998. Arrow Reservoir Limnology and Trophic Status - Year 1 (1997/1998) Report. Fisheries Project Report RD 67, Victoria.

Pieters, R., L. Thompson, L. Vidmanic, M. Roushorne, J. Stockner, K. Hall, M. Young, S. Pond, M. Derham, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastion, G. Scholten, F. McLaughlin, A. Wuest, A. Matzinger, and E. Carmack. 1999. Arrow Reservoir Limnology and Trophic Status Year 2 (1998/1999) Report. Fisheries Project Report Number RD 72, Victoria.

Pinsent, M. E., J. Stockner, T. Northcote, S. MacDonald, B. St. John, J. Blanton, H. Ng, D. Williams, A. Lerman, K. Patalas, O. Saether, M. McLean, and A. Salki. 1974. The Limnology of the Major Okanagan Basin Lakes. Page 261. Canada-British Columbia Okanagan Basin Agreement, Victoria.

Richards, R., C. R. Goldman, E. Byron, and C. Leviton. 1991. The Mysids and Lake Trout of Lake Tahoe: A 25-Year History of Changes in the Fertility, Plankton, and fishery of an Alpine Lake in T. P. Nesler, and E. P. Bergersen, editors. Mysids in Fisheries: Hard Lessons from Headlong Introductions. American Fisheries Society, Symposium 9.

Shrader-Frechette, K.S., and E.D. McCoy. 1992. Statistics, costs and rationality in ecological inference. Trends in Ecology and Evolution 7: 96-99.

Shepherd, B.G. 1993. Mysis surveys on Okanagan and Skaha Lakes,1992. Memo to C. Bull (Fisheries Section Head) dated July 23, 1993 (File: 34030-20)

Stewart-Oaten, A., W. M. Murdoch, and K.R. Parker. 1986. Environmental impact assessment: "Pseudoreplication" in time? Ecol. 67: 929-940.

Walters, C.J. and R. Green. 1997. Valuation of experimental management options for ecological systems. J. Wildl. Manage. 61(4): 987-1006.

Wright, R.H. 2001. Assessment of Juvenile Sockeye/Kokanee Rearing Capacity of Okanagan Lake, Skaha Lake, Vaseux Lakes and Osyoos Lake in H. D. Smith, editor. Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake, Year 2 of 3. Okanagan Nation Fisheries Commission, Westbank.

Appendix A: Information Requests Assigned at Hypothesis Workshop in October 2002

The following list of information requests was distributed on October 22, 2002, with a request to send the information by November 15th. ✔indicates information received by ESSA as of February 14, 2002; if no ✔ appears, the information is still outstanding; a □ indicates partial information received. High (H) priority items have been included or considered in this report.

Priority	Information Needs	Responsibility/Status
H	Estimates of juvenile sockeye densities in Osoyoos Lake	Kim
H	Estimate of Osoyoos stock SAR (from CNAT)	Kim
H	Time series of Barkley Sound SARs (to get sequential variation around mean SAR for Osoyoos)	Kim ✔
L	Other CNAT data	Kim □ *(version 1 only)*
H	Summary info on TP and fish status of coastal vs. interior lakes to illustrate how higher trophic status enables sockeye and kokanee to co-exist	Kim □ *(qualitative summary of data received)*
H	Reasonable range of assumptions for egg to fry survival in sockeye hatcheries	Kim ✔
H	Shepherd (1993) memo on *Mysis* in Skaha Lake	Howie ✔
H	Compile literature for synoptic survey of mysid/kokanee interactions in other systems to assess ability of KOK to sustain healthy populations in presence of mysids. (e.g., Kootenay, Arrow, Slocan, Flathead, Wood, Kalamalka, etc.)	Howie (to do preliminary synthesis) ✔
L	Okanagan Lake - time series of TP (check if already on Ken Hall CD), acoustic trawl and spawning kokanee #s from WLAP database (for exploratory test of limnetic interactions of SK and KOK)	Steve
L	Okanagan Lake - estimates of the area of kokanee spawning habitat for Okanagan Lake. *{Howie's estimate of habitat for kokanee and sockeye: 90 km of beach spawning habitat * 2m band of suitable depths = 180,000 m^2)*	Steve and Howie? □
L	Area of Okanagan :Lake spawning habitat potentially available to sockeye (Cecilia Wong report) *{Howie noted that required information is not in Cecilia Wong report; use above estimate for sockeye and kokanee}*	Howie to send □
L	Historical habitat area in Okanagan River above Skaha Lake and potential area of restored habitat	Howie (contact Marc Gaboury @ LGL)
Baseline information for Skaha Lake for detecting impacts of reintroduction on other ecosystem components:		
H*	Any other data on mean sizes of Ages 0, 1, 2, 3, 4 KOK from recent sampling in Skaha Lake • within year and between year variation in these sizes (i.e., coefficient of variation)	Howie & Steve ✔
M	existing survival estimates of year classes of KOK (Eric Parkinson) + new information from any recent sampling (model used default values drawn from LLKM model). *Howie confirmed that best available information is what is in LLKM model; no better estimates are available.*	Howie ✔
M**	15 years of Skaha KOK spawning abundance and distribution (if possible with a rough estimate of bias and precision)	Steve ✔

Priority	Information Needs	Responsibility/Status
H	5 years of Skaha juvenile KOK density estimates from acoustic trawl (and estimate of bias and precision) *Only have estimates of total limnetic fish; has not yet been apportioned between species.*	Kim
H	5 years of Skaha mysid densities (and estimate of bias and precision) *Densities about 150 to 250 /m2 in mid to late summer (sub-adults + surviving adults)*	Kim □
M	Summary of frequency and methods of past sampling for Skaha zooplankton) (Vic Jenson; Kim since 1997) and other explanatory variables (e.g., O2 and temp)	Kim and Howie

* We already have a spreadsheet from Steve Mathews with trawl data for 1992, 38 fish (ages 0,1 and 2), Okanagan R. data for 1987 to 1992, 540 fish (ages 2 and 3), and dip net samples from Okanagan R. channels from 1996 to 2001 (just lengths and weights, no ages). Anything else?

** We have data from 1991 on.

ESSA Model development/analyses tasks (all High priority tasks have been completed):

Priority	Task
Model development (model, interface, database)	
L	flag 'back-mapped' data in database/interface (show in different colour on GUI, in-EXCEL)
L	flag parameters that need to be changed as a group
L	new temperature/migration rule, 'If time to peak spawning is <= X days, stay where you are and spawn.'
H	run model to trap and truck fixed # of Skaha adults from Osoyoos stock, or to stock fry (i.e., simulate expt. described under re-introduction slides above). Under latter, need to prevent adult upstream migration
L	develop appropriate scaling for strength of competition across range of biomass, or trophic state {defer}
H	add array of year-specific variation around mean SAR (e.g. 1971: +1.2; 1972: 0.8…) based on Barkley Sound SARs
H	add array of fry additions for each year of experiment (e.g., year 1:0, year 2: 0; year 3:200,000; year 4:400,000)
H	compute # females required from Osoyoos Stock (i.e., #fry / (0.75 egg to fry survival * # average eggs / female) and subtract these females from Osoyoos stock
M	add in array of mysid harvest rates for each year of experiment (e.g., year 1: 0; year 2:0; year 3: 0; year 4: 0.5)
Model development (output): [output to EXCEL template to help people interpret results for both Osoyoos and Skaha]	
H	Show cumulative graph over time of lake total rearing capacity (TotalCap in kg/ha), with bands underneath showing actual production of SK, KOK, mysids, unallocated prodn (kg/ha)
H	Show graph over time of egg-fry survival rate (will be constant for Skaha if in hatchery), fry-smolt survival rate (show Skaha vs Osoyoos), SAR for both stocks (will be the same for now, but we might want to add a simple relationship in which mean SAR is proportional to size, which will favour Osoyoos)
H	show fry to age 0 survival for KOK
Model analyses	
H	compare base runs to runs using new SAR time-series
H	Skaha Lake: How many fry can be introduced before there is an impact to the kokanee population? (as # fry/ha), re expt design - explore different mixes of SK fry and mysid densities for the experiment, assuming current KOK densities.
M	Need to have enough fry to have measurable outputs; determine when effects occur. Need to design expt. so that output can be used to better parameterize the model...
H	Skaha: could you maintain 80,000 KOK with more & better habitat, no mysids; and then w mysids included…
L	Okanagan Lake - how many sockeye fry to impact kokanee? (back calculate to sockeye adults), compare to fry estimates based on area of potential spawning habitat.

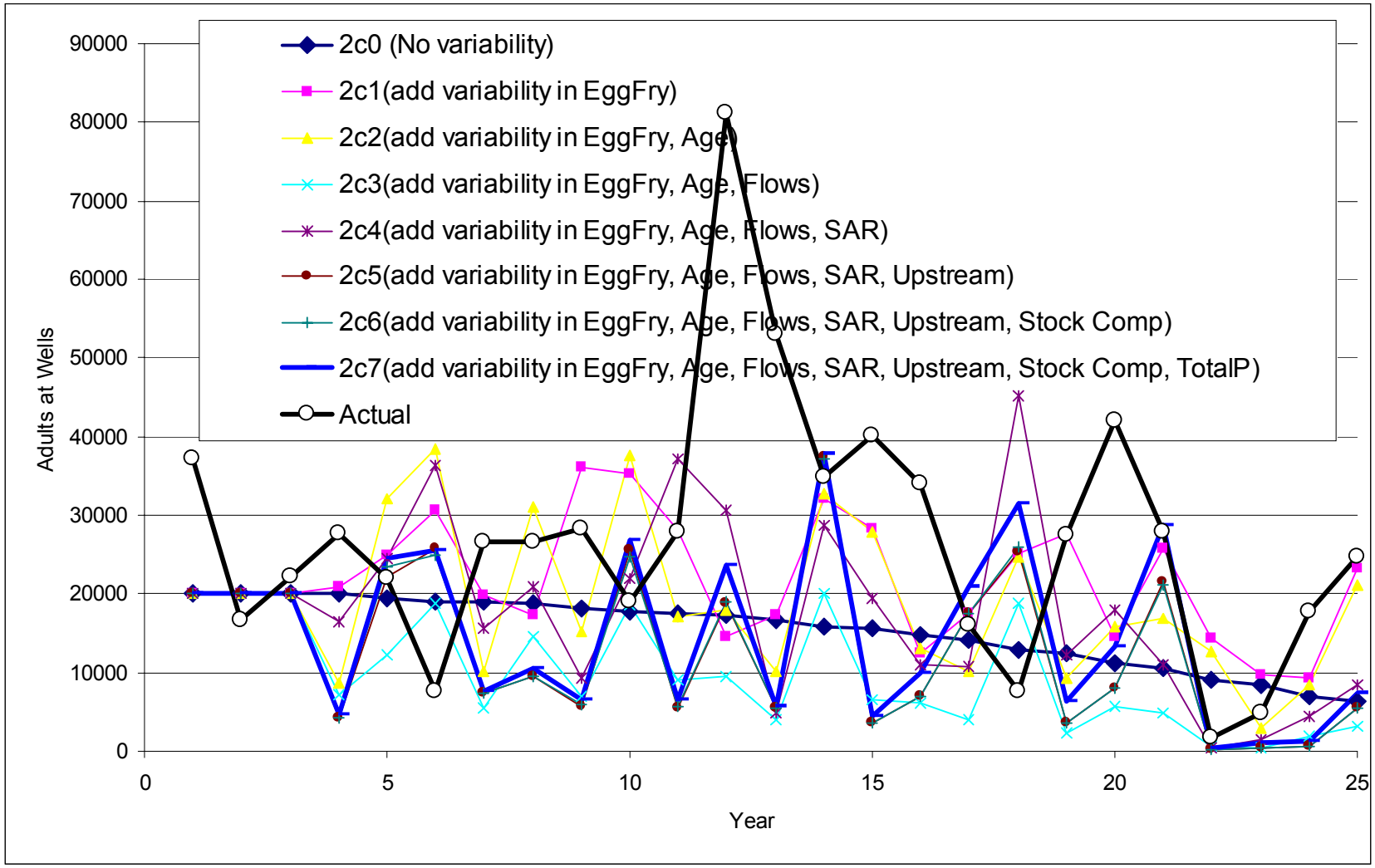
Appendix B: Detailed Model Results

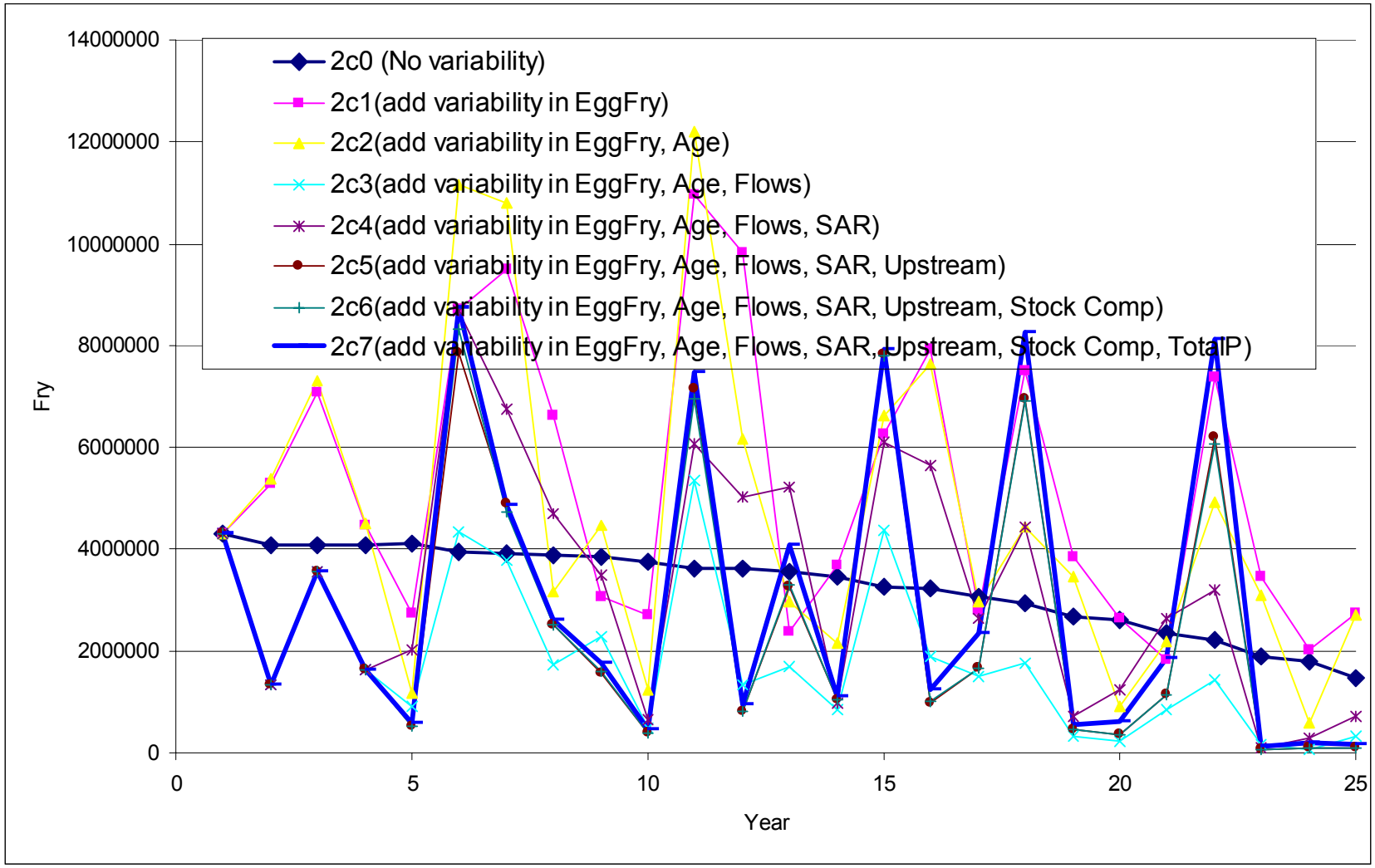
In this appendix, we provide more detailed results from the equilibrium modelling results described in *Section 4.3: Preliminary analysis*. We provide a table of model definitions, and a series of graphs showing the results.

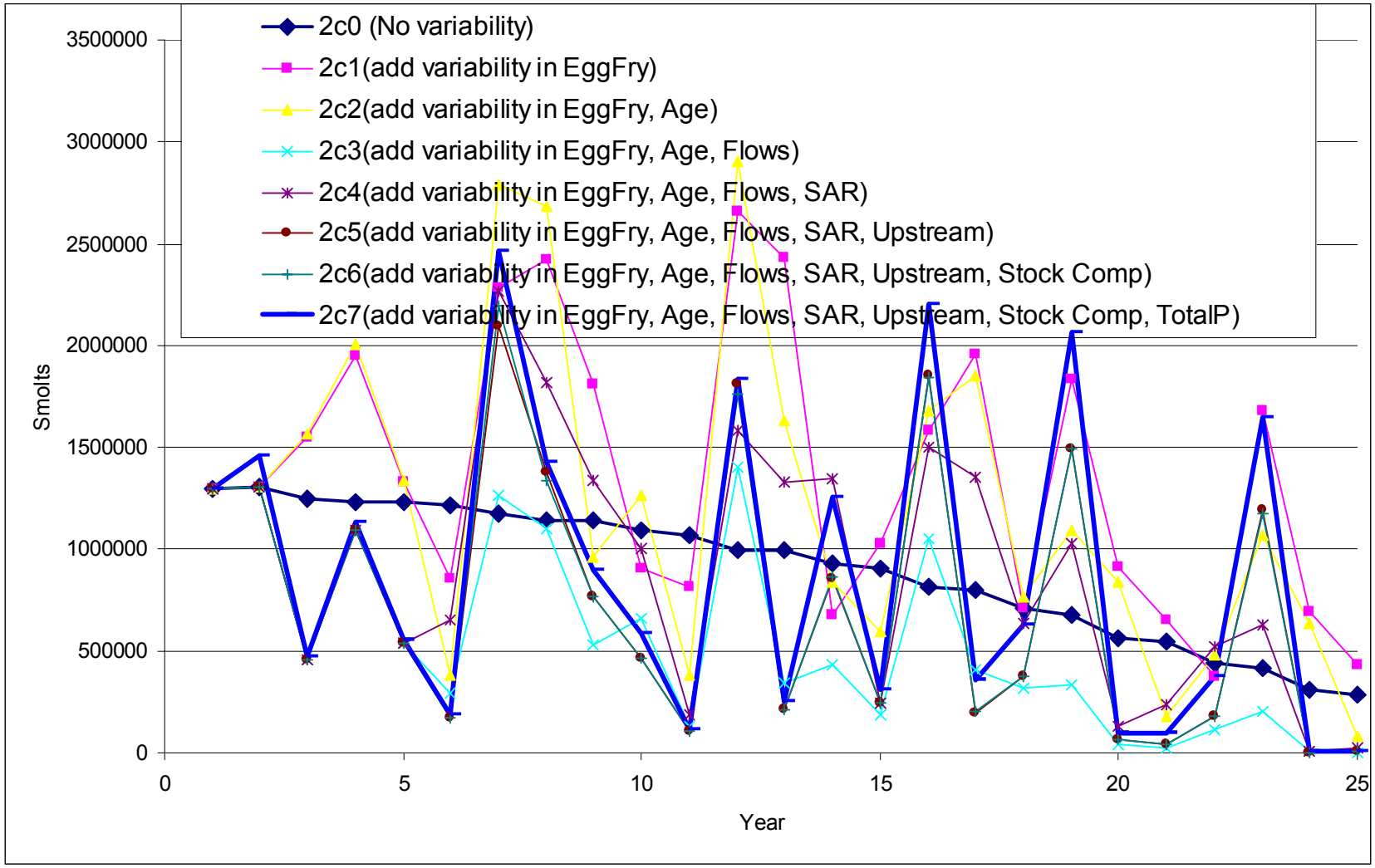
Table B-1: Summary of model runs for sockeye equilibrium analysis (Osoyoos Lake only).

Run #	Initial Mysid Density	SAR	Model Factors		Run Info
			Not variable	Variable	
1	0	2.65%		• Sockeye egg-fry survival rate • Sockeye age structure • Annual mean, maximum flows during spawning and incubation • SAR • Sockeye upstream survival rate • Okanagan/Wenatchee sockeye proportions • Total Phosphorus concentration	RunID: 157; Dec. 16/02; OkSockeye(Report).mdb
2a	0	2.65%	• Egg-fry survival rate • Age structure • Annual mean, maximum flows during spawning and incubation • SAR • Upstream survival rate • Okanagan/Wenatchee proportions • Total Phosphorus concentration		RunID: 159; Dec. 16/02; OkSockeye(Report).mdb
2b	6/m^2	2.65%		• Egg-fry survival rate • Age structure • Annual mean, maximum flows during spawning and incubation • SAR • Upstream survival rate • Okanagan/Wenatchee proportions • Total Phosphorus concentration	RunID: 160; Dec. 16/02; OkSockeye(Report).mdb
2c-0	6/m^2	2.65%	• Egg-fry survival rate • Age structure • Annual mean, maximum flows during spawning and incubation • SAR • Upstream survival rate • Okanagan/Wenatchee proportions • Total Phosphorus concentration		RunID: 176; Dec. 17/02; OkSockeye(Report).mdb

Run #	Initial Mysid Density	SAR	Model Factors		Run Info
			Not variable	Variable	
2c-1	6/m^2	2.65%	• Age structure • Annual mean, maximum flows during spawning and incubation • SAR • Upstream survival rate • Okanagan/Wenatchee proportions • Total Phosphorus concentration	• Egg-fry survival rate	RunID: 161; Dec. 17/02; OkSockeye(Report).mdb
2c-2	6/m^2	2.65%	• Annual mean, maximum flows during spawning and incubation • SAR • Upstream survival rate • Okanagan/Wenatchee proportions • Total Phosphorus concentration	• Egg-fry survival rate • Age structure	RunID: 170; Dec. 17/02; OkSockeye(Report).mdb
2c-3	6/m^2	2.65%	• SAR • Upstream survival rate • Okanagan/Wenatchee proportions • Total Phosphorus concentration	• Egg-fry survival rate • Age structure • Annual mean, maximum flows during spawning and incubation	RunID: 171; Dec. 17/02; OkSockeye(Report).mdb
2c-4	6/m^2	2.65%	• Upstream survival rate • Okanagan/Wenatchee proportions • Total Phosphorus concentration	• Egg-fry survival rate • Age structure • Annual mean, maximum flows during spawning and incubation • SAR	RunID: 172; Dec. 17/02; OkSockeye(Report).mdb
2c-5	6/m^2	2.65%	• Okanagan/Wenatchee proportions • Total Phosphorus concentration	• Egg-fry survival rate • Age structure • Annual mean, maximum flows during spawning and incubation • SAR • Upstream survival rate	RunID: 173; Dec. 17/02; OkSockeye(Report).mdb
2c-6	6/m^2	2.65%	• Total Phosphorus concentration	• Egg-fry survival rate • Age structure • Annual mean, maximum flows during spawning and incubation • SAR • Upstream survival rate • Okanagan/Wenatchee proportions	RunID: 174; Dec. 17/02; OkSockeye(Report).mdb
2c-7	6/m^2	2.65%		• Egg-fry survival rate • Age structure • Annual mean, maximum flows during spawning and incubation • SAR • Upstream survival rate • Okanagan/Wenatchee proportions • Total Phosphorus concentration	RunID: 175; Dec. 17/02; OkSockeye(Report).mdb


2c0 (No variability)
2c1(add variability in EggFry)
2c2(add variability in EggFry, Age)
2c3(add variability in EggFry, Age, Flows)
2c4(add variability in EggFry, Age, Flows, SAR)
2c5(add variability in EggFry, Age, Flows, SAR, Upstream)
2c6(add variability in EggFry, Age, Flows, SAR, Upstream, Stock Comp)
2c7(add variability in EggFry, Age, Flows, SAR, Upstream, Stock Comp, TotalP)
Actual
Adults at Wells
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0
5
10
15
20
25
Year


14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
Fry
0
5
10
15
20
25
Year
2c0 (No variability)
2c1(add variability in EggFry)
2c2(add variability in EggFry, Age)
2c3(add variability in EggFry, Age, Flows)
2c4(add variability in EggFry, Age, Flows, SAR)
2c5(add variability in EggFry, Age, Flows, SAR, Upstream)
2c6(add variability in EggFry, Age, Flows, SAR, Upstream, Stock Comp)
2c7(add variability in EggFry, Age, Flows, SAR, Upstream, Stock Comp, TotalP)


2c0 (No variability)
2c1(add variability in EggFry)
2c2(add variability in EggFry, Age)
2c3(add variability in EggFry, Age, Flows)
2c4(add variability in EggFry, Age, Flows, SAR)
2c5(add variability in EggFry, Age, Flows, SAR, Upstream)
2c6(add variability in EggFry, Age, Flows, SAR, Upstream, Stock Comp)
2c7(add variability in EggFry, Age, Flows, SAR, Upstream, Stock Comp, TotalP)
Smolts
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0
5
10
15
20
25
Year

Appendix C: OkSockeye Version History

Version	Date	Major Revisions	Comments
1.0	Jun 19, 2002	• Prototype; design as described in June 19th 2002 model Design Document.	• Public release June 19, 2002 • demonstrated Oct 15, 2002
2.0	Dec 4, 2002	• Added annual SAR year effects based on Barkley Sound coho SARS • Updated water temperature functions and parameter values to be consistent with FWMT assumptions (Hyatt and Stockwell 2002) • Updated sockeye model parameters using escapement, harvest, age data in CNAT v. 1.0 (Hyatt et al. 2002)	• Internal release
2.1	Dec 9, 2002	• Added annual fry supplementation schedule • Added annual adult supplementation schedule • Added SAR and production information to Excel Report	• Internal release
2.1.1	Dec 12, 2002	• Corrected minor bugs related to upstream survival (only had an effect on very large sockeye escapement values) • Minor enhancements to data edit screens	• Internal release
2.1.2	Dec 17, 2002	• Allow working with different databases • Minor enhancements to user interface (Run listbox and Save As dialog boxes) • Revise scour relationships to be consistent with Summit (2002) • Improved efficiency of initialisation	• Internal release • used to generate results in Jan 8 2003 Experimental Design Report • demonstrated Jan 16, 2003
2.2	Jan 23, 2003	• Revised approach to computing total Okanagan + Wenatchee adult returns • Design as described in January 30 2003 Design Document	• Public release Jan 30, 2003 • used to generate results in February, 2003 Experimental Design Report

FINAL

OBJECTIVE 6
An Evaluation of a Proposed Experimental Reintroduction of Sockeye Salmon into Skaha Lake:
Project Summary 2000-2003

Contribution No. *14* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

Presented to: Colville Confederated Tribes

Date: May 31, 2003

Author: Howard Smith

An Evaluation of a Proposed Experimental Reintroduction of Sockeye Salmon into Skaha Lake: Project Summary 2000-2003

by

Howard D. Smith

Prepared for the Okanagan Nation Fisheries Commission

May 31, 2003

EXECUTIVE SUMMARY

The Okanagan stock is one of only two surviving sockeye salmon populations of the Columbia River. While the true size of its escapement in early times is not known, it may have been of considerable size in Okanagan L. and environs, but it has clearly been declining for many years (except for two good returns in 2000 and 2001) and has recently been reduced to an average annual escapement of about 20,000 fish at Wells Dam, where pre-spawners are enumerated before entering the Okanogan River.

Nine large hydroelectric dams on the Columbia R., and several smaller barrier dams on the Okanagan, along with changing environmental conditions have no doubt been instrumental in causing the population decline. McIntyre Dam below Vaseux L., British Columbia is a significant barrier as it has limited upstream migrations of sockeye since its installation in 1921 and it figures prominently in current Okanagan sockeye management decisions.

The Okanagan Nation Fisheries Commission (ONFC), and the Colville Confederated Tribes (CCT) have advocated restoration of the run to upstream areas of the basin, and with assistance from federal and provincial agencies and elsewhere, and financial support from the Bonneville Power Administration, they have undertaken investigations and coordinated inputs to evaluate possible reintroduction methods.

A major concern has been an apparent deterioration in the juvenile rearing area (now existing only in the north basin of Osoyoos Lake), and a team of investigators has concluded that development of a second, or backup rearing area is needed. Sighting on large Okanagan L. as a possible future target, they nevertheless chose the interim goal of an experimental introduction of sockeye to Skaha L., downstream from it and the third year of work to that end has now been completed

The researchers wanted a program which would not adversely affect valued resident species – particularly kokanee; one which could if necessary be discontinued without adverse effect; and one which would reveal the nature and magnitude of any risks associated with sockeye reintroduction to Okanagan L. in future.

The work has been driven by six objectives, and after three years of widely based and intensive investigation, these and interim results and conclusions are as follows:

> Obj.1: Assess the risk of disease transmission from reintroduced sockeye to resident fishes: Conclusion – at this time there is no evidence of serious risk, though recent discovery of a parasite, *Parvicapsula*, (new to the drainage) may oblige investigators to take it into account when designing reintroduction methods and monitoring.

Obj.2: Assess the risk of introducing exotic fish species to upstream waters. (i.e. above McIntyre Dam): Conclusion – Concerns are now largely limited to walleye which is at present believed to be restricted to U.S. waters.

Obj.3: Determine whether spawning and incubation areas are likely to be limiting for introduced sockeye: Conclusion – Spawning areas are sufficient for current population levels, and there is potential to increase them. New areas will almost certainly be needed in the Okanagan R. above Skaha L. eventually.

Obj 4: Develop a life cycle model: Result – A model has been developed, and found useful for a range of applications, and it has significantly improved understanding of stock dynamics and interactions with other fishes.

Obj.5: Evaluate options for an experimental reintroduction: Result – Three options have been analyzed and a first choice has been made, wherein egg takes, with hatchery incubation and fry plants would be conducted over several years.

Obj.6: Finalize a plan for an experimental reintroduction: Result - At a program review held Mar 5, 2003, most participants appeared to agree that fry plants should be the first choice, though further review may be needed as proposed implementation and monitoring plans unfold.

Research results also showed that the Osoyoos L. rearing area is currently restricted by temperature and oxygen limitations to a 3m deep vertical band of water termed a "zone of tolerance," for young sockeye. In addition the opossum shrimp *Mysis relicta*, found to be a serious competitor for food with salmonids elsewhere, may be affecting salmonid food supplies in Osoyoos, and possibly Skaha and other lakes of the Okanagan Basin. These ecological pressures may be increasing and if so they could have serious consequences for the stock.

There are no historical records of sockeye stock performance or behaviour in the upper part of the Okanagan drainage, so fish imported from the downstream components of the population will need to be monitored carefully to determine how they will respond to Skaha L. rearing conditions.

Progress to date has not revealed factors which should preclude a successful reintroduction to Skaha L. However as some questions remain unanswered, a two-track implementation program may be desirable. This would reestablish the population in Skaha and at the same time determine how widely, and with what success returning fish will again utilize the river above McIntyre Dam when it is removed or breached.

Because of the declining stock numbers and concerns about possible further habitat degradation, these initiatives should be undertaken without delay. There is a considerable body of evidence presented by independent scientists to suggest that failure to act promptly could seriously jeopardize the run. The two large escapements (2000 and 2001)

could return enough fish, and provide the best opportunity for some time, to make substantial progress toward desired goals (i.e. in 2003-2005).

Participating government agencies are contributing indispensable research results, as well as participating in program planning and evaluation. It will be important to know as early as possible their availability during the next phase.

Furthermore, the fact that reproduction and early stages of Okanagan sockeye production (spawner to smolt) occur in Canada, and most of the fresh water migration (smolt to adult return) occurs in the United States underscores the importance of continuing effective across-border cooperation as the run recuperates.

Comprehensive planning is needed now to ensure both effective and efficient use of human and material resources and a number of specific actions are recommended.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
TABLE OF CONTENTS iv
PREFACE v
1. INTRODUCTION 1
2. LIFE STANZAS AND HAZARDS 1
3. DEVELOPING A PLAN 4
4. INVESTIGATIONS TOWARD A REINTRODUCTION INTO SKAHA LAKE 5
4.1. Objectives 5
4.1.1 Risk of Disease (Obj.1). 5
4.1.2 Risk From Exotic fishes (Obj. 2) 6
4.1.3 Habitat Inventory and Enhancement Opportunities (Obj. 3). 6
4.1.3.1 Limnology and the Osoyoos Lake Zone of Tolerance 7
4.1.3.2 Mysis relicta 8
4.1.4 Develop a Life Cycle Model (Obj. 4) 8
4.1.4.1 Modeling of Reintroduction Options 8
4.1.4.2 Effect of fry density 9
4.1.4.3 Kokanee increases 9
4.1.4.4 Other preliminary conclusions 10
4.1.5 Methods of Reintroduction 10
4.1.5.1 Options 10
4.1.5.2 Criteria for Success 10
5. SYNTHESIS OF RESULTS AND SOME SUGGESTIONS FOR THE FUTURE 12
5.1. Behavioural Issues 13
5.2. Need for a Two-Track Approach. 15
5.3. Agency Participation. 15
6. RECOMMENDATIONS 16
7. LITERATURE CITED 17

PREFACE

The purpose of this paper is to outline features of the Okanagan River sockeye salmon (*Oncorhynchus nerka*) population which have been presented at workshops or cited in Documents and Annual Reports of the Okanagan Nation Fisheries Commission, and to consider how initiatives now under way might be successfully completed. The author wishes to acknowledge the range of technical literature and original work by many investigators, some of whom may not have been cited here in the most deserving manner, and also to thank the Okanagan Nation Fisheries Commission staff and their collaborators for making these data available. To those individuals who read the draft manuscript and provided valuable comments and suggestions, many thanks.

1. INTRODUCTION

The Columbia River sockeye salmon population, of which the Okanagan stock is a part, may have numbered in excess of 4 million fish around the end of the 20th century (Fryer 1995). Since then it has been decimated by a combination of man-made and natural events such that the commercial catch, probably once well over one million fish, has been reduced to a few thousands in recent decades. Only the Okanagan stock and the Wenatchee stock in Washington State remain from the many sockeye stocks which propagated in the Columbia River Basin in early times.

2. LIFE STANZAS AND HAZARDS

The Okanagan population spawns in October, primarily in a 6 km stretch of the Okanagan River north of the town of Oliver, British Columbia (Fig 1), and about 900 km from the estuary. The vulnerable fry emerge in early spring and migrate or are carried downstream about 20km to Osoyoos Lake where they feed and grow exclusively in the northernmost lake basin until the following spring when as smolts they resume their journey south to the Columbia R. and thence to the sea. Mature fish usually return to the Columbia R. in their fourth year of age - after a little more than 24 months at sea.

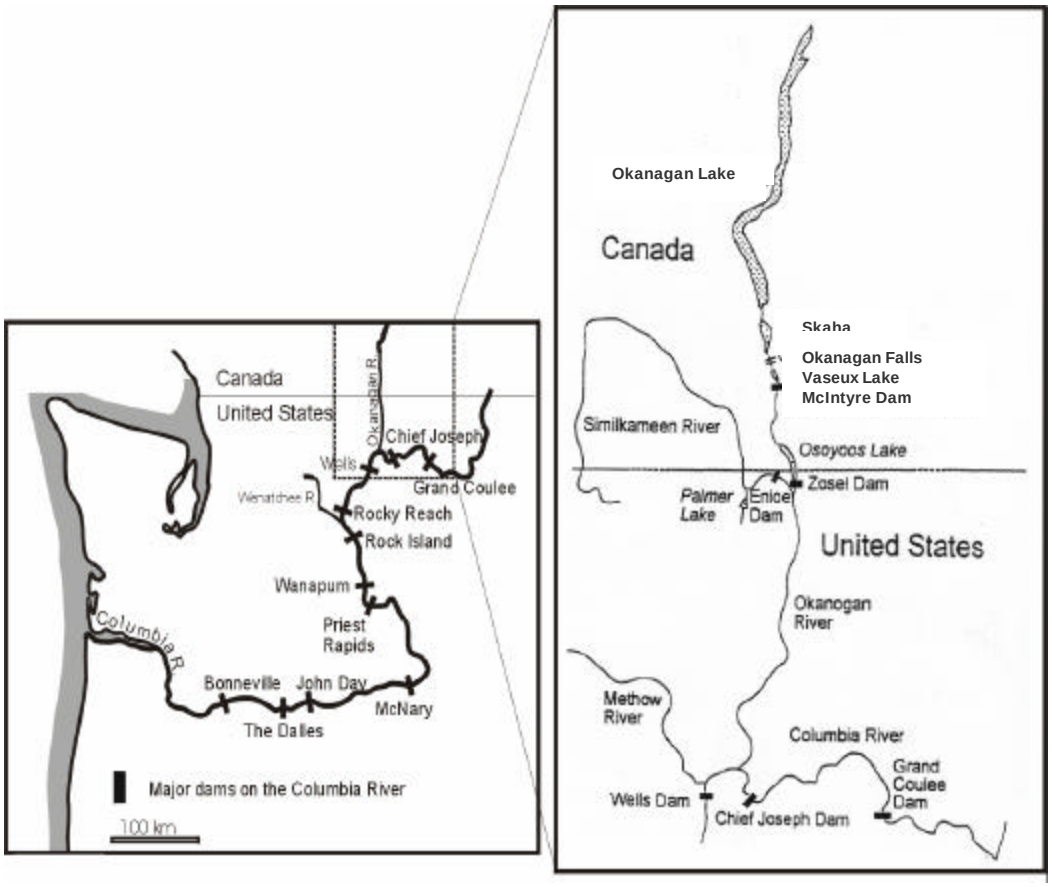


Figure 1. Columbia River and Okanagan River Drainages

Okanagan sockeye face a plethora of life threatening hazards. Returning adults proceeding upstream from the Columbia R. estuary must run the gauntlet of commercial, personal use and sport fisheries and overcome a series of 9 huge hydroelectric and water diversion dams and the reservoirs above them, even before they reach the mouth of the Okanogan R.[1] Losses have been estimated as high as 5-10% per dam (Fryer, 1995). The Wells Dam is the last the fish encounter before entering the Okanogan R, and it is the principal site of annual escapement counts. (Fig. 2 presents Wells Dam escapement data 1971-2001 as presented by Hyatt et al. MS 2002).

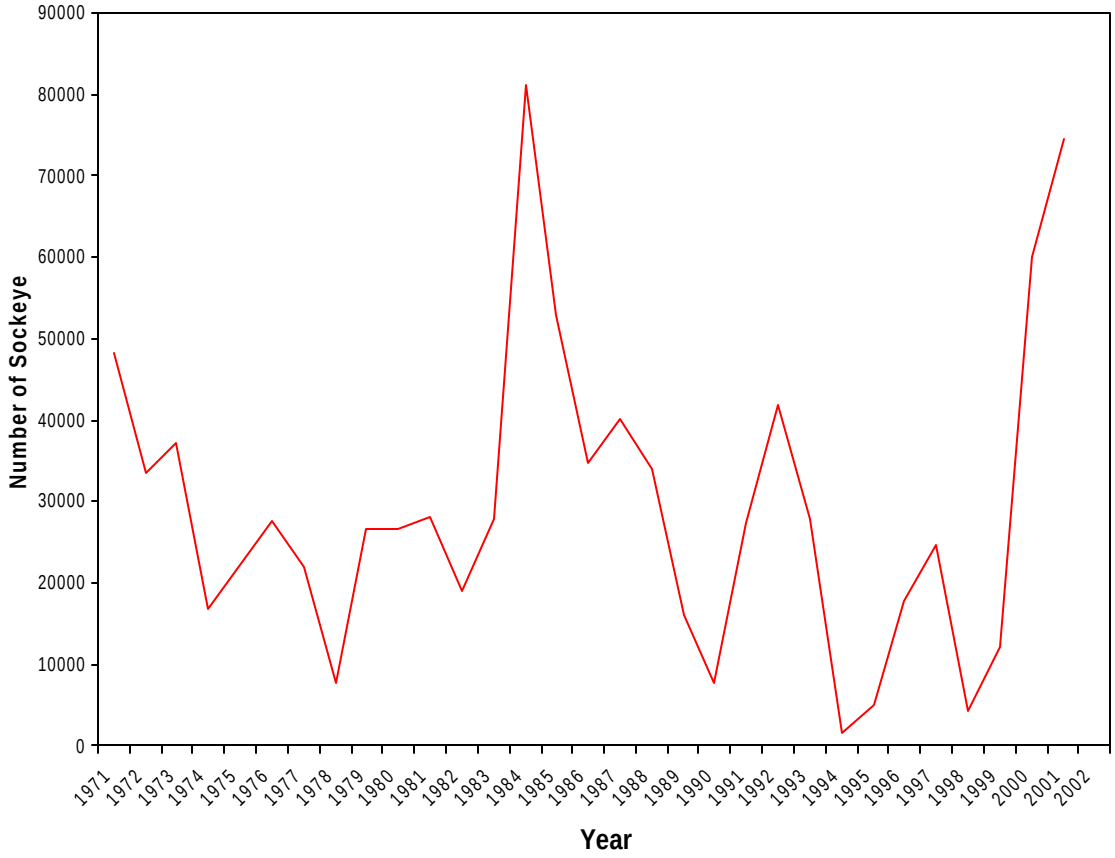


Figure 2. Counts of Okanagan sockeye salmon at Wells Dam, 1970-2001

Within the home river, agricultural needs for water, and installation of low head dams, engineered structures for flood control, diversions for irrigation, poorly screened water intakes, waste loads and the thermal and chemical changes that some of these entail, have had further significant impact on the stock. Much of the original fish habitat has gone or been radically altered and huge sections have been canalized. A water diversion and control structure – Zosel Dam - was constructed at the town of Oroville in Washington State (rebuilt in 1987), and three complete barriers to sockeye migration between Okanagan and Osoyoos lakes persist today. These are the Okanagan Lake Dam built in 1915; the Okanagan Falls, or Skaha Lake Dam (1921) and McIntyre Dam built below

[1] Okanagan R. in British Columbia is the Okanogan R. in Washington State.

Vaseux Lake also in 1921; a series of 17 vertical drop structures for flow control were added between Okanagan Falls and Osoyoos L. in the 1950s.

The burgeoning human population in the Okanagan Valley and further transformation of riparian lands can be expected to exacerbate many of these hazards. McIntyre Dam is particularly significant in that it limits further upstream migration of sockeye, thus denying access to the extensive waters above. It is a major factor in projected management decisions.

Returning adults may school at the mouth of Okanogan R. for a month or more while water temperatures cool to acceptable levels for entry and spawning. Once on the spawning grounds the salmon must find suitable beds, with rather strict requirements for gravel size and both surface and subsurface water flow and temperature, and eggs must remain well protected and safe from freezing or displacement by freshets until the young emerge. Soon thereafter the fry compete vigorously for food while constantly at risk from predators both indigenous and exotic. They are particularly susceptible to predation during their downstream migrations and during their (usually) one year of residence in the lake basin. Thereafter, as smolts, many are destroyed or injured at dams on their way seaward. Fryer (1995) considered low smolt – adult returns (commonly referred to as SARs) as the primary reason for the low population of Columbia River sockeye salmon, and characterized this daunting array of hazards to sockeye by suggesting that:

"…it is amazing that these fish manage to survive at all".

In fact 8 years after Fryers prophetic observation the stock has continued to decline except for two strong returns in 2000 and 2001. It is very difficult to forecast future run performance, but it seems probable that unless some remedial action is taken soon, the future of the stock is bleak.

Against this worrisome background the Okanagan Nation Fisheries Commission (ONFC) in Westbank, British Columbia, the Colville Confederated Tribes (CCT) in Washington State, and other groups and individuals have energetically sought restoration of the sockeye run to the Upper Okanagan R. basin, where they are believed to have flourished until the early 1900's.

While the strength of Okanagan sockeye runs, as well as those of chinook, coho, chum and possibly even pink salmon, entering the river in the early 1900's is poorly documented, newspaper articles, photographs and other publications of the time suggest that the runs not only existed, but that their combined numbers probably sustained significant native fisheries. The presence in the lakes of kokanee, sometimes termed (usually inappropriately) the "landlocked" sockeye, is further indication that the anadromous form once populated Okanagan, Skaha and likely other lakes of the upper drainage where generations of their offspring remain to the present. It is rather ironic that the kokanee, which began as a population incidental to the anadromous form, is the target of a recreational fishery in Wood and Kalamalka lakes – both tributary to Okanagan Lake - and while kokanee abundance has declined in Okanagan and Skaha lakes in recent years

there was an encouraging increase again in 2002 (S. Matthews pers. comm.) and considerable sport fishing potential remains.

3. DEVELOPING A PLAN

The International Pacific Salmon Fisheries Commission established the Okanagan Basin Technical Working Group, (OBTWG) with domestic Terms of Reference (COBTWG) to be established by June, 2003 (E. Fast pers. comm.) and in 1997 a workshop comprised of their members, representatives of the ONFC and a number of invited experts was convened by the ONFC at Westbank, with discussion and proceedings facilitated by ESSA Technologies Ltd. of Vancouver, B.C. Pertinent historical data (e.g. findings of Mullan (1986), Fryer (1995) and technical information collected in ongoing investigations of the British Columbia Ministry of Water Land and Air Protection and its precursors; Fisheries and Oceans Canada, (Pacific Biological Station) and others were included in the record of the 1997 meeting and collectively these provided a strong base for further investigative planning. The Bonneville Power Administration of Portland, Oregon has provided invaluable funding for much of the work.

With a view to ultimately restoring the sockeye run to Okanagan L., workshop participants outlined areas of investigation they considered essential before the reintroduction should proceed. In particular they suggested that the critical and only rearing area in Osoyoos L. was threatened by deteriorating water quality perhaps exacerbated by climate change, and that an alternative or supplementary rearing area should be sought.

The huge Okanagan L. appeared attractive as such a rearing area. However workshop members proposed a temporizing step which was to first reintroduce fish into Skaha L., reasoning that the risks associated with a direct introduction to Okanagan L. could be substantial. In a "Skaha first" approach, much information of value to an eventual introduction to Okanagan L. could be gathered before the stock was committed to it, and given its smaller size, Skaha would probably be more amenable to a project reversal if that was necessary. In fact the proposed reintroduction was termed "An Adaptive Management Experiment", reflecting the research component and the belief that if serious difficulties arose the project could be aborted.

Required research was implicit in six program objectives. Particulars of these, and an outline of some major results after 3 years of investigations are as follows:

4. INVESTIGATIONS TOWARD A REINTRODUCTION INTO SKAHA LAKE

4.1. Objectives

Six objectives provide the framework for most of the investigations to date.[2]

1. Assess the risk of disease transmission from reintroduced sockeye to resident fishes.
2. Assess the risk of accidental introduction of exotic species to upstream waters.
3. Determine whether spawning and/or incubation areas are likely to be limiting or introduced sockeye.
4. Develop a life-cycle model.
5. Evaluate options for implementing an experimental introduction.
6. Finalize a plan for an experimental reintroduction.

(Objectives 5 and 6 are still being finalized at time of writing.)

Coordination of studies has been by the ONFC, which has also conducted much of the fieldwork and presented results in Annual Reports of 2001 and 2002. In a number of cases when background information was scant, investigators began their projects by preparing and printing extensive literature reviews, and throughout there was a demonstrated concern for the welfare of resident fish species.

4.1.1 Risk of Disease (Obj.1).

Disease experts in Provincial and Federal laboratories cooperated in the analyses of sockeye and other fish specimens collected by ONFC personnel in two river regions, i.e. above and below the McIntyre Dam barrier. Investigators tested for the presence of five potentially troublesome disease agents in several thousand specimens collected in years 2001 and 2002 and concluded:

> ”There is no evidence that the fish populations above and below McIntyre Dam differ with respect to pathogens of concern. Nor is there any indication that Okanagan and Skaha lakes pose an extraordinary risk of causing disease in fish” (ONFC 2002).

This conclusion lessened concerns over the possibility of the disease spreading, but it was recommended that the barrier dam be left in place until final conclusions were reached[3].

---

[2] A more detailed description can be found in Annual Reports of the ONFC,, in Peters and Marmorek (2003), and in Parnell et al (2003.)

[3] Recently, the parasite *Parvicapsula* was discovered in Okanagan sockeye from below McIntyre Dam, and while at time of writing the implications of this discovery are uncertain, if the organism does not already occur above the dam, the possibility of it spreading to there could be a serious concern.

4.1.2 Risk From Exotic fishes (Obj. 2)

It was recognized that successful reintroduction of sockeye to upstream areas could be complicated by concurrent or later upstream movement of unwanted exotic species. Initially these were thought to be: *bluegill sunfish, black crappie, largemouth bass, tench, and walleye.*

Range extension could occur when particularly McIntyre Dam, but also Okanagan Falls Dam was removed, as these species might then reach production areas above and prey on sockeye, kokanee or trout eggs or their young, or compete successfully for limited common food resources. There are a number of known predators - e.g. *smallmouth bass, rainbow trout, northern pike minnow*, already well established above McIntyre, but the concern has been largely limited to possible new arrivals.

A good understanding was needed of the likely kind and severity of hazards to valued salmonids – particularly kokanee and rainbow trout – from various exotic species. ONFC staff therefore reviewed published records of relevant interactions and habitat preferences then undertook three years of extensive riverine sampling from Okanagan L. to Osoyoos L., as well as within the lakes, utilizing six kinds of fishing gear and pre-established sites and schedules. Detailed records of catch per unit of effort (CPUE), specimen sizes and stomach analyses were taken and published in the ONFC Annual Reports along with many descriptive photographs of sampling sites and representative fish habitats (Alexis et al. 2003).

Results suggest that only walleye should still be of serious concern and then only if they should move upstream beyond their present range in the Columbia and Lower Okanogan rivers. They are known to prey on juvenile salmonids, but may not move farther upstream because of an aversion to strong light.

Studies by Williams & Brown (1982), as discussed by Vedan (ms 2003), suggest that unsuitable rearing habitat and sparse shielding from light in the Okanagan R. may be at least a partial deterrent to walleye movement there. A prominent walleye sports fisherman was consulted about the species habitat preferences, and it was concluded that if walleye reached Okanagan Valley lakes they would likely thrive and have an impact on salmon. (Alexis et al, 2003). Effort is needed to ensure that walleye do not reach Osoyoos L. Perhaps strong lighting at night would be an effective deterrent.

4.1.3 Habitat Inventory and Enhancement Opportunities (Obj. 3).

Mullan, (1986), as reported by Bull (1999) estimated the carrying capacity of the primary spawning beds north of Oliver at 35,000-50,000 fish, depending upon flows. This would be ample for escapements of the size recorded over the past 30 years. However, in view of expected demands of the reintroduced fish and extensive changes made to the river, it was deemed important to reassess the quantity, quality and carrying capacity of remaining spawning grounds, and to assess the lake rearing conditions through appropriate limnological studies.

Experienced observers provided a preliminary appraisal of the suitability of existing riverine areas and noted that there were a number of locations in channelized portions of the river where, with introduction of suitable gravels, successful spawning could be expected. In addition the area between McIntyre Dam and Okanagan L. is considered capable of supporting as many as 18,000 spawners (Bull 2001). Long (2002) has prepared a detailed inventory of potential spawning habitat in this area.

In addition preliminary engineering assessments showed that it may be feasible to improve some existing spawning beds and/or develop new ones (Newbury 2002). A "pad" of rock and gravel placed below one of the drop structures supported a number of spawning sockeye in 2002. Additional pads, placed in suitable configurations adjacent to other drop structures could be productive.

Apparently adult sockeye entering the current Skaha L. environs would have few spawning options there. Bull (2001) saw very little opportunity for lakeshore or tributary spawning, and there are no known deep water possibilities. Apparently, like the present kokanee population, sockeye rearing in Skaha L. and returning as adults will need to spawn in the river, and almost certainly above, rather than below the lake. Inspection and measurement of the canalized river channel and flow conditions there showed that several spawning beds could be developed with space for about 4,000 pairs of sockeye and 3,700 pairs of kokanee (Long & Newbury 2002). In summary it appears that existing Okanagan River spawning areas could be significantly augmented if required and it is likely that such action will eventually be needed to provide for returning Skaha L. fish.

4.1.3.1 Limnology and the Osoyoos Lake Zone of Tolerance

Limnological investigations on larger Okanagan Valley lakes have been carried out by both federal and provincial agencies for many years, and a considerable body of relevant and valuable information exists. Building on this, and in concert with ongoing agency work, ONFC studies have largely been concentrated at established stations on Skaha, Osoyoos, Vaseux and Okanagan lakes to collect physical, chemical and biological data bearing upon carrying capacity for sockeye juveniles, and conditions in holding and resting areas where adults wait for river temperatures to decline.

Data presented by Wright & Lawrence (2003) show a juvenile rearing capacity in Skaha L. equal to about 80-90% of that currently found in Osoyoos L and when "zones of tolerance" were plotted (areas where maximum seasonal water temperatures and minimum oxygen levels are tolerable for young sockeye -- P. Rankin to H. Wright, pers. comm.), it appeared that juveniles would not likely have been restricted by those factors in Skaha L. in either 2001 or 2002. On the other hand in Osoyoos L. only the north basin (water mass north of Osoyoos, B.C.) had suitable rearing area in August and September, and in September that was restricted to a narrow horizontal band only about 2 – 3 m. deep. This area will require a close watch in order to detect any further reduction in carrying capacity. It could be very helpful if relevant conditions prior to 2001 could also be determined.

Three km. long Vaseux Lake, with a maximum depth of about 28m lies on the migration path and would pose a serious hazard for any sockeye juveniles attempting to migrate through it between July and September when intolerably high temperatures and low dissolved oxygen levels prevail. It is thought not to have any year-round rearing habitat suitable for sockeye juveniles (Wright 2002) and it supports a large population of rough fishes, including species predatory on salmonids.

4.1.3.2 Mysis relicta

The ½inch long opossum shr imp, Mysis relicta is now ubiquitous in most of the larger Okanagan Valley lakes. Introduced to Okanagan L. in 1966 as a food source for kokanee, it has expanded its range, and because its own planktonic food preferences mirror those of young salmonids, it may affect food availability for the latter in Osoyoos and Skaha lakes and elsewhere. Mysis has been introduced into other kokanee bearing lakes, and may have been the cause of fish reductions there. Because food supplies of sockeye juveniles in Osoyoos L. and kokanee in Skaha L. could be threatened by further proliferation of mysis, concerted sampling and research continues. A small commercial fishery for mysis exists on Okanagan L.

4.1.4 Develop a Life Cycle Model (Obj. 4)

Salmon stock performance is influenced by a great number of variables in each of river, lake and ocean environments and this makes forecasting abundance and behaviour very difficult to achieve. For instance, smolt to adult survival rates (SAR) among Okanagan sockeye are estimated to have varied from 0.6% to 6.6% in the few years for which there are data within the period 1965 - 1976 (Mullan 1986), cited in Fryer (1995). (Okanagan River sockeye data sets are notoriously incomplete.) However modeling can often be a useful tool for exploring variability and suggesting how stock dynamics may unfold.

ESSA Technologies developed a life cycle model for Okanagan sockeye and, interacting closely with workshop participants over several years, they completed a number of very informative analyses. The model considers factors affecting survival at each life history stage, and allows users to easily modify both human management actions and to hypothesize functional relationships, as described in the Design Document (Peters and Marmorek 2003) and Users Guide (Pinkham and Peters 2003). Details of the applications of the model can be found in Parnell et al. (2003).

4.1.4.1 Modeling of Reintroduction Options

ESSA scientists demonstrated model effectiveness by reproducing the observed geometric mean abundance of Okanagan adult sockeye (about 20,000 at Wells Dam counting station over a 25-year period) but – significantly – to achieve this, the mean SAR[4] had to be increased to 2.65 %, well above recent observed average values of about 1.0%. Nevertheless this successful escapement size simulation lends confidence that the

[4] SAR here refers to the survival of fish from smolts leaving Wells Dam to adults returning to Bonneville Dam (ESSA, pers.comm)

model can reflect reality and in this instance it also suggests the importance of the SAR as a determinant of run success.

In one series of analyses, the 3 reintroduction methods discussed on p.9 were modeled and results supported the view that reintroduction option No. 3, wherein fry would be released to the lake, would best satisfy the specified criteria. In options 1 and 2 the need to take larger numbers of spawners affected the stock unfavourably.[5]

This analysis also showed that introductions of 200 sockeye fry/ha should have relatively little effect on overall sockeye adult and fry performance, as well as on numbers of kokanee, and density of mysids, though in common with several other analyses in the modeling series, stock strength was seen to decline rapidly in the final few assessment years. This analysis was repeated, with removal of 50% of the mysis population each year and in this run both kokanee and sockeye fry numbers increased Apparently removal of part of the mysis population could benefit both kokanee and salmon populations.

4.1.4.2 Effect of fry density

When sockeye fry were introduced to give, successively densities of 200, 800, and 1000 fry/ha the survival rates of each of sockeye, kokanee and mysids remained unchanged. However the species specific survival rates at all three levels of introduction suggested that:

1. Kokanee are sensitive to mysis but not sockeye.
2. Sockeye are sensitive to kokanee, but more sensitive to mysis.
3. Mysis are insensitive to both sockeye and kokanee.

This analysis suggests that introducing sockeye fry in Skaha L. at concentrations as high as 1000 fry per hectare should not be a problem for kokanee, and it reinforces the view that mysis is apt to be a troublesome creature for both kokanee and sockeye.

4.1.4.3 Kokanee increases

Workshop attendees wished to know what conditions would likely increase the long-term average Skaha kokanee spawner population from the current 7,950, to the levels observed in the late 1960's of about 80,000 fish. The model suggested that removing competition (from mysis), doubling egg-fry survival, and tripling the amount of spawning habitat, could accomplish that end. (This is not to say that other combinations of change would not be capable of a similar result, but it does suggest that considerable effort might be required to sustain a population of 80,000 spawners under present conditions of stock and habitat).

[5] Under option one, 385 spawners would be required for an introduction of 200 fry/ha, given normal fertilization and hatchery survival rates, whereas 3,454 would be required under option 2. (Some reduction in numbers might be achieved by reducing the number of males needed for fertilization)

4.1.4.4 Other preliminary conclusions

The following items drawn from the modeling exercise are also important:

a) When mysis density in Osoyoos Lake was increased from 6m3/ha, to130m3/ha – the latter being the simulated density in Osoyoos Lake at the end of 25 years, -sockeye spawners were reduced from 20,000 to 6,000 fish.
b) In the absence of mysis Skaha L. kokanee appear to have an equilibrium spawning population (wherein natural variability is removed from the equation) of about 23,000, but with mysis present only 1500.

These results once again suggest that mysis has the potential to diminish salmonid production. It should be noted however, that because mysis is also a food item for larger kokanee there may be tradeoffs, featuring both positive, and negative effects on the population. The interaction dynamics are likely quite complex and deserve further research.

The model was also used for initial evaluations of the ability to detect impacts on kokanee of different types of sockeye re-introduction experiments (e.g. a 5-year baseline period followed by a 5-year re-introduction period). Preliminary analyses indicated that because the apparent effects of sockeye re-introduction on kokanee survival were so small in magnitude, they would be almost impossible to detect. Larger changes in kokanee fry to age 0 survival (e.g. a 40% change in survival either up or down) could likely be detected at an acceptable level of statistical power. More comprehensive work on statistical analyses and experimental design could be instructive (see pg. 69 of Parnell et al. 2003).

4.1.5 Methods of Reintroduction

Sockeye workshop participants considered three viable options for reintroducing sockeye into Skaha L., and put forward criteria which could be used to prioritize them:

4.1.5.1 Options

1. Remove barriers (McIntyre and Okanagan Falls dams) to migration between Osoyoos and Skaha lakes – thus allowing migrants to move into Skaha unimpeded.
2. Trap migrants (probably below McIntyre Dam), transport to Skaha and release allowing them to find their own spawning areas.
3. Trap migrants, extract and fertilize eggs, incubate in a local (and disease free) hatchery and release fry into Skaha.

4.1.5.2 Criteria for Success

It was thought that a successful reintroduction process should:

a) provide a satisfactory level of learning
b) conserve existing stocks of both sockeye, and kokanee; and
c) eventually produce a population with a large enough surplus to once again support a substantial fishery, notably for ceremonial purposes.

Option three was thought to best satisfy the three criteria, all things considered. It was particularly strong from a learning perspective; it would enable precisely the required numbers of fry to be introduced into the lake; and by marking the fry investigators could accurately measure their survival to later life stages. Option 3 also has conservation value in that a comparatively small number of pre-spawners would need to be sacrificed, and any possible deleterious interaction, (e.g. strong competition between returning sockeye and resident kokanee for spawning space) would be avoided -- at least during years when sockeye adults were prevented from entering the upper river. Finally it should be a relatively dependable, and speedy way of generating data on Skaha L. rearing effectiveness provided abundance of kokanee and sockeye juveniles are carefully monitored. In the other methods, wherein fish would need to find their own spawning grounds in or above Skaha L., their spawning and incubation success would be unpredictable and very difficult to measure, and uncertain escapement strength or upstream travel distance could preclude a satisfactory spawning in or near Skaha L.

In reintroduction options one and two, there would also be doubt as to how fish produced in Skaha L. would be distributed at return, as they would not be distinguishable from spawners that reared in Osoyoos Lake. In any choice of reintroduction, wherein barriers remained to prevent complete homing, the fish would most likely spawn with the main population near McIntyre Dam. That could result in an unwanted level of competition both on the spawning grounds and later in the Osoyoos L. rearing area. This concern could of course apply in any year of exceptionally high abundance with or without enhanced production.

While option three is particularly attractive from the important standpoint of quickly achieving the desired Skaha L. population level, there is nevertheless a body of resistance to any "non-natural" reintroduction process. It may be argued that if given the opportunity (i.e. removing or broaching barriers) the fish will find their own way, select productive spawning sites and thereby obviate the need for hatchery rearing with all the uncertainty that implies. Some workshop participants thought that because each method has its own risks and benefits, it may be desirable to implement each of these sequentially or concurrently in an experimental framework. Further review may be needed before a final decision is made.

Some parts of the run may be more successful than others if used as donor stock for the reintroduction. A number of fish usually arrive at McIntyre Dam ahead of the main run each season, attempt to get through the dam, then fall back and presumably spawn somewhere below it. If, as seems credible, these fish are remnants of an early run component seeking access to historical spawning grounds – perhaps in Okanagan L.- they may be genetically the best suited as brood stock for Skaha. In any event both the run and the dam can be managed to utilize fish from any desired part of the run. However,

one should anticipate that due to temperature-induced migration delays in the Okanogan River above Wells Dam or for other reasons, in many years there may be very few or no 'early run' spawners.

Workshop planners thought that a number of "pre-experiment" years would be needed to develop reliable baseline data, and given the likely variability in year-to-year fry survival, additional time would be required before accumulated production data could be accepted with confidence. Furthermore some minimum number of fish would have to arrive at McIntyre Dam before investigators were satisfied that the required numbers could be safely removed for the egg take. Based upon past run performance there could very well be years when no removal could be permitted, thus necessitating further extension to the period of experimental reintroduction. The total numbers of years required and the minimum acceptable escapement size are still to be finalized but may prove to be a critical burden in achieving a speedy reintroduction.

5. SYNTHESIS OF RESULTS AND SOME SUGGESTIONS FOR THE FUTURE

Progress toward meeting the six program objectives has been effective and has not revealed factors which should preclude a successful reintroduction to Skaha Lake:

1. Serious disease transfer between waters above, and waters below McIntyre Dam seems unlikely, unless recently discovered *Parvicapsula* becomes a problem.
2. Concerns over exotic fish introductions can now be centred on walleye though that species has not been recorded from upstream of the International Boundary. In view of its potential for damage to salmonids every effort should be made to keep it out of Osoyoos L.
3. Spawning areas appear adequate for present population levels, and there is potential to increase them to accommodate Skaha L., or other new production.
4. A life cycle model has been developed and tested and shown to be promising as a tool for improving understanding of run dynamics, exploring intraspecific competition, and assessing the relative benefits and risks of alternative reintroduction, mitigation and monitoring strategies. Several options for an experimental introduction of sockeye to Skaha L. have been evaluated, and prioritized. In balance a fry introduction seems the best approach, though it may deserve further exploration.
5. Planning for the reintroduction is progressing and with secure funding some preparatory work could probably get under way quite quickly.

These are substantial and encouraging accomplishments, and they provide a strong rationale for recommending reintroduction of sockeye salmon to Skaha L. At the same time some significant concerns persist and these will need to be explored farther as work progresses.

For instance the persistent stock decline is worrisome: In 30 years of data from Wells Dam (data courtesy of Hyatt et al. 2001) the sum of 15 consecutive escapements, from 1971 – 1986, were 1.3 times the sum of the following 15 consecutive escapements from 1987 – 2001. Peters et al (1998) suggested that without some form of intervention to improve survival rates the stock could go to extinction. A competent biometrician might be able to extrapolate from available data to cast further light on the likely outcome.

Concern over low smolt to adult survival is also pervasive, and if it cannot improved, for instance by affording greater protection at dams, a larger number of juveniles may be required to bolster the stock. Reductions in commercial, and other Lower Columbia River fisheries may be needed, both as a means of getting more fish onto the spawning grounds and (incidentally) in the long term interests of the fishermen themselves. Moreover, the very limited layer of Osoyoos L. waters which at present seems capable of supporting juveniles in the summer months could become further restricted, and under extreme circumstances might disappear entirely, with disastrous consequences for the fish. Finally the burgeoning mysis population seems a serious threat to both anadromous sockeye and kokanee and the existing mysis fishery may deserve expansion.

In view of these concerns there is a need to move quickly to a Skaha L. reintroduction as well as to extend data sets which will be needed to more completely assess sockeye interactions with resident fishes and the environment. No stock assessment data exists for sockeye using waters above McIntyre Dam, so their perceived reproductive success and behaviour there must be considered somewhat conjectural.

Though it is not a concern while the barrier dams are intact, the shortage of spawning area in Skaha and its tributary streams will oblige the fish to spawn in the river, either below or above the lake. The channelized section of river below Okanagan L. is where considerable kokanee spawning occurs now, but at present there is insufficient graveled area to additionally support the expected anadromous population. As noted previously, more spawning area will have to be created before adults return.

The workshop recommendation to reintroduce sockeye to Skaha Lake first, rather than directly to Okanagan L. appears to have been a sensible one despite some substantial physical and biological differences in the two lakes, which could make the Skaha experiment less than a perfect model for Okanagan. Nevertheless progress has been made on a number of critical questions about run dynamics and species interactions which could apply equally well to populations in either lake. A great deal of valuable information has been assembled from the three years of study and the rigorous approach to the work exhibited by participants should give comfort to those contemplating the next steps.

5.1. Behavioural Issues

There are some uncertainties about how fry reintroduced to Skaha L. from the downstream segment of the population will behave and these will need to be resolved as quickly as possible. For instance, depending upon where in the lake they are released, fry may move toward the outlet, and some might then choose to enter, or be carried by the

current into the river. After all, the fry stage of the parent stock was apparently genetically programmed to move downstream to the Osoyoos L. nursery area and presumably their progeny will carry the same predisposition. A release well away from the lake outlet and away from any discernible southerly current would seem prudent, as would subsequent monitoring at the Okanagan Falls Dam to enable any exodus to be measured.

It is not unusual for sockeye population units in the same river system to have different responses to flow and substrate and Brannon (1972) reporting on fry behaviour in several Fraser River stocks concluded that: "…mechanics controlling sockeye fry migration are genetically based, and involve racially specific velocity response patterns..."

It is also important that the fish move directly seaward as smolts. While a significant number might reach Osoyoos L. as fry and become integrated with the down river fish this would largely defeat the aim of establishing a back-up rearing area in Skaha L., and in a year of high production and/or lowered carrying capacity in Osoyoos L. it could pose an untenable burden on the rearing area. Furthermore the 30 km downstream trip as fry could be very hazardous, perhaps intolerable, particularly in view of the inhospitable conditions expected to occur in Vaseux L. A migration at smolt size should impart significant survival advantage, and intuitively one would expect migration to occur at that stage but in the absence of relevant upstream sockeye stock data the outcome is hardly assured.

It is also possible that introduced juveniles, perhaps influenced by food availability and different growth rates to those experienced in Osoyoos L, could find the Skaha environment conducive to a longer period of residence, and in a further departure from expected behaviour, part of the population might remain and become mixed with the kokanee population. These possibilities seem rather unlikely but should be watched for. Such behaviour might be more likely to occur in a larger water body such as Okanagan L.

It should also be remembered that the Okanagan River has been drastically modified since times of past larger runs. Sockeye behaviour geared to conditions extant then, may not serve quite so well in today's environment. One cannot help wondering if Skaha L. could simply have been a conduit for salmon passing to and from Okanagan L., without there being much in the way of local spawning opportunity, but with a lake basin able to support a kokanee population originating in more attractive Okanagan Lake spawning grounds?

Investigators also need to learn as soon as possible how adult spawners will distribute themselves in the river between McIntyre and Okanagan Falls; how effective their spawning there will be; and how serious a problem Vaseux Lake will be for juveniles passing through it. Unless the fry introduction is to continue indefinitely managers will have to face these issues eventually and as time is surely an issue, this river work should be carried on at the same time as the fry experiments in a kind of "two track" approach. The central question is: What combination of number of spawners, river discharge and

temperature will result in fish reaching the Okanagan Falls barrier dam as opposed to spawning farther downstream?

5.2. Need for a Two-Track Approach.

In such a two-track approach McIntyre dam would remain in place as recommended for reintroduction option three discussed above, but modified to allow a controlled number of fish to enter the upper river perhaps via a narrow fish ladder, or a side channel as illustrated by Newbury (2001, Figs 4.8 & 4.9). A decision on numbers would be subject to the same kind of critical examination proposed for the fry introduction. Knowledge of the productivity of this stretch of river will be needed to manage stock distribution over the long term. While Skaha L. adults can be expected to home on the nursery lake, a fraction of the population will no doubt always remain in the river.

As noted in the modeling workshop, there is no assurance that escapement numbers in any given year will be sufficiently large to permit removal of adults for the fry introduction, so a further removal of spawners for the river studies would be a substantial additional burden when returns are weak. Given the large escapements in 2000 and 2001, the next two or three years (2003 – 2005) may, with reasonably good smolt, marine and adult migration survivals, provide the largest surplus to be seen for some time and considerable effort would be justified to ensure capitalizing on such a "window of opportunity". Timely information from Wells Dam on escapement size can provide advance warning about numbers of fish likely to be available on the spawning grounds and allow field crews to plan accordingly.

These issues will need to be closely monitored in order to obtain prompt warning of any further stock decline or alteration of habitat. Climate change, which could also affect the runs is largely beyond control but needs watching if effects are to be anticipated.

5.3. Agency Participation.

The agencies now participating in the reintroduction project are providing vital expertise and information, and it will be important to know, as early and as fully as possible, the nature of their contributions to the next phase. While reproduction and the early stages of Okanagan sockeye production capacity (spawner to smolt) occurs in Canada, most of the fresh water migration (smolt to adult return) occurs in the United States. Clearly agencies of both countries will need to be involved to ensure that rearing facilities are sufficient and protected, and that commercial, personal use and sport fisheries are well regulated as the run recuperates. Initiatives to improve adult and juvenile passage through the Columbia River dams should continue, and it will be helpful to know their nature and degree of success.

Reconstitution of past stock performance using the best information available, and maintaining up to date records will be of great importance to investigators seeking improved understanding of run dynamics and a solid information base on which to build future initiatives.

As a final note attention should be directed to the workshop participants concern over finding the right balance between too slow action which could result in loss of the stock (the conservation issue) and too precipitous action leading to bad decisions (the production issue). One cannot foresee with any degree of assurance how many years the run can persist unaided. It is clear however that unless the run is kept reasonably robust there will be few options for intervention of any kind. A cautious and thoughtful lean toward conservation appears justified to ensure that this highly valued resource survives.

6. RECOMMENDATIONS

Comprehensive planning should accelerate to ensure both effective and efficient use of human and material resources. The following steps are suggested:

1. Take eggs from adults of the 2003 escapement, incubate for release into Skaha L. in 2004, and establish a sampling facility at the lake outlet.
2. Adjust McIntyre Dam gates to enable a controlled adult sockeye access to the river above.
3. Continue evaluation of Osoyoos L. "Zone of Tolerance" for juvenile sockeye, and if possible delineate boundaries prevailing prior to 2001.
4. Continue mysis studies to clearly reveal population trends at least in Osoyoos, Skaha and Okanagan lakes.
5. Develop a study specifically to describe sockeye-kokanee-mysis interactions and food regimens.
6. Install spawning pads in the river below Okanagan L as described by Long & Newbury (2002).
7. Review sockeye stock information and arrange for timely acquisition of data needed seasonally: e.g. escapement at Wells Dam, catch from all sources, numbers of river spawners, smolts at Zosel Dam etc.
8. Continue surveillance to assess walleye distribution and explore means of keeping them out of Osoyoos Lake.
9. Develop detailed 5-yr or similar length plan for reintroduction steps: e.g. rules to govern required escapement size before egg takes occur; sampling required to assess fry reintroduction success, etc.
10. Develop a monitoring program for critical data acquisitions

7. LITERATURE CITED

Alexis, Fabian, Herb Alex and Shayla Lawrence. 2003. Exotic Fish Risk Assessment *In*: Evaluation of Experimental Reintroduction of Sockeye Salmon into Skaha Lake: Year 3 of 3.(In preparation)40p.

Brannon, E.L. 1972. Mechanisms controlling migration of sockeye salmon fry. Int. Pac. Salmon Fish. Comm. Bull. 21: 86p. (cited *In*: Groot & Margolis (eds. 1991).

Bull, C.J. 1999. Options for protecting and enhancing fisheries habitat in the Okanagan River. Prepared under provisions of the British Columbia Conservation Foundation. 49p.

Bull, C.J. 2001. Sockeye salmon habitat assessment in Okanagan River upstream of McIntyre Dam. *In*: Evaluation of Experimental Reintroduction of Sockeye Salmon into Skaha Lake: Objective 3. 14p.

Fryer, J.K. 1995. Columbia Basin sockeye salmon: Causes of their past decline, factors contributing to their present low abundance, and the future outlook. PhD thesis. University of Washington. 274 p.

Mullan, J.W. 1986. Determinants of sockeye salmon abundance in the Columbia River, 1880 – 1982: A review and synthesis. U.S. Fish and Wildlife Service. Special Report: Fisheries 38, 41 p. (cited in Bull 1999)

Long, Karilyn. (2002).Inventory of Existing Sockeye Habitat and Opportunities for Habitat Enhancement. *In* Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: Objective 3. 20p and 6 appendices.

Long and Newbury. 2002. Okanagan River (Reach A) spawning area restoration feasibility. *In*: Evaluation of Experimental Reintroduction of Sockeye Salmon into Skaha Lake: (In preparation) 14p

ONFC. 2002. Objective 1. Disease Risk Assessment. *In*: Evaluation of Experimental Reintroduction of Sockeye Salmon into Skaha Lake. 17p and 6 appendices.

Peters, Calvin M, D.P.Bernard, and David R. Marmorek. 1998. Should sockeye be re-introduced to Okanagan Lake ? An exploration of potential benefits, impacts and uncertainties. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for participants of the Okanagan Sockeye Workshop. 50p.

Peters, C.N. and D.R. Marmorek. 2003. OkSockeye: A Simple Life-cycle Model of Okanagan Basin Sockeye Salmon, Version 2.2, Design Document. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for the Okanagan Nation Fisheries Commission, Westbank, BC. 95 pp.

Parnell, I.J., C.N. Peters and D. R. Marmorek. 2003. Evaluate alternative experimental strategies for reintroducing sockeye salmon to Skaha Lake: Draft report. Prepared by ESSA Technologies Ltd., Vancouver B.C. for Okanagan Nation Fisheries Commission, Westbank, B.C. 83p.

Pinkham, C. and C.N. Peters. 2003. Life-cycle Model of Okanagan Basin Sockeye Salmon: User's Guide Version 2.2. Prepared by ESSA Technologies Ltd., Vancouver, BC. 23 pp.

Williams, Ken and Larry Brown, 1982. Mid-Columbia Walleye fisheries: Life history management. 1982. Cited in (Vedan 2003) (Prepared for :Evaluation of Experimental Reintroduction of Sockeye Salmon into Skaha Lake).

Wright, Howie. 2002. Assessment of juvenile O*ncorhynchus nerka* (Sockeye and Kokanee) rearing Capacity of Skaha Lake, Vaseux Lake and Osoyoos Lake 2001.*In* Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake Objective 3. 53p.

Wright & Lawrence, 2003.Assessment of juvenile *Oncorhynchus nerka* (Sockeye and Kokanee) rearing conditions of Skaha and Osoyoos lakes 2002. *In*: Evaluation of an experimental reintroduction of sockeye salmon into Skaha Lake. (In preparation) 62p.

Manuscripts

Hyatt, K.D., M. Stockwell and D.P. Rankin.(2002). Fish water management tools project – Okanagan sockeye salmon, core numbers and traits (CNAT) data set version 1.0

Newbury, Bob. 2002. Spawning reaches and enhancement feasibility. *In*: Evaluation of Experimental Reintroduction of Sockeye Salmon into Skaha Lake. Appendix E of (Long, (2002) see Literature Cited

Vedan, Adrienne.(2003) Movement and Colonization of Walleye. *In* Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake. Literature Review 6p.