The State of Fish and Fish Habitat in the *Okanagan and Similkameen Basins*

Fisheries & Oceans Canada

Okanagan Nation Alliance

BC Ministry of Water Land & Air Protection

2005

The State of Fish and Fish Habitat in the Okanagan and Similkameen Basins

Fisheries and Oceans Canada

Okanagan Nation Alliance

BC Ministry of Water Land and Air Protection

2005

Acknowledgements

This report was commissioned by the Canadian Okanagan Basin Technical Working Group (COBTWG) as one component of Phase I in a Watershed-based Fish Sustainability Planning process. COBTWG has representatives from Okanagan Nation Alliance, Fisheries and Oceans Canada, and the provincial Ministry of Water, Land and Air Protection the subcommittee for this project also include Ministry of Sustainable Resource Management.

Reports, data, and information were provided during the preparation of this report by:

- Deana Machin, Jillian Tamblyn, and Howie Wright, Okanagan Nation Alliance.
- Orville Dyer, Brian Jantz, Vic Jensen, Steve Matthews, Dale Sebastian, Brian Symonds, and Andrew Wilson, Ministry of Water, Land and Air Protection.
- Dave Smith, Fisheries and Oceans Canada.
- Greg Armour, Okanagan Basin Water Board.
- Bob Brodie, Al Dean and Steve Rowe, Land and Water BC, Inc.
- Chris Bull, Glenfir Resources.
- Todd Cashin, Regional District of Central Okanagan.
- Glenn Smith, Monashee Environmental.

Editorial comments were provided on drafts of this report by:

- Jillian Tamblyn and Howie Wright, Okanagan Nation Alliance.
- Steve Matthews, Ministry of Water, Land and Air Protection.
- Elmer Fast and Dave Smith, Fisheries and Oceans Canada.

Citation

Rae, Rowena. 2005. The State of Fish and Fish Habitat in the Okanagan and Similkameen Basins. Prepared for the Canadian Okanagan Basin Technical Working Group, Westbank, BC.

Production Team

Writer	Rowena Rae, Sumac Writing and Editing
Facilitation and support	Jillian Tamblyn, Okanagan Nation Alliance
Design and Production	Jane Ritchie, Big Sage Resources

Printed in Canada by Print Three, Kelowna

Colour Photos

Cover	Ministry of Water, Land and Air Protection
Chapters 1, 5, 9	Okanagan Nation Alliance
Chapter 2, 3, 8	Ministry of Water, Land and Air Protection
Chapter 4	Fabian Alexis
Chapter 6, 7, 10	Chris Bull
Maps	Wilson Wiley, Upper Similkameen Indian Band

For further information Please visit www.obtwg.org
or call Okanagan Nation Alliance at (250) 707-0095

Introduction

February 2005

Dear Reader:

I am pleased to forward you a copy of the report entitled *"State of Fish and Fish Habitat in the Okanagan / Similkameen Basin"*.

This report describes the state (health) of fish and fish habitat in the Okanagan and Similkameen River basins. It is one component of a watershed based fish sustainability planning (WFSP) process that was initiated in 2003. The ultimate goal of the WFSP process is sustainable long term conservation of fish and fish habitat. To achieve this goal requires knowledge of factors that have influenced quality of fish habitat and fish productivity. Information gaps also need to be identified. These topics are addressed in this report.

The WFSP process in the Okanagan / Similkameen River basins is a joint effort of the Okanagan Nation Alliance, the B.C. Ministry of Water, Land, and Air Protection and Fisheries and Oceans Canada. These agencies, working cooperatively via the Canadian Okanagan Basin Technical Working Group (COBTWG), solicited this State of Fish and Fish Habitat report to synthesize existing information, provide a common base from which to start the planning process, and develop a communication mechanism to engage the public in fish conservation efforts. The mandate of the COBTWG is to conserve fish stocks and that originate in the Canadian portion of the Okanagan River basin and protect/restore associated critical fish habitat.

Many different species of fish inhabit the lakes, streams, and rivers of the Okanagan / Similkameen watersheds. The threat to fish and fish habitat continues to increase as a result of a rapidly growing population in these areas. A variety of impacts over the past 150 years have negatively affected fish production and have significantly altered the amount of quality fish habitat historically found in these watersheds. To combat this trend many positive actions are underway to help protect existing fish populations and areas of quality fish habitat. These actions are also intended to restore and enhance some of what has been damaged or lost.

The main objective of this report is to provide an overview of the health of Okanagan / Similkameen fish populations and associated habitat. Specific objectives are:

- To document the history of fish populations and habitat, particularly for sockeye salmon, kokanee salmon, and rainbow trout;
- To document the current condition of fish and fish habitat;
- To identify key impacts and factors that limit fish production;
- To identify gaps in our knowledge of fish and fish habitat;
- To identify major initiatives underway.

Lakes, rivers, and streams are ecosystems that contain myriads of different plant and animal species. Some species, including many fish, can be singled out as indicators of the overall health of a particular ecosystem. If species populations are healthy, the ecosystem is likely to be healthy. Salmon and trout in particular have highly sensitive habitat requirements and are a key component in maintaining a healthy ecosystem. Recent studies indicate that over 130 animal species eat the carcasses of salmon that have spawned and died.

In this report, three different fish are used as indicators: sockeye salmon, kokanee salmon, and rainbow trout. These salmonid species each play an important role in the freshwater ecosystems of the Okanagan / Similkameen River basins.

Although this report focuses on sockeye, kokanee and rainbow trout, other native fish species are included. Some of these species are considered rare and endangered. Introduced (exotic) species which are species not found naturally in the Okanagan / Similkameen River basins are also noted in the report.

I hope you find this report interesting and enlightening.

Sincerely,

Elmer Fast – DFO

Chair

Canadian Okanagan Basin Technical Working Group

Table of Contents

LIST OF MAPS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOS

Okanagan Similkameen River Basins

Summary

This report describes the state, or health, of fish and fish habitat in the Okanagan and Similkameen basins. It is one component of a Watershed-based Fish Sustainability Planning process that was initiated in 2003, and should be used as a starting point to identify priorities during this process. In order to plan for fish sustainability, we must know what has happened in the past, how fish populations and habitat have changed as a result, what is being done already to conserve fish, and what information is lacking. The report focuses on sockeye salmon, kokanee salmon, and rainbow trout as indicators of ecosystem health.

Okanagan Basin

The Okanagan Basin consists of headwater lakes, tributary streams that flow to lakes and the river at the valley bottom, six large main valley lakes and Okanagan River. The basin crosses the international border with the United States and ultimately drains into the Columbia River. One of only two remaining viable Columbia sockeye salmon stocks returns to spawn in the Canadian portion of the Okanagan Basin. Resident fish are also important both economically and to sustain healthy freshwater ecosystems.

The Okanagan headwater lakes include all lakes in the valley except the six that are linked along the valley bottom. For the past 85 years, rainbow trout and eastern brook trout have been stocked into the headwater lakes for angling. Little spawning habitat exists for these fish, so few naturalized populations have formed and stocking continues on an annual basis to support a large recreational fishery. Many of the headwater lakes have been dammed at their outlets and are regulated for domestic and irrigation water supplies.

Most tributary streams flow into Okanagan Lake, but a few enter other lakes and the Okanagan River. Streams in the Okanagan are home to resident fish and are also used by spawning rainbow trout and kokanee salmon from lakes as well as spawning sea-run salmon. The streams are driven by snow melt so that their peak flows occur in about a two-month period in spring, which is followed by low water flow in summer, autumn, and winter. This pattern of annual flow is out of sequence with human water uses, especially irrigation, which peaks in summer and early autumn.

Water withdrawals are a significant issue for streams, affecting the quality and quantity of fish habitat available. Land development, channel straightening and dyking, and streamside vegetation removal have had negative impacts on several streams, including Mission Creek, where the majority of salmon and trout from Okanagan Lake spawn. About 90% of spawning habitat in streams north of Penticton was estimated to be gone by the 1950s. The number of stream-spawning kokanee has declined significantly since at least the early 1970s.

Six large lakes in the Okanagan Basin form a chain along the valley floor. Wood Lake is highly productive and joins the less productive Kalamalka Lake. Next in the chain is Okanagan Lake, the largest in the valley, which has experienced a crash in its kokanee population over the past three decades. Contributing factors include damaged stream and shore-spawning habitat, competition for food with the introduced shrimp *Mysis relicta*, and possibly a lack of high quality food for kokanee.

A major initiative called the Okanagan Lake Action Plan has completed eight years of a 20-year plan and has made progress in stream protection and restoration measures, initiating and testing a *Mysis* fishery, and improving water level fluctuations. Skaha Lake, downstream of Okanagan Lake, has a kokanee population that recently increased in numbers but reasons for this are unclear.

The lake is the site of an experimental reintroduction* of sockeye salmon, which were released into Okanagan River upstream of Skaha Lake in early June, 2004. Vaseux Lake, the smallest and shallowest in the chain, is a moderately productive lake.

Osoyoos Lake straddles the Canada-US border, has high productivity, and is important as a nursery lake for sockeye fry. The productivity of Vaseux and Osoyoos lakes creates a condition in late summer known as a temperature-oxygen squeeze. Water temperature gets too high for many fish in the surface layers of the lake and oxygen gets too low in bottom layers, resulting in only a small middle layer being tolerable for some fish species.

Okanagan River begins at the outlet of Okanagan Lake and flows through Skaha, Vaseux, and Osoyoos lakes before reaching the Columbia River in Washington. Each of these lakes has an outlet dam, and although fish ladders were built, only Zosel Dam at the outlet of Osoyoos Lake is operated to allow fish passage.

The river provides critical habitat for numerous fish species, including spawning habitat for kokanee, sockeye, and other salmon such as chinook, rainbow and steelhead trout, and other resident species. As a result of land development, water withdrawals, dams for flood control, channel straightening and dyking, and removal of streamside vegetation, most fish habitat in Okanagan River has been eliminated. Only a short stretch downstream from Vaseux Lake remains in natural condition.

The returns of adult sockeye salmon to Okanagan River vary from year to year and show no consistent trends. Despite the many severe impacts to Okanagan River, considerable potential exists for habitat restoration.

International salmon management on the Columbia River has affected fish populations in the Okanagan Basin. When the Grand Coulee Dam was built on the Columbia River in 1939, fish passage into the Canadian portion of the upper Columbia was eliminated. Thus, the Okanagan Basin remained as the only Canadian basin accessible to sea-run fish species.

The Grand Coulee Fish Maintenance Program was then established to mitigate losses to the upper Columbia by trapping returning salmon at Rock Island Dam further downstream on the Columbia, and either transporting the adults or raising their eggs in hatcheries for transplant into other tributaries.

* *Regarding the terminology "sockeye reintroduction": Native populations of kokanee were present throughout the Okanagan's main valley lakes when Europeans first settled in the area. Kokanee are derived from sea-run sockeye salmon, and therefore these fish must have been present in the Okanagan main valley lakes on one or more occasions since the last glaciation. Accordingly, the term "sockeye reintroduction" is used here and elsewhere in the text.*

Of all the returning salmon species, only sockeye were transported to the Okanagan Basin during the program's operation from 1939-1943.

Sockeye salmon now have passage at Rock Island Dam and return to the Okanagan Basin annually, along with a few chinook and steelhead. Because of this transplant program, the Okanagan sockeye are considered to be a composite of sockeye populations that historically returned to the upper Columbia system.

Similkameen Basin

The Similkameen Basin consists of headwater lakes, tributary streams and rivers that flow to the valley bottom, and Similkameen River. The basin crosses the international border with the United States and ultimately drains into the Columbia River. Sea-run fish do not migrate to the Canadian portion of the Similkameen Basin because of Enloe Dam which is a barrier to fish passage near the river's mouth. Before the dam, a natural barrier existed at the same location, so sea-run fish have never had access to the upper Similkameen. Rainbow trout, mountain whitefish, and longnose dace are the dominant fish species resident in the basin.

Many of the Similkameen headwater lakes are stocked with rainbow trout and eastern brook trout for angling. Some spawning habitat exists for these fish and a few naturalized populations have formed, but stocking continues on an annual basis.

Similkameen River flows north from the mountains near the US border, turns southeast at Princeton and eventually meanders through a wide flood plain before crossing into Washington State. During its journey, several large tributaries join the Similkameen River, the largest of these being the Tulameen River.

With their mountain origins and steep gradient, streams and rivers in the Similkameen have few nutrients and cool temperatures. As a result, resident fish populations have low densities and slow growth rates compared to other streams in British Columbia. Similkameen streams and rivers are fed by snow melt and experience high flows for only a short period in spring, followed by low water flows for the remainder of the year.

The combination of low flow and cold temperatures in winter leads to the formation of anchor ice, which scours river bed habitat and harms both fish and eggs. Land alterations for forestry, agriculture, and urban areas, water withdrawals, and streamside vegetation removal have likely had negative effects on habitat quality in several tributary streams and along stretches of the Similkameen River.

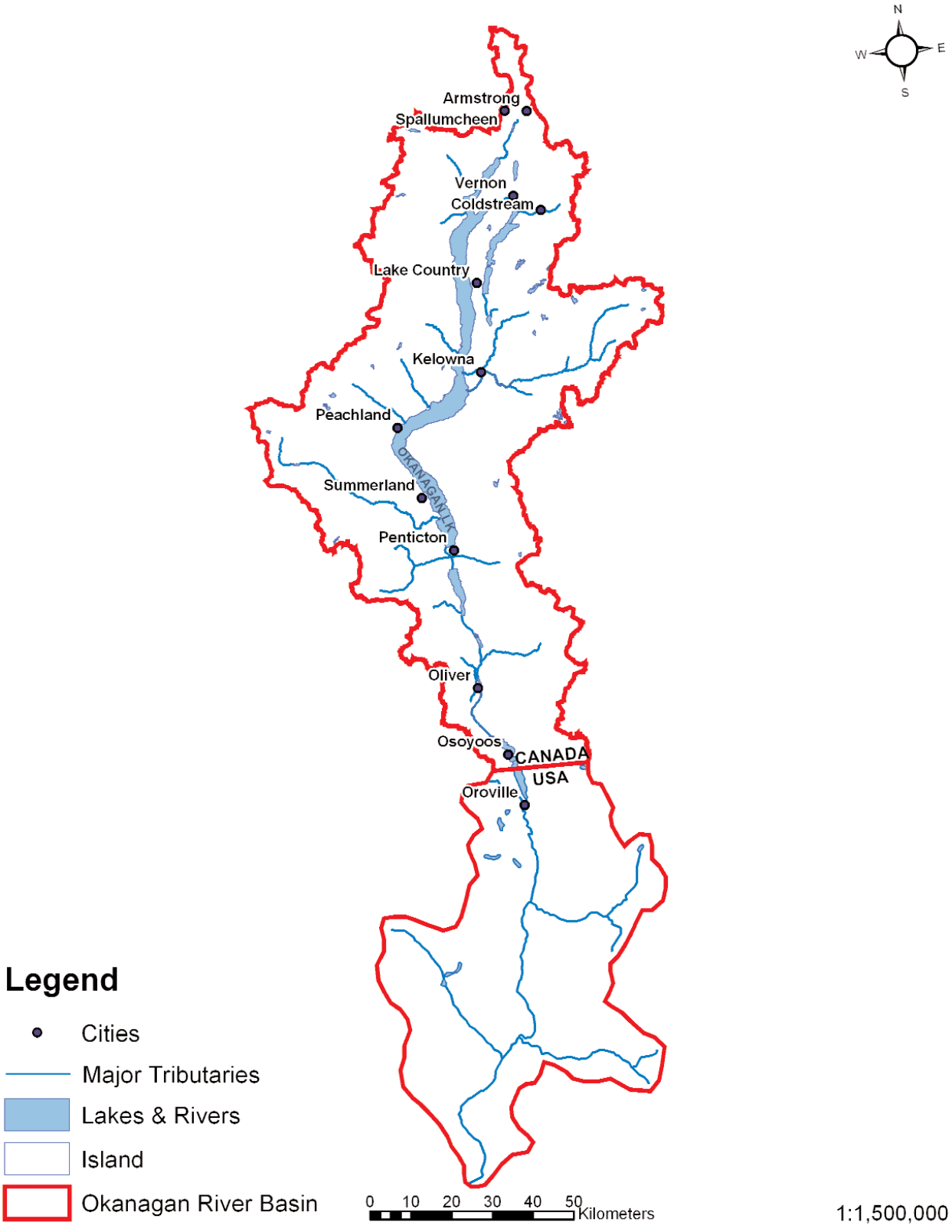
The Future

Population projections for the next thirty years indicate a high growth rate in both the Okanagan and Similkameen basins, particularly the former. Land development and water demands will inevitably increase. Climate changes that alter the volume and timing of water flow in streams are also anticipated.

With these future impacts as the backdrop, the need to protect and restore fish populations and fish habitat has never been more urgent. Several government agencies, the Okanagan Nation, and community groups are already involved in many meaningful projects throughout the Okanagan, and to a lesser degree in the Similkameen.

These efforts must be continued, expanded, and coordinated in order to realize the greatest benefits for both people and fish.

Part I: *The Okanagan Basin*



Chapter One

Overview of the Okanagan Basin

Description

- The Okanagan Basin includes all the land surrounding the streams and lakes that ultimately drain into the Okanagan River (Map 1 Section I cover). The basin covers an area of about 8,200 square kilometres in British Columbia. From the town of Armstrong to the international border with the United States, the Okanagan Valley is about 160 kilometres long; it extends another 115 kilometres to Brewster, Washington, where the Okanogan River flows into the Columbia River. In the United States, Okanagan is spelled Okanogan, which will be used in this report when referring to the river south of the border.
- Mountains rise on either side of the Okanagan Valley to heights up to 2,500 metres. The valley bottom, which contains a chain of six large lakes, drops in elevation by 133 metres from Wood Lake at the top of the chain to Osoyoos Lake at the bottom (391 to 258 metres above sea level). In order of elevation, the lakes are Wood, Kalamalka, Okanagan, Skaha, Vaseux, and Osoyoos. Osoyoos Lake straddles the border with Washington State.
- Water flows from small lakes in the hills, referred to as headwater lakes, into streams and creeks that flow to the six large lakes in the valley bottom and to Okanagan River. The Okanagan River begins at the outlet of Okanagan Lake and flows south through three of the lakes, Skaha, Vaseux, and Osoyoos, and eventually to the Columbia River. The Okanagan/Okanogan Basin is one of the major basins that contributes water to the Columbia River.
- For two years running, 2002 and 2003, the Outdoor Recreation Council of BC designated Okanagan River as British Columbia's most endangered river. In 2004, the river is number three on the list. Earthwild International ranked Okanagan River 3rd on the 2003 list of endangered rivers in Canada. For specific details on why the river receives these rankings, see *Chapter 6: Okanagan River.*

What is the origin of streams and lakes in the Okanagan Basin?

- Many of the features in the okanagan Basin, particularly the large lakes, were formed in large part by glaciers. The most recent glacier covering the okanagan began to melt about 15,000 years ago. At its peak, the glacier may have been as thick as three kilometres. During the melt, or deglaciation, ice dams formed at several locations in the okanagan Basin, the last being at okanagan Falls. This backed up the water and created Lake Penticton, which was more than 100 metres higher than the surface of today's okanagan Lake. Eventually, the water drained and left the configuration of lakes and rivers that we know.

What is the climate of the Okanagan Basin?

- The Okanagan is in the rain shadow of the Coast and Cascade mountains and so has a dry climate. Precipitation increases from south to north in the valley, with about 33 centimetres falling each year in Oliver and nearly 50 centimetres each year in Armstrong. Air temperature is about 2 ^{0} C higher, on average over the year, in Oliver than in Armstrong.
- Climate change is taking place in the Okanagan Basin. The climate has become warmer and wetter in the last century. For example, in Summerland, an average of 27 more frost-free days occurred in 1993 than in 1907. With more frost-free days, the agricultural season is longer and requires more water. More precipitation also falls as rain rather than snow, so the timing changes of water inputs to streams (see Figure 1).

What is the hydrology, or stream flow pattern, in the Okanagan Basin?

- Streams in the Okanagan are fed mainly by snow melt. The snow that falls each winter melts in spring and enters the streams. The resulting high water flow is called the spring freshet, and accounts for two-thirds of annual stream flow. By July, the freshet has subsided and water flow remains low for the summer, autumn, and winter. This means that water flow in creeks is low during the peak irrigation months and during the peak migration and spawning periods for fish.
- Scientists have noticed changes in streams that are probably related to climate change: an earlier start to the spring freshet, lower water flow in autumn, and higher water flow in early winter (Figure 1). They predict that these trends will continue over the next 80 years.

Past and projected water flow in Whiteman Creek, which enters Okanagan Lake near Vernon

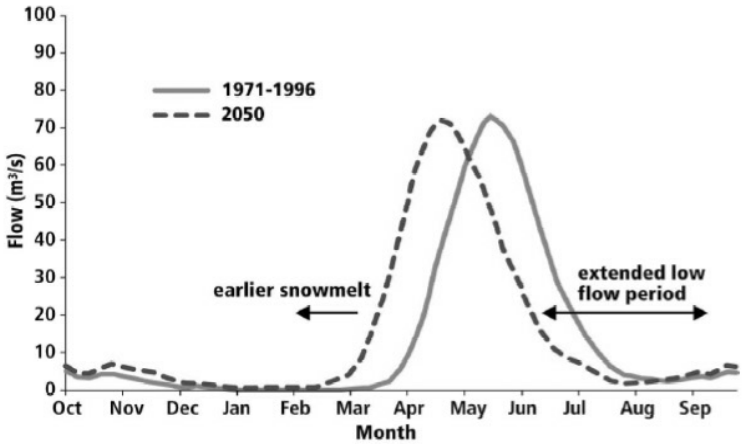


Figure 1. Past and projected water flow in Whiteman Creek.
Modified from: Cohen and Kulkarni 2001.

What do we know about fish populations in the Okanagan Basin?

- During the most recent glaciation, which was at its maximum extent about 15,000 years ago, the okanagan Basin was covered in ice. The southern two-thirds of the Columbia River system was not covered with ice, and most of the present native fish species in the okanagan came from the lower Columbia.
- Thirty-eight different types of fish currently live in the okanagan's lakes and streams (Table 1). This number includes sockeye and kokanee salmon as different types, even though they are the same species, and the same for steelhead and rainbow trout.
- Fourteen of these 38 fish types are not native to the valley. Some, such as eastern brook trout and lake whitefish, were stocked into okanagan lakes or streams for angling. others, including carp and yellow perch, had been stocked in the United States and they found their own way across the border into Canadian waters.
- Traditional Ecological Knowledge tells us that four other fish species were once native in portions of the okanagan, but are no longer found here. These are chum, coho, and pink salmon, and white sturgeon. Some people believe white sturgeon are still present.
- of the 20 fish native to the okanagan and still found here, one, chiselmouth, is considered to be "at risk" and was placed on a provincial blue list. This means that chiselmouth are vulnerable to impacts from either human or natural events. Habitat loss or damage is frequently a big threat to species at risk.
- The endangered status of steelhead, chinook, and sockeye is currently under investigation.

Table 1. Fish species in the Okanagan Basin

Common name	Scientific name	Status	Notes
Black bullhead	*Ameiurus melas*	Introduced	First recorded 1941. Invaded from US.
Black crappie	*Pomoxis nigromaculatus*	Introduced	First recorded 1985. Invaded from US.
Bluegill	*Lepomis macrochirus*	Introduced	First recorded 2001. Invaded from US.
Bridgelip sucker	*Catostomus columbianus*	Native	
Brown bullhead	*Ameiurus nebulosus*	Introduced	Presence unconfirmed.
Burbot	*Lota lota*	Native	
Carp	*Cyprinus carpio*	Introduced	First recorded 1917. Invaded from US.
Chinook salmon	*Oncorhynchus tshawytscha*	Native	
Chiselmouth	*Acrocheilus alutaceus*	Native – at risk	Blue-listed.

Common name	Scientific name	Status	Notes
Chum salmon	*Oncorhynchus keta*	Extirpated	
Coho salmon	*Oncorhynchus kisutch*	Extirpated	
Eastern brook trout	*Salvelinus fontinalis*	Introduced	First recorded 1924. Stocked.
Goldfish	*Carassius auratus*	Introduced	Presence unconfirmed.
Kokanee	*Oncorhynchus nerka*	Native	
Lake chub	*Couesius plumbeus*	Native	
Lake trout	*Salvelinus namaycush*	Introduced	First recorded 1909. Stocked.
Lake whitefish	*Coregonus clupeaformis*	Introduced	First recorded 1894. Stocked.
Largemouth bass	*Micropterus salmoides*	Introduced	First recorded 1909. Invaded from US.
Largescale sucker	*Catostomus macrocheilus*	Native	
Leopard dace	*Rhinichthys falcatus*	Native	
Longnose dace	*Rhinichthys cataractae*	Native	
Longnose sucker	*Catostomus catostomus*	Native	
Mountain whitefish	*Prosopium williamsoni*	Native	
Northern pikeminnow	*Ptychocheilus oregonensis*	Native	
Peamouth chub	*Mylocheilus caurinus*	Native	
Pink salmon	*Oncorhynchus gorbuscha*	Extirpated	
Prickly sculpin	*Cottus asper*	Native	
Pumpkinseed	*Lepomis gibbosus*	Introduced	Date unknown. Invaded from US.
Pygmy whitefish	*Prosopium coulteri*	Native	
Rainbow trout	*Oncorhynchus mykiss*	Native	
Redside shiner	*Richardsonius balteatus*	Native	
Slimy sculpin	*Cottus cognatus*	Native	
Smallmouth bass	*Micropterus dolomieu*	Introduced	First recorded 1937. Invaded from US. Stocked in 1985.
Sockeye salmon	*Oncorhynchus nerka*	Native	
Steelhead trout	*Oncorhynchus mykiss*	Native	
Tench	*Tinca tinca*	Introduced	First recorded 1941. Invaded from US.
White sturgeon	*Acipenser transmontanus*	Extirpated (?)	
Yellow perch	*Perca flavescens*	Introduced	First recorded 1937. Invaded from US.

Data from: Fish Wizard, Northcote et al. 1972, Wright et al. 2002.

What is the human population in the Okanagan Basin?

- Between about 9,000 and 6,000 years ago, the Salish people came to the Okanagan, which is the name they used and means "head of the river." At its peak, the First Nations population in the valley and surrounding areas numbered about 12,000 people. Fish and fishing were important to their culture. Today there is little opportunity for the Okanagan people to fish because of numerous habitat and fish management implications.
- European settlement began in 1859 and grew to an estimated 400 settlers in the valley by 1890. The settlements arose next to water, mostly Okanagan Lake. Vernon, Kelowna, and Penticton were all founded in 1892.
- In 1971, the Okanagan was home to approximately 114,000 people and in 2001 about 300,000 – an increase of more than double in 30 years. In the next 30 years to 2031, the estimates are that about 450,000 people will live in the Okanagan (Figure 2). This growth rate is in the top three for British Columbia. In addition to residents of the valley, huge numbers of tourists flood in each year, mostly in summer. In 1970, 485,000 tourists visited the Okanagan, and in the mid-1990s (the latest numbers available), 4.8 million tourists visited.

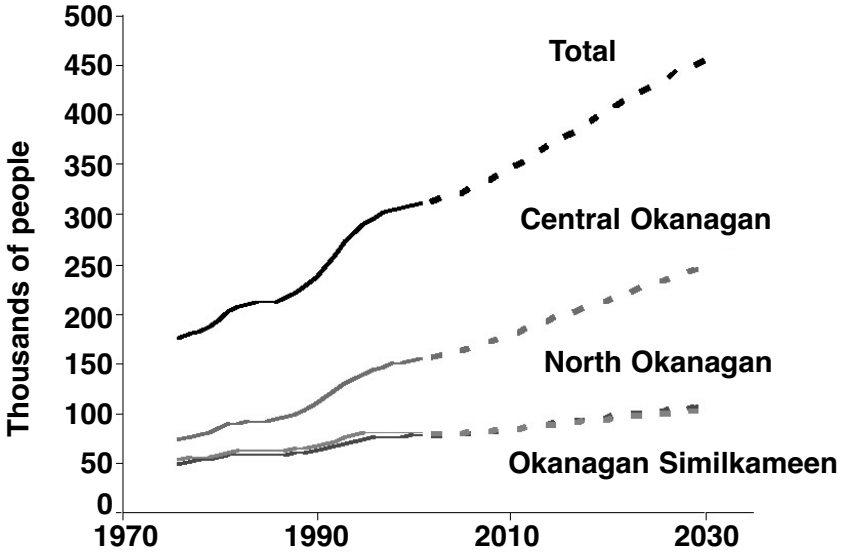


Figure 2. The population of Okanagan Basin from 1976 to 2031.
Solid lines = actual population, dotted lines = projected population. Data from BC Statistics.

What impacts and human activities affect fish and fish habitat in the Okanagan Basin?

- Human activities have had wide ranging impacts on the lakes, streams, and rivers in the Okanagan Basin. These activities include land use, water use, flood control, recreational fishing, and species introductions.
- The influx of people to the Okanagan Valley has had enormous impacts on the landscape. Primary land uses are agriculture, forestry, and urban development. There is also some mining. These activities frequently occur near lakes and streams, altering shorelines and streambanks. Even when land use activities aren't near water, they can still have impacts. Land alterations, such as logging or land clearing, affect the way in which water runs across the land, what it carries with it, and what ultimately enters lakes and streams.
- With land use, there is water use. Water is withdrawn from lakes and streams for domestic, irrigation, and industrial activities. To help ensure that water is available for human use year-round in the dry Okanagan, dams have been erected on most of the valley's streams and headwater lakes. In 1913, there were 11 dams on streams that flow into Okanagan Lake, and by 1998, there were 147 (Figure 3).
- Three-quarters of all water used in the Okanagan Basin goes to agriculture. A significant problem is the timing of peak water needs compared to the timing of peak water availability. Agricultural activities generally need water from June to September, but most of the water flow in streams occurs in April and May (see Figure 1 Page 2).
- About 90% of all streams in the Okanagan are already at, or in some cases beyond, their capacity to have water withdrawn for human use. In other words, there is no extra water available in these streams after we have withdrawn water and after the needs of fish and wildlife have been considered. For those streams beyond their capacity, the fish and wildlife are generally the ones that lose out when water shortages occur.

  A recent estimate says that with current water consumption and population growth rates, human demand will exceed the available water supply by 2020. Even without water withdrawals on Okanagan streams, the low flows that naturally occur in summer and autumn limit fish production and survival. Water withdrawals simply exacerbate this limitation.
- In 1969, a proposal was made to divert water from the Shuswap River into the Okanagan Basin. This prompted a four-year, intensive study of the Okanagan, known as the Okanagan Basin Study. The diversion never occurred, but other inter-basin water diversions have been made. Water diversions change water flow patterns, and also increase the risk of introduced species moving into a new location.
- As the population of the Okanagan Basin grew during the 1900s, more and more nutrients were being discharged in the sewage that went into, primarily, the main valley lakes. Large amounts of phosphorus, in particular, deteriorated the water quality in the lakes and caused algal blooms to occur. During the 1970s, sewage treatment facilities were upgraded and phosphorus loading began to drop. By 2000, the phosphorus load had dropped by 90%, despite the increasing volume of effluent discharged as a result of population growth.

- Before human settlement, extensive wetlands existed in the Okanagan Valley bottom. These wetlands absorbed water from the spring freshet and stored it, releasing the water slowly. More than 85% of these wetlands were filled in and destroyed as settlements grew.

  Not only was the wetland habitat lost and many plants and animals affected, but the capacity to absorb the spring freshet was gone. The communities alongside Okanagan River, especially Penticton in the early 1900s, were then subjected to frequent floods.

  Eventually, to control flooding, Okanagan River was straightened into a channel with dykes on either side. This channelization had major impacts on the habitat within the river and on the vegetation that grew alongside the river. Today, the channel bears little resemblance to the original river, with only a short section upstream of Oliver remaining in natural condition.

- Plant and animal species that are not native to an area, also called exotic or introduced species, can have serious consequences for native species. In the Okanagan, 14 fish species, the aquatic plant Eurasian water milfoil, and the freshwater shrimp *Mysis relicta* are introduced species that have varying degrees of effect on native fish. They displace native fish from their habitat or compete with them for food. Some, like the water milfoil, were not intentionally released and probably came from a home aquarium.

  Others, specifically *Mysis* shrimps, were intentionally released to provide a benefit to native fish, but their harmful effects weren't yet realized. Once established, introduced species can be difficult, or impossible, to eradicate.

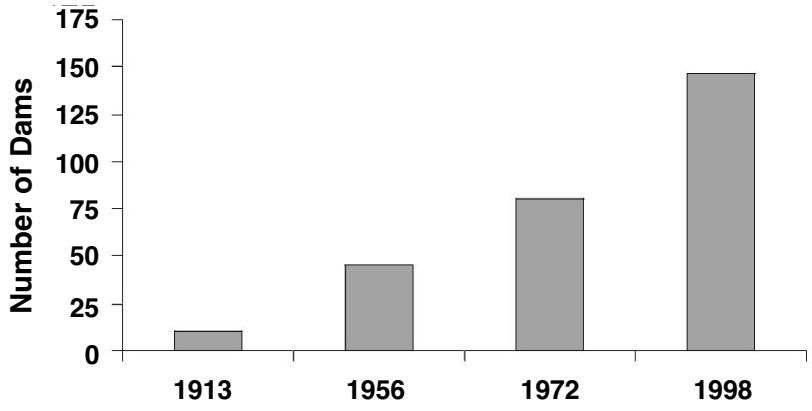


Figure 3. Dams in the Okanagan Basin north of Penticton, 1913-1998.

Data from Hall et al. 2001.

What do we know about the fishery in the Okanagan Basin?

- Historically, the Okanagan people fished throughout the Okanagan Basin. A key fishing site was in Okanagan River at Okanagan Falls where sockeye, chinook and steelhead were captured.
- Sport-fishing is important in the Okanagan Region (includes Okanagan, Similkameen, Kettle and Shuswap rivers), with nearly 900,000 fish caught in 2000. Rainbow trout are most frequently angled, followed by kokanee salmon and brook trout.
- The economic value of angling in the Okanagan Region was estimated at over $16 million in direct expenses from 420,000 angling days in 2000.
- In the early 1900s, most fishing took place on the main valley lakes because access to headwater lakes was limited, and few fish of interest to anglers lived in them. By the 1940s, however, fish stocking had begun and angling effort shifted towards the headwater lakes.

Chapter Two

Okanagan: Headwater Lakes

Description

- The headwater lakes in the Okanagan include all lakes in the basin except the six large ones along the main valley floor (Kalamalka, Wood, Okanagan, Skaha, Vaseux and Osoyoos lakes). Approximately 200 headwater lakes exist, but most of them are small with a surface area less than 80 hectares (0.8 square kilometres). Maximum depths vary from less than 4 metres to 58 metres (Pinaus Lake). Many are also at high elevation (>1,000 metres), especially those that have been identified as having good sport-fishing opportunities.
- Productivity varies in the Okanagan headwater lakes. One measure of lake productivity is the concentration of total dissolved solids, or TDS, in the water. TDS is generally measured in parts per million, ppm. TDS in 78 of the Okanagan headwater lakes ranges from 11 to 472 ppm, with an average of 119 ppm. Two lakes near Okanagan Falls, Green and Mahoney, have exceptionally high TDS values of about 2000 ppm and 9000 ppm. These lakes are hyper-saline, meaning that they are many times saltier than the sea, and they result from unusual bedrock conditions.
- At least 70 headwater lakes have dams at their outlets. Most of the headwater lakes in the Okanagan Basin are managed for water use and/or recreational fisheries.

What do we know about fish populations in the Okanagan Headwater lakes?

- Historically, few of the headwater lakes supported fish populations, and those that did had small populations of suckers or dace. However, a fish stocking program began in 1917 and continues today. In the early days of the program, rotenone and other chemicals were used in some lakes in an attempt to eliminate the native fauna before stocking trout. This practice occurred in 14 Okanagan headwater lakes between 1954 and 1972, but is no longer used. As a result of stocking, rainbow trout and eastern brook trout now occur in over 100 of the headwater lakes.
- In the late 1960s, 60 lakes were actively stocked. This rose to 73 lakes a decade later, and remains at this number. In total, 260,550 rainbow trout of various sizes and ages were released into headwater lakes in 2003, making up more than 80% of all fish stocked into these lakes during the year. The remaining stocked fish were eastern brook trout, all of which are released as all-female or sterile fish.

What do we know about fish habitat in Okanagan headwater lakes?

- In the early 1970s, 129 headwater lakes were surveyed and most couldn't support self-sustaining game fish populations because they lacked

spawning habitat. Therefore, they were identified for fish stocking. Those lakes with dams on them experience water level fluctuations that have negative effects on the productivity of whatever shoreline habitat does exist. A few lakes now have rainbow trout populations that have naturalized, or which reproduce on their own, but annual stocking still occurs in 73 lakes because naturalized production is low.

- During the 1970s study, 11 lakes were sampled intensively for one summer. They ranged from 3 to 300 hectares in surface area, and 2 to 22 metres in depth. They all contained stocked rainbow trout, two also had fine-scaled suckers, and one had dace.

  Some of the lakes were productive in terms of the microscopic plant and animal life that grew in them, but none had good quality spawning habitat to support the stocked rainbow trout. This information remains as the only large study that was ever conducted on the headwater lakes of the Okanagan. However, the Ministry of Water, Land and Air Protection conducts annual studies on specific lakes.

What impacts and human activities affect fish and fish habitat in Okanagan headwater lakes?

- Dams created at the outlet of headwater lakes cause lake levels to fluctuate, and therefore affect the productivity of these lakes (Photo 1).
- In a few locations, water has been diverted between watersheds. In two cases, this has resulted in water entering the Okanagan from other drainages: water from Duteau Creek (Shuswap drainage) was diverted into Coldstream Creek, and water from the Kettle River (Kettle drainage) was diverted into KLO Creek. Water diversions change water flow patterns, and also increase the risk of introduced species moving into a new location.
- Land use in the watersheds of headwater lakes includes high impacts from urban and agricultural activities at lower elevations, and moderate impacts from forestry, agriculture, and urban development at higher elevations. Logging roads are extensive in many watersheds, and frequently follow streams up to their headwaters. These roads increase access to headwater lakes, change water runoff patterns, and contribute to erosion.
- A total of 141 leased properties adjacent to 16 headwater lakes may be sold by Land and Water BC, Inc. When these sales were initially proposed, local governments, irrigation districts and the public raised concerns about possible impacts to water quality. Land and Water BC commissioned a study of water quality in the lakes, and currently awaits the final report.

  If the report concludes that the water quality concerns are unfounded, a further study of water quantity issues will be done before making a decision about selling the leased properties.
- Fish now exist in over 100 lakes where they didn't previously live. The majority of these fish – rainbow trout – are native to the Okanagan, although not all the rainbow trout stocked over the years have originated from Okanagan strains. The remainder of stocked fish, eastern brook trout, are not native, but they are stocked as all-female or sterile fish.

What do we know about the fishery in Okanagan headwater lakes?

- Angling is a major activity on the headwater lakes, and helps to divert fishing pressure away from wild fish populations. The principal fish stocked, and angled, are rainbow trout. Some lakes are stocked with all-female or sterile eastern brook trout.
- In 1995 (the most recent data available), the number of angler days was estimated at nearly 260,000 for stocked lakes in the Okanagan Region, which includes Okanagan, Similkameen, Kettle, and Shuswap basins. In the Okanagan, only headwater lakes are stocked for angling, and not the main valley lakes. A more recent angler survey in 2000 does not specify angling effort on stocked lakes.

What factors limit fish production in Okanagan headwater lakes?

- The two key limiting factors for trout production in the headwater lakes are available spawning habitat and water drawdown on those lakes that are dammed. However, the lakes are being managed as recreational stocked fisheries, thus it is preferable not to have spawning habitat so the populations don't become stunted.
- There is no information about the habitat or limiting factors for production of suckers and dace, which are known to exist in a few headwater lakes.
- Some of the headwater lakes have productive food chains of microscopic plants and animals. High productivity can limit overwinter survival of fish because oxygen levels decline in the water. Other lakes have low productivity, which limits the available food and can restrict the number of fish that survive and the size to which those fish grow. For lakes at high elevation, the growing season is also short and water temperature remains low, even in summer.

What gaps exist in our knowledge of fish and fish habitat in Okanagan headwater lakes?

- A 1971 survey of 129 headwater lakes, which included detailed study of physical, chemical and biological characteristics on 11 lakes, has never been repeated. Some information can be found on specific lakes, such as Hydraulic and Swalwell lakes, in the provincial ministry database for environmental monitoring. A fisheries database held in Penticton also contains information about fish stocks and recreational fishery status on a large number of naturally recruiting and stocked lakes. However, the information is limited or out of date on some priority lakes.
- Apart from the passing mention of suckers and dace in a few headwater lakes examined during the 1971 survey, no inventory of native fish populations or fish habitat exists for Okanagan headwater lakes. Native fish populations may have been eliminated from a few of the lakes where rotenone and other chemicals were used prior to stocking with trout. Net and creel surveys for trout are conducted annually on a limited number of wild stock and hatchery supported lakes.

What is being done to protect or restore fish and fish habitat in Okanagan headwater lakes?

- The Ministry of Water, Land and Air Protection gathers information each year about the status of fish stocks in a limited number of the headwater lakes. They also assess the recreational fishery. These assessments provide information to assist in developing or modifying management strategies. The number of lakes assessed each year depends on available funds. Lakes are prioritized for assessment based on the potential for impacts to wild fish stocks, angler use, fishery status, reported problems or conflicts, and the length of time since a previous assessment.
- The Ministry of Water, Land and Air Protection continues to stock 73 of the headwater lakes with fish each year. Restrictive regulations and access restrictions are in place to protect both hatchery and wild fish stocks in these and other lakes in the Okanagan Basin.
- The Ministry of Water, Land and Air Protection has installed aerators in several stocked lakes to increase oxygen levels in the water and improve overwinter fish survival.

Photo: R. Rae

Photo 1. Big Horn Reservoir on Terrace Creek, a trubutary to Lambly Creek.

The reservoir was formed by a 29-metre high dam on Terrace Creek. Although not a natural headwater lake, the effect of water drawdown on the shoreline is visible in this photo.

Chapter Three

Okanagan: Tributary Streams North of Penticton

Description

- Most Okanagan Valley streams that flow north of Penticton enter Okanagan Lake, although a few flow first into Wood or Kalamalka lakes (Map 2, page 15). Forty-six named tributary streams flow directly into Okanagan Lake.
- Mission Creek is the largest stream entering Okanagan Lake and has a watershed area of 860 square kilometres. More details on Mission Creek are given below. Middle Vernon Creek is the main inflow to Wood Lake, and Coldstream Creek to Kalamalka Lake. Kalamalka Lake drains into Okanagan Lake via Lower Vernon Creek.
- In a 2003 assessment of focal watersheds, 18 tributary streams north of Penticton were named as having high or very high significance for fish protection because of the sensitivity of fish stocks (kokanee salmon, rainbow trout, and rare species) and the current or potential level of fish production in the stream (Table 2).
- Approximately 80% of all surface water licensed in the Okanagan comes from streams; the rest comes from main valley lakes. Ground water is not licensed, so no data are available for ground water use. Over 90% of streams are now at, or beyond, their maximum capacity for water withdrawals. Therefore, there is no extra water available in these streams after we have withdrawn water and after the needs of fish and wildlife have been considered. For those streams beyond their capacity, the fish and wildlife are generally the ones that lose out when water shortages occur.

Table 2. Ratings of tributary streams north of Penticton.

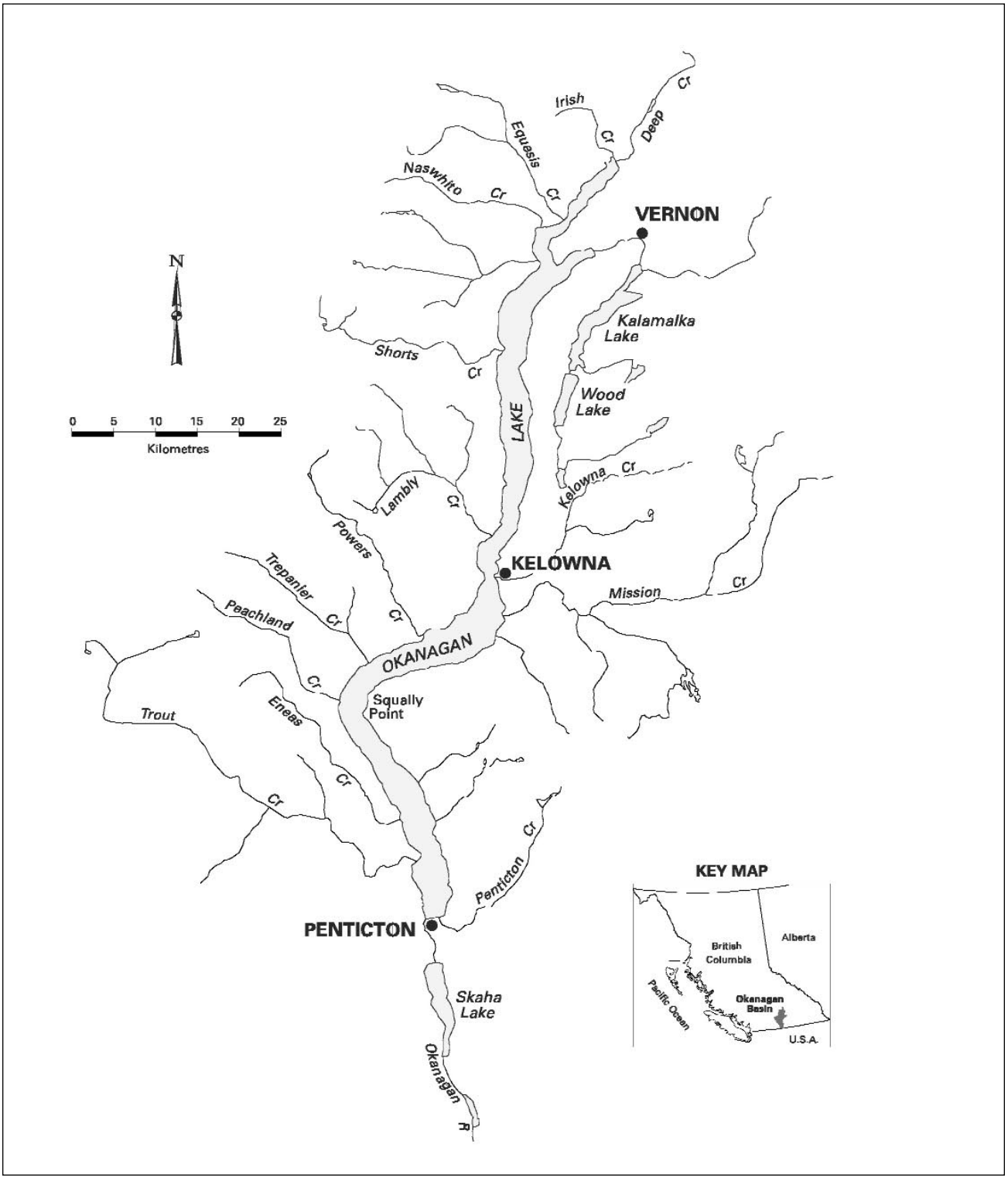
Creek	Significance for Fish Protection [a]	Habitat Impact [b]	Significance for Habitat Restoration [c]
BX	High	High	High
Coldstream	Very High	High	Very High
Equesis	Very High	High	Very High
Hydraulic	High	Medium	High
KLO	High	Medium	High
Lambly	High	High	High
Mill (Kelowna)	High	High	High
Mission	Very High	High	Very High
Naswhito	High	High	High
Oyama	High	Medium	Medium
Peachland	Very High	Medium	High
Penticton	High	High	High
Powers	Very High	High	High
Shorts	High	High	High
Trepanier	High	High	High
Trout	Very High	High	High
Vernon	Very High	High	High
Whiteman	Very High	High	High

From Matthews and Bull 2003.

a The ratings of significance for fish protection refer to focal fish species (rainbow trout and rare species) and were obtained by ranking the sensitivity of fish stocks and the current or potential level of fish production in the stream.

b Habitat impact was rated for forestry, agriculture, urban development, low water flow, and temperature. The highest score from any of these impacts was used as the habitat impact for the whole creek or river.

c Significance for habitat restoration was based on the fish protection and habitat impact scores if they were the same and on expert opinion if they differed.



Map 2. Tributary streams north of Penticton

From Okanagan Lake Action Plan Report

What do we know about fish populations in tributary streams north of Penticton?

Rainbow trout

- Two variants of rainbow trout occur in Okanagan streams: those that live in one of the large lakes and spawn in creeks, and a second that both lives and spawns in creeks. The creek rainbow trout are found in most streams north of Penticton, and may be upstream of barriers that rainbow trout from lakes can't pass. Some of these creek rainbow trout may move downstream during their lives in search of larger areas of habitat.

  The lake rainbow trout use 17 creeks for spawning, and their resulting young either return to the lake as fry or stay in the streams for one or two years before returning to the lake. They return as adults to spawn at ages of 3 to 6 years.

- There is little information on the numbers of rainbow trout inhabiting Okanagan streams, or on the numbers in lakes that return to spawn in the streams. A single creek, Mission Creek, accounts for at least 65% of the spawning by rainbow trout that live in Okanagan Lake.

Kokanee salmon

- Many kokanee salmon from Okanagan, Wood, and Kalamalka lakes return to tributary streams to spawn during late September and early October. A survey in 1971 examined 26 streams but found that only nine had more than 500 kokanee spawning in them. (Some kokanee from these three lakes also spawn in habitat along the lake shoreline; see *Chapter 4.1: Okanagan Lake)*.

- Okanagan Lake kokanee spawn in 17 of the tributary streams, but the number returning to spawn has declined in the last three decades. Estimates are that in 1971, over 450,000 kokanee spawned in streams, but this dropped in 1999 to seven thousand, the lowest returns on record. The current numbers are 44,000 for 2002 and 24,000 for 2003 (Table 3, Figure 4).

- Kokanee eggs and fry have been stocked into Okanagan Lake and its tributaries since the 1920s. For several decades, the fry came from the west arm of Kootenay Lake and Meadow Creek at the north end of Kootenay Lake. The most recent stocking occurred in Mission Creek from 1986-1991, when nearly 4 million eggs and fry from Mission Creek stock were released. In total, about 10 million kokanee eggs and fry have been stocked into Okanagan Lake and streams, but the impact of this stocking is unknown.

What do we know about fish habitat in tributary streams north of Penticton?

- In most Okanagan streams, only the first 1-2 kilometres above the stream mouth are used for spawning by fish from Okanagan Lake. The exceptions are Mission Creek, where 19 kilometres are used, and Whiteman Creek, with nearly five kilometres. Stream-resident species may spawn higher up.

- According to a report from the 1930s, rainbow trout spawning habitat had already been severely degraded by 1935 as a result of flood protection and irrigation. By the 1950s, about 90% of the spawning habitat in streams north of Penticton was estimated to be gone.

- For kokanee to migrate into streams and spawn in late summer, there must be sufficient water of an appropriate temperature, about 10-15° C for spawning. Water flow in most streams is affected by dams and withdrawals with the result that the level can be too low for fish migration.

  Riparian, or streamside vegetation, helps keep water temperatures cool, but the vegetation alongside many streams has been removed or disturbed, particularly in lower stretches where most kokanee salmon and rainbow trout spawn. Low water flow also increases the temperature of the water as it pools or flows slowly in the creek.

- In addition to having suitable migration conditions, salmon and trout need good quality spawning gravel in which to lay their eggs. The gravel must be clean and have enough water flowing over it to provide oxygen for the incubating eggs and remove wastes. Spawning habitat is variable among the tributary streams. Trout Creek, for example, has poor in-stream spawning conditions from a perpetual landslide that causes a large amount of silt to enter the creek.

  In most years, such as in 2003, these poor conditions are exacerbated by extremely low water flow conditions resulting from water withdrawals. This limits or prevents kokanee accessing the creek from Okanagan Lake, and also results in high water temperatures.

Table 3. Estimates of kokanee spawners in selected streams.

Creek	1971	1990s#	2002	2003
Mission*	354,200	50,000	20,203	13,650
Peachland	22,650	7,000	7,218	4,150
Trepanier	8,700	2,000	2,991	1,000
Powers	7,940	13,500	6,591	1,500
Lower Vernon	950	800	276	50
Kelowna (Mill)	nd	3,500	1,288	350
Penticton	nd	nd	1,420	1,800
Trout	nd	nd	2,980	100

Data from Northcote et al. 1972, Wildstone Resources 1992, Andrusak et al. 2003, Wilson 2004.

* Since 1988, numbers include both the creek and spawning channel.
\# An average from the early 1990s; source doesn't specify years.
nd no data

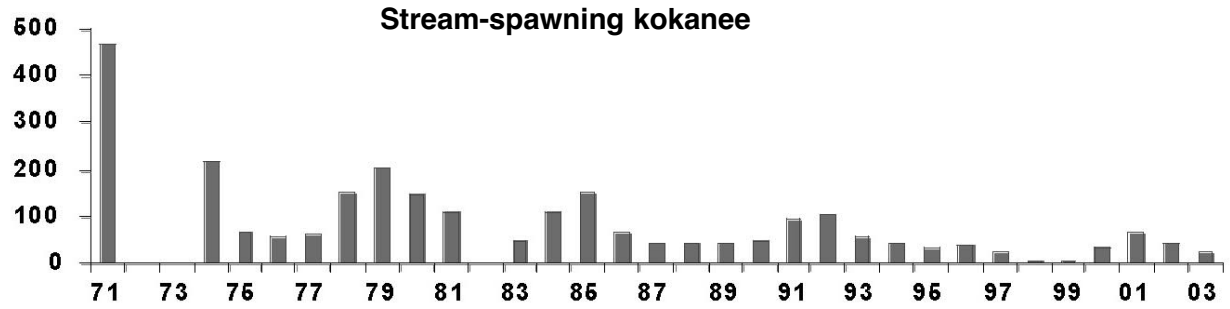


Figure 4. Stream-spawning kokanee from Okanagan Lake, 1971-2003
Data from Matthews 2004

What impacts and human activities affect fish and fish habitat in tributary streams north of Penticton?

- Dams on the outlets of headwater lakes and along stream channels regulate the amount of water flow. Most of the Okanagan tributary streams have been affected by dams; Whiteman and Nashwito creeks are two main tributaries without dams.
- Water flow is naturally low in Okanagan streams in late summer when fish begin to migrate into them. Water withdrawals also tend to be high at this time of year, particularly for irrigation. Climate changes that extend the growing season and alter the timing and volume of water in streams will increase the severity of low stream flow in late summer.
- Some water withdrawal intakes, particularly older ones, were constructed with a sill that crosses the creek to direct water into the intake. These can become barriers to fish, preventing them from migrating upstream. Inadequate screening of intake pipes can also result in significant fish mortality.
- Brenda Mines releases treated water from its tailings pond into Trepanier Creek (via MacDonald Creek). These water releases are scheduled during the spring freshet, and also during the autumn to supplement migration and spawning flows for kokanee. Brenda Mines extracted copper and molybdenum for a 20-year period (1970-90) and decommissioning started in 1998. Channels divert precipitation away from the mine site.
- Land use in the stream watersheds includes high impacts from urban and agricultural activities at lower elevations, and moderate impacts from forestry, agriculture, and urban development at higher elevations. Logging roads are extensive in many watersheds and frequently follow stream channels. These roads affect water runoff patterns and contribute to erosion and the accumulation of sediments. Overall habitat impacts for a selection of streams are in Table 2.
- Spawning habitat is generally reduced where streams have been straightened into confined channels for water control purposes. Examples of streams with poor habitat as a result of this type of channelization are Penticton, Trout, and Mission creeks (Photo 2).

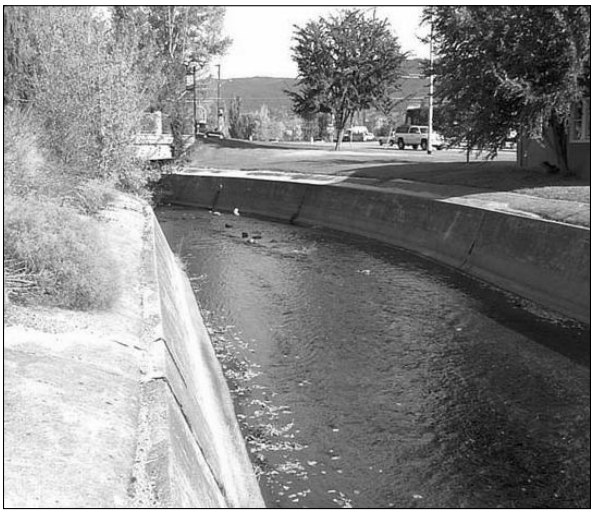


Photo: S. Matthews

Photo 2. Penticton Creek, channelized and lined with concrete.

What do we know about the fishery in tributary streams north of Penticton?

- Historically, the Okanagan people harvested rainbow trout spawners during the spring. Today, a small rainbow trout fishery continues. Kokanee were also harvested during the autumn spawning period from many of the tributaries, including Trout, Peachland, Mission, and Equesis creeks. However, there has been little harvest of kokanee since the late 1970s due to conservation concerns and observations of poor quality of the flesh.
- Recreational angling in tributary streams is limited to small fisheries in the upper sections of these streams and is aimed at stream-resident rainbow trout. Many of these tributaries are closed to angling in the lower sections to protect the lake-resident populations which use the streams for spawning and rearing.

What factors limit fish production in tributary streams north of Penticton?

- Fish production in the tributary streams north of Penticton is most limited by water quantity (sufficient water flow during migration), water quality (acceptable water temperature for migration and low levels of sediment), and availability of good quality spawning and rearing habitat. The loss of natural water flow patterns in streams, increasing population growth and land development, and climate change all play a role in limiting the capacity of streams to produce fish.

What gaps exist in our knowledge of fish and fish habitat in tributary streams north of Penticton?

- Kokanee salmon are the only fish that have been regularly assessed when they return to spawn in the streams. Little information exists on rainbow trout populations, either those that live entirely in streams or those that live in lakes and spawn in streams. Little information exists about other resident fish populations.
- Although water withdrawals from surface waters are licensed by the crown corporation Land and Water BC, there is no system of tracking the quantity of water that license holders actually withdraw. There is also no information on the impact to streams from ground water extractions. (New ground water regulations introduced by the Ministry of Water, Land and Air Protection in July 2004 focus on water quality and safety.)

What is being done to protect or restore fish and fish habitat in tributary streams north of Penticton?

- Stream water quality is monitored by the Environmental Protection branch of the Ministry of Water, Land and Air Protection. They monitor both water samples and the insect larvae that grow attached to the stream bed. The insect larvae are sensitive to changes in temperature, sediments, and other factors associated with land use. They can be used to rank the severity of land use impacts to streams.
- The Ministry of Water, Land and Air Protection has closed the fishery on many tributaries to protect spawning and rearing fish populations from Okanagan Lake. An angling closure is in effect for all streams during the rainbow trout spawning period (April 1 to June 30). Additional restrictions described in the *Freshwater Fishing Regulations Synopsis* (published annually by the Ministry of Water, Land and Air Protection) are also in place to protect stream populations.
- Several groups, including provincial, regional, and local governments, First Nations, and community groups have stream restoration work underway or planned for Okanagan streams. These include Mission and Penticton creeks. Land and water use planning processes are also in progress; for example, on Trepanier and Trout creeks. Stream protection is an important part of the planning.
- The Okanagan Lake Action Plan is a program run by the Ministry of Water, Land and Air Protection to recover kokanee populations in Okanagan Lake. As a component of this program, biologists and hydrologists have been assessing the current water flow conditions in streams, and the water flow required to meet basic needs of fish. With this information on actual and required water flow, they are now working with water license holders to address the needs of fish.
- Every year, biologists with the Okanagan Nation Alliance monitor the number of returning kokanee spawners in Nashwito, Whiteman, and Equesis creeks. Other tributaries are monitored through the Okanagan Lake Action Plan.

CHAPTER 3.1 MISSION CREEK

Description

- Mission Creek flows into Okanagan Lake on its eastern shore. It is the largest inflowing watershed, draining an area of approximately 860 square kilometres. As the stream approaches Okanagan Lake, it flows through Kelowna. The urban development of Kelowna has had huge impacts on Mission Creek by confining the stream channel, eliminating bends in the stream, and removing streamside vegetation, among others.

What do we know about fish populations in Mission Creek?

- Mission Creek supports the most kokanee and rainbow trout spawners of any stream on Okanagan Lake. Historically, 80% of Okanagan Lake kokanee and at least 65% of Okanagan Lake rainbow trout have spawned in Mission Creek.
- In 1971, over 350,000 kokanee spawners returned to Mission Creek in the autumn. By 1998, this had dropped to the lowest number of spawners on record, about 1,000 fish. Since then, the numbers have risen to about 20,000 in 2002 and 13,650 in 2003 (Figure 5).
- The only estimates of rainbow trout spawners returning to Mission Creek were made from 1975-79. The average number returning over these years was 421 per year. From 1978 to 1984, 144,000 hatchery-raised fry, originating mostly from Mission Creek but also from Kootenay stocks, were released to Okanagan Lake via Mission Creek.
- Other fish species listed as being present in Mission Creek include brook trout, burbot, longnose dace, peamouth chub, redside shiners, and suckers.

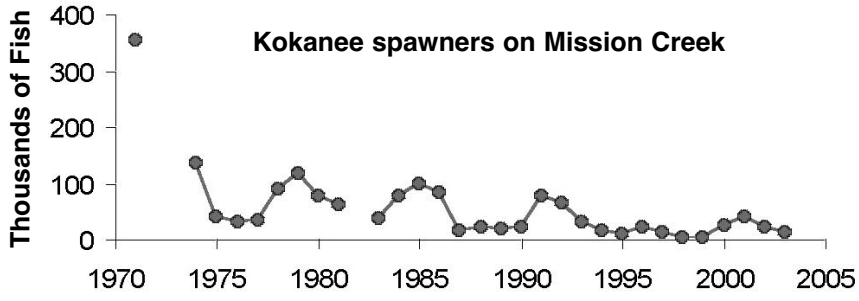


Figure 5. Estimates o f kokanee spawners in Mission Creek, 1971-20003
Data from Northcote et al. 1972, Andrusak et al. 2000.

Note: The 1971 data were direct counts of fish passing a counting fence, while the remaining data are estimates based on peak counts during the spawning eriod.

What do we know about fish habitat in Mission Creek?

- The lower 19 kilometres of Mission Creek are accessible for kokanee salmon and rainbow trout migrating from Okanagan Lake. Gallagher's Falls, a series of impassable waterfalls and cascades, prevents the fish swimming further upstream. Although 19 kilometres are accessible, most kokanee spawn in the lower 8-10 kilometres. More rainbow trout spawn in the stream's higher reaches, which support the highest number of juvenile trout.
- The diversity of habitat in the lower 13 kilometres of Mission Creek is limited by urban development. For example, there are few areas where large boulders or large pieces of wood create pools, and there are few riffles – areas of fast-moving water that form excellent spawning and feeding habitat. Side channels and backwater areas that were once joined to the main stream channel were cut off when the river was straightened and confined. Side channels and backwater areas create excellent refuge and holding habitat for fish.
- Historically, the lower end of Mission Creek's stream channel meandered in a series of bends. Now, the first 13 kilometres of Mission Creek have been partly or totally straightened into a uniform channel for flood control. To help offset this loss of habitat, a spawning channel was built in 1988 using an abandoned irrigation ditch. The spawning channel starts about 7 kilometres upstream of Okanagan Lake, within Kelowna city limits, and extends for about 900 metres. Up to 25% of the kokanee spawners in Mission Creek use the channel, although this is less than expected.

What impacts and human activities affect fish and fish habitat in Mission Creek?

- Channelization and dyking of Mission Creek occurred in the 1950s for flood control. This has confined the stream channel and removed much of the variability in habitat types.
- Landslides, many of which are natural and have happened historically, dump sediment into the stream. Recently, 95 active and inactive landslides were found in the Mission Creek watershed. The high sediment load in Mission Creek reduces the quality of spawning gravel, and probably affects the type and quantity of insect larvae that live on the stream bottom.

  These larvae are a food source for fish. The spring freshet, when a lot of water from snowmelt flows down the stream, usually cleans sediments out of the gravel. However, with dams, water withdrawals, and climate change altering the timing or volume of water flowing in the creek each spring, more sediments may accumulate.
- The amount of water licensed for withdrawal from Mission Creek is greater than the amount of water that would actually be in the stream during late summer in low flow, or drought, years. This can result in poor conditions for fish migration, spawning, and rearing, and therefore can limit fish production.
- Many of the irrigation pipes and ditches that remove water from Mission Creek have inadequate screens. This means that fish – especially juvenile fish – can get sucked into the pipes and killed.

- In the 1970s, kokanee eggs were taken from Mission Creek spawners and raised in a hatchery for release into Skaha Lake. This may be a contributing factor to the decline in kokanee spawners returning to this creek.

What do we know about the fishery in Mission Creek?

- Historically, the Okanagan people harvested kokanee from Mission Creek, and this is reflected in a small reserve belonging to the Westbank First Nation. This harvest ended in the late 1970s due to conservation concerns and changes in the quality of the kokanee.
- A small recreational fishery for rainbow trout takes place in the upper sections of Mission Creek.
- Fishing is not allowed in the lower 19 kilometres of Mission Creek to protect Okanagan Lake kokanee and rainbow trout that use the creek for spawning and rearing.

What factors limit fish production in Mission Creek?

- Both kokanee and rainbow trout are limited by available spawning habitat in Mission Creek, and rainbow trout are additionally limited by rearing habitat. The quality of spawning habitat is affected by the high sediment load to the stream.
- Low water flow creates problems for fish migration, and limits habitat quantity and quality, including temperature control.

What gaps exist in our knowledge of fish and fish habitat in Mission Creek?

- The numbers of Okanagan Lake rainbow trout that use Mission Creek as a spawning ground have not been estimated for over two decades. Little is known about the rainbow trout that live only in the stream.
- In the early 1990s, several fish were found in Mission Creek spawning channel that had not previously been documented from the stream. A fish biologist who examined them thought they might be a hybrid between Umatilla dace and another species. Umatilla dace are included on the red list of species at risk in BC, meaning that they are or could soon become endangered or threatened. The fish found in Mission Creek were never formally identified, and there have been no further reports of them in the stream.

What is being done to protect or restore fish and fish habitat in Mission Creek?

- The spawning channel continues to be maintained for spawning kokanee.
- A comprehensive restoration plan has been developed for Mission Creek by a partnership of community groups and local and provincial governments. It includes options for setting back some of the existing dykes to give the stream a wider channel, re-establishing some of the meanders, or bends, that were cut off when the stream was straightened, and building artificial riffles.

- Through the Okanagan Lake Action Plan, efforts are underway to better understand the hydrology, water use, and fish flow requirements of this important creek. The Ministry of Water, Land and Air Protection, which conducts the Okanagan Lake Action Plan, continues to work with water purveyors and other major water users to develop strategies that address the water quantity needs of both people and fish.
- The Ministry of Water, Land and Air Protection has been working with people who hold water withdrawal licenses to reduce fish losses resulting from inadequate screening of intakes.

Chapter Four

Okanagan: Main Valley Lakes

Description

- Six lakes lie along the floor of the Okanagan Valley and form a chain, linked by streams and Okanagan River. Wood Lake is joined to Kalamalka Lake by a short dredged channel, and Kalamalka Lake flows into Okanagan Lake via Lower Vernon Creek. The outlet of Okanagan Lake, at Penticton, is Okanagan River, which flows south through Skaha, Vaseux, and Osoyoos lakes. The elevation drop between Wood Lake and Osoyoos Lake is 133 metres (391 to 278 metres above sea level).
- Several other smaller lakes also lie along the floor of Okanagan Valley, and include Otter, Swan, Ellison, and Tugulnuit lakes. These lakes have been grouped with the headwater lakes (see *Chapter 2: Headwater Lakes*)
- The six lakes are variable in size with Okanagan Lake much larger and deeper than all the others, and Vaseux Lake the smallest and shallowest (Table 4). They also vary in water quality and productivity, as discussed below.
- Okanagan, Skaha, Vaseux, and Osoyoos lakes all have outlet dams, but only Zosel Dam downstream of Osoyoos Lake is managed for upstream fish passage. McIntyre Dam downstream of Vaseux Lake was originally built with a fish ladder, but it is not operational and would require considerable upgrading to become operational. Occasionally, fish are able to pass upstream of McIntyre Dam depending on how the dam is operated.

  The outlet dams on Skaha and Okanagan lakes were also built with fish ladders that have never been used.
- In addition to a general description of fish and fish habitat in the six lakes, more details are given in this report on Okanagan, Skaha, and Osoyoos lakes. Okanagan Lake and its kokanee salmon populations have been the subject of intensive recovery efforts, Skaha Lake is the site of an experimental reintroduction* of sockeye salmon in 2004, and Osoyoos Lake is the nursery for one of only two viable sockeye salmon populations that remain in the Columbia River watershed.

* See footnote regarding sockeye reintroduction terminology on page ii of Summary.

Table 4. Physical characteristics of the six Okanagan main valley lakes.

Lake	Length (km)	Surface area (km2)	Volume (km3)	Mean depth (m)	Maximum depth (m)	Water residence time (years)
Wood	6.6	9	0.2	22	34	20
Kalamalka	16	26	1.5	59	142	71
Okanagan	113	344	26.2	75	242	60
Skaha	12	20	0.56	26	57	1.2
Vaseux	4	2.8	0.02	6.5	27	0.03 (=1.5 weeks)
Osoyoos (North Basin)	7.5	9.9	0.2	21	63	
Osoyoos (Whole Lake)	16	23	0.4	14	63	0.7 (=36 weeks)

Data from Stockner and Northcote 1974.

What do we know about fish populations in Okanagan main valley lakes?

- Thirty-one different types of fish, both native and introduced, live in the six lakes, but not all are found in every lake (Table 5). This number includes sockeye and kokanee salmon as different types, although they are the same species, and the same for steelhead and rainbow trout.
- Eight native species occur in all six lakes: kokanee salmon, rainbow trout, largescale sucker, longnose sucker, mountain whitefish, northern pikeminnow, peamouth chub, and prickly sculpin.
- Sockeye salmon are only found in Osoyoos Lake, but Traditional Ecological Knowledge supports the view that historically they were present in other Okanagan lakes. Other sea-run species, including chinook salmon and steelhead trout, are also said to have migrated into the upper Okanagan Basin.
- Sturgeon have never been confirmed in the Okanagan Basin, but anecdotal reports suggest that they may be present.
- Fourteen introduced fish live in the Okanagan lakes, and two of them, carp and pumpkinseed, are found in all six lakes. Some of the introduced species were stocked directly into the lakes, while others were stocked in Washington and invaded BC waters. For this reason, Osoyoos Lake has the greatest number of introduced fish species.
- Between 1894 when the first fish were stocked in the Okanagan, and 1990 when stocking of the six main valley lakes stopped, more than 46 million fish were released in Okanagan lakes. In 2004, Okanagan sockeye fry were released into Skaha Lake in a pilot reintroduction* program anticipated to continue for 12 years. The Okanagan Nation aspires to establish a sockeye population in Skaha Lake to begin the cultural restoration of their salmon fishery (see *Chapter 4.2: Skaha Lake*).

* See footnote regarding sockeye reintroduction terminology on page ii of Summary.

Table 5. Current presence of fish species in Okanagan main valley lakes.
Entries with a '?' indicate presence of the species is unconfirmed.

	Main Valley Lakes					
Common name	**Wood**	**Kalamalka**	**Okanagan**	**Skaha**	**Vaseux**	**Osoyoos**
Black bullhead				x	x	x
Black crappie					x	x
Bluegill						x
Brown bullhead						x?
Burbot			x	x		
Carp	x	x	x	x	x	x
Chinook salmon						x
Chiselmouth				x	x	x
Eastern brook trout			x	x?	x?	x?
Goldfish						x?
Kokanee	x	x	x	x	x	x
Lake chub	x?	x?	x	x	x?	x?
Lake trout	x?	x	x?			
Lake whitefish			x	x	x	x
Largemouth bass					x	x
Largescale sucker	x	x	x	x	x	x
Leopard dace			x			
Longnose dace		x	x			
Longnose sucker		x	x	x	x	x
Mountain whitefish	x	x	x	x	x	x
Northern pikeminnow	x	x	x	x	x	x
Peamouth chub	x	x	x	x	x	x
Prickly sculpin	x	x	x	x	x	x
Pumpkinseed	x	x	x	x	x	x
Pygmy whitefish			x	x		x
Rainbow trout	x	x	x	x	x	x
Redside shiner	x	x	x	x	x	x?
Slimy sculpin		x	x			
Smallmouth bass				x	x	x
Sockeye salmon						x
Steelhead trout						x
Sturgeon			x?	x?		
Tench					x	x?
Yellow perch			x	x?	x	x

From Northcote et al. 1972, Wright et al. 2002, Fish Wizard.

What do we know about fish habitat in Okanagan main valley lakes?

- The amount of nutrients in the six main valley lakes varies from low levels in Kalamalka and Okanagan lakes to higher levels in Skaha, Osoyoos, and Wood lakes. Nutrients are important and form the basis of fish production in lakes.
- Both Vaseux and Osoyoos lakes have problems with deep-water oxygen levels during the late summer and autumn. Conditions in these lakes mean that deep water lacks the oxygen many fish need while water temperature in the upper part of the lake is too high. Therefore, many fish, particularly salmon and trout, are confined to a narrow band in the middle of the lake that is cool enough but also has sufficient oxygen.

  More details on this phenomenon are in *Chapter 4.3: Osoyoos Lake*. Other lakes in the Okanagan Basin have high temperature in the upper part of the lake, but do not experience the low oxygen in deeper water.
- An introduced shrimp called *Mysis relicta* lives in Kalamalka, Okanagan, and Skaha lakes, and has invaded Osoyoos Lake within the last five years . The shrimp eats the same food as kokanee and sockeye salmon and tends to be a better competitor for the food. As a result, less food is available for the kokanee and sockeye. This is thought to be a contributing factor in kokanee declines in Okanagan Lake.

  Okanagan and Kalamalka lakes currently have the greatest densities of Mysis shrimps; more information on the impacts of this introduced species is in *Chapter 4.1: Okanagan Lake*.
- Eurasian water milfoil is an introduced aquatic plant that was first found in Okanagan Lake in 1970, and has since been found in Skaha, Vaseux, and Osoyoos lakes, as well as Okanagan River.

  Milfoil, which was probably introduced accidentally from a home aquarium, grows quickly and spreads through shallow areas of lakes. It may reduce wave action that cleans spawning gravel and brings oxygen to incubating kokanee eggs. It also provides more habitat for predatory fish species.
- Shoreline habitat is used by some fish for spawning, and is particularly important for kokanee salmon in Okanagan, Wood, and Kalamalka lakes. The other lakes have little or no shoreline habitat that is suitable for kokanee spawning.

What impacts and human activities affect fish and fish production in Okanagan main valley Lakes?

- Although nutrients are necessary in lakes for fish production, too much of one nutrient, usually phosphorus, causes problems in the food chain. Phosphorus began increasing in the lakes during the mid-1900s as the human population increased and more sewage effluent was released. Skaha and Osoyoos lakes, in particular, had problems with blooms of algae (microscopic plants) in the 1960s and 1970s. Since then, improvements in sewage treatment plants led to over 90% decline in phosphorus loading to the lakes. On the other end of the scale, too few nutrients can also be a problem.

  Okanagan Lake, in particular, may have too little nitrogen as a result of dams on the streams throughout its watershed. Dams are known to trap nutrients.

- Land use impacts from urban development have been greatest in the bottom of Okanagan Valley alongside the six main lakes. The three largest cities in the Okanagan – Vernon, Kelowna, and Penticton – are all built on the shores of Okanagan Lake. Wood, Skaha, and Osoyoos lakes also have towns or cities built beside them. The impacts of urban centres on streams and lakes include water-tight surfaces and storm drains.

  Water-tight surfaces, such as pavement and roof tops, reduce the amount of water that seeps into the ground and changes the direction in which water flows over land. Water that runs over these surfaces also collects oils, chemicals, sediments, and other pollutants and carries them into storm drains. Storm drains flow directly into lakes and streams.

- Shoreline habitat on all six lakes has been affected by land changes, including urban development, agricultural activities, and road and railway building. These activities have altered the stability of lake shores, increased erosion of sediments into lakes, and removed vegetation. Docks also disturb shoreline habitat by altering wave patterns and reducing spawning habitat quality.

- Dams built during the 1900s cut off the connections between several of the main valley lakes. In particular, dams at the outlet of Okanagan Lake and on Okanagan River downstream of Vaseux Lake restrict the movement of fish. A dam at the outlet of Skaha Lake at Okanagan Falls also prevents fish passage, but the original waterfall and cascades may have prevented upstream fish passage historically.

  Traditional Ecological Knowledge indicates, however, that fish were able to swim upstream over the cascades. As a result of the dams, and particularly of the dam on Okanagan Lake, water level fluctuates over the course of the year. The fluctuations are most pronounced in Okanagan Lake and can strand fish eggs, particularly kokanee eggs, out of water where they freeze and dry out.

- The six main valley lakes have received the greatest number of introduced species of all freshwater systems in the Okanagan. Introduced fish, Eurasian water milfoil, and Mysis shrimps all affect native fish populations living in Okanagan valley lakes.

- Sport-fishing for rainbow trout occurs on all the main valley lakes, and for kokanee salmon on some of them. The popular kokanee fishery on Okanagan Lake closed in 1995 out of concern for the severely depleted populations. Sport-fishing was worth an estimated $16 million in direct expenses in 2000 across the entire Okanagan Region (includes Okanagan, Similkameen, Kettle, and Shuswap basins).

What do we know about the fishery in Okanagan main valley Lakes?

- The main valley lakes in the Okanagan have several important fisheries, particularly for kokanee and rainbow trout. Whitefish and burbot are also targeted recreationally. Bass provide a popular fishery in Vaseux Lake and some are fished in Osoyoos Lake.

- Historically, the highest recreational fishing effort was on Okanagan Lake, but since the kokanee fishery was closed in 1995, much of this effort has been directed at Wood and Kalamaka lakes. Osoyoos and Skaha lakes are sites of spring fishing and sporadic fishing during the remainder of the year.

What factors limit fish production in Okanagan main valley Lakes?

- Many factors limit fish production in the Okanagan lakes. The key factors are poor quality shoreline (and stream) habitat for spawning, nutrient levels that are too low or too high, and competition for food with introduced species. In Vaseux and Osoyoos lakes, the combination of low oxygen and high temperature limits fish production.
- Traditional Ecological Knowledge identifies access to historical areas as a limitation to salmon production, specifically sockeye.

What gaps exist in our knowledge of fish and fish habitat in Okanagan main valley Lakes?

- Evidence suggests that overwinter mortality of kokanee is high in their first year and may be a major reason for kokanee declines in Okanagan Lake. This may be connected to nutrients which are key to fish production. However, the way in which nutrients are transferred from level to level in the food web is poorly understood. Inefficient flow of nutrients through the food web might affect the overwinter survival of fish.
- The interactions between different species, particularly between native and introduced species, haven't been well documented. Sockeye salmon in Osoyoos Lake and kokanee salmon in Okanagan and Skaha lakes are the only populations for which accurate abundance estimates have been made. No recent information, and only spotty historical information, is available for other species.
- Information is limited on Traditional Ecological Knowledge of the Okanagan lakes, including historical fish species and their distributions.
- The number and species of fish that anglers take from the lakes each year is estimated by periodic boat counts and infrequent creel surveys. The allowable harvest levels are set, therefore, without knowledge of the true population size.
- No information exists about pharmaceuticals in Okanagan lakes. In other places with large urban populations, high levels of pharmaceutical products can enter water systems from wastewater. The wastewater treatment plants in the Okanagan are some of the best in the world; however, they are not set up to remove pharmaceuticals before releasing the treated water.
- Climate change will have impacts on inflowing streams and on lake water temperature, but the effects are difficult to predict. Osoyoos Lake may be most severely affected by temperature shifts, and all lakes will be affected by changes in the volume or timing of inflowing water.

What is being done to protect or restore fish and fish habitat in Okanagan main valley Lakes?

- Sewage treatment plants in the Okanagan Valley continue to remove most of the phosphorus from sewage before the effluent is released into the lakes. The Environmental Protection division of the Ministry of Water, Land and Air Protection monitors nutrient levels in all the lakes each spring and autumn.

- The Ministry of Water, Land and Air Protection began a 20-year program in 1996 to investigate the crashing kokanee salmon population in Okanagan Lake. The program has numerous recovery methods underway, which include stream protection and restoration, Mysis shrimp removal, and an investigation of nutrient levels in the lake. For more information, see *Chapter 4.1: Okanagan Lake*.
- The Okanagan Nation Alliance monitors water quality and different parts of the food web in both Skaha and Osoyoos lakes. The work on Skaha Lake is in support of experimentally reintroducing* sockeye salmon fry into the lake, and the work on Osoyoos Lake is directed towards monitoring and identifying problems for sockeye salmon.
- Fisheries and Oceans Canada monitors the sockeye population in Osoyoos Lake with in-lake sockeye fry abundance and spawning ground surveys, and also maintains long-term data sets.
- Creel census data are being collected this year for Okanagan, Wood, and Kalamalka lakes in an effort to gain better estimates of fish populations in these lakes and sport-fishing pressure on them.

  Estimates of the number of kokanee spawners from Wood, Kalamalka, Okanagan, and Skaha lakes will also continue.
- A project called Fish Water Management Tools was completed in 2004. A computer-based tool was developed to assist water managers in deciding when and how much water to release through Penticton Dam at the outlet of Okanagan Lake.

  Better management of water levels in Okanagan Lake helps to prevent the stranding of kokanee eggs incubating in shallow shoreline areas. It may also help to reduce or control the temperature-oxygen squeeze in Osoyoos Lake by injecting oxygen-rich water into the lake at critical times in summer.

* *See footnote regarding sockeye reintroduction terminology on page ii of Summary.*

CHAPTER 4.1 OKANAGAN LAKE

Description

- Okanagan Lake is the largest in the valley with a length of about 110 kilometres, surface area of 344 square kilometres, and volume of 26 cubic kilometres. It takes 60 years for all the water in the lake to be flushed out, commonly known as the water residence time of a lake. The lake's average depth is 75 metres, and the maximum depth is 242 metres near Whiskey Cove towards the north end of the lake.
- The lake has two distinct arms, the north and south arms, and a smaller arm in the northwest called Head of the Lake, or Armstrong Arm. This is frequently singled out because it has different physical, chemical, and biological characteristics to the rest of the lake.
- The north and south arms of Okanagan Lake generally have clear water and low levels of nutrients compared to other Okanagan lakes.

What do we know about fish populations in Okanagan Lake?

General

- Twenty-one fish species, five of which are not native, live in Okanagan Lake. This lake was the first in the valley to have an introduced species stocked into it when lake whitefish were released in 1894. In the early 1970s, an estimate was made that about 40% of the fish in the lake were salmon and trout species.
- Rainbow trout are native to Okanagan Lake, but 8.8 million were also stocked into the lake between 1919 and 1960. The stocked fish came from a variety of sources, primarily Pennask and Pinantan lakes (Thompson Basin) and Swalwell Lake (Okanagan Basin). From 1978 to 1984 an additional 144,000 hatchery-raised fry, originating mostly from Mission Creek but also from Kootenay stocks, were released to Okanagan Lake via Mission Creek. Historical reports indicate that rainbow trout weighing 30 pounds were fished from the lake.
- The current size of the rainbow trout population has not been estimated. Rainbow trout are a major predator in the lake, with kokanee salmon forming a substantial part of their diet. A 1980 study found few or no Mysis shrimps in rainbow trout stomachs, even though the shrimps had been introduced into Okanagan Lake as a food source for both rainbow trout and kokanee salmon.
- Traditional Ecological Knowledge identifies the historical presence of sockeye, coho, chinook, and steelhead in Okanagan Lake.

Kokanee salmon

- Two variants of kokanee salmon live in Okanagan Lake, a shore-spawning population and a stream-spawning population. They are the same species but are genetically different, and probably separated after the glaciers retreated about 11,000 years ago. The shore-spawners tend to be smaller than the stream-spawners and they mature a year earlier to spawn at age two.

- A dramatic decline in kokanee numbers occurred during the 1970s. The number of stream-spawners dropped from 470,000 in 1971 to 7,000 in 1999, and the number of shore-spawners dropped from 730,000 in 1974 to 1,000 in 1998. The stream-spawners were at 24,000 and the shore-spawners at 44,000 in 2003. Some limited written records and anecdotal reports indicate that the number of kokanee spawners was likely greater than one million prior to the 1970s.
- Estimates of the total kokanee population in the lake began only in 1985. From then until 1992, the number averaged 12.5 million fish. A steady decline then began, and in 2000, the lowest number was recorded at 3.1 million fish (Figure 6). As a result of declines in the early 1990s, the kokanee fishery closed in 1995.

  The population has since increased to about 11 million fish in 2003. However, most of these fish are fry or young-of-the-year, meaning that they haven't yet survived a winter. The number of fish that survive their first winter is a critical phase and is believed to be a problem for Okanagan Lake kokanee.
- The initial response to the kokanee decline was to stock kokanee fry into the lake; 5.4 million kokanee of various origins were released into Okanagan Lake streams between 1978 and 1987. This method was stopped in favour of improving the lake and stream habitat conditions (see the description below of Okanagan Lake Action Plan activities in *What is being done?*).
- In early summer, Okanagan Lake sometimes experiences kokanee kills. They have been occurring since at least the 1960s, although anecdotal reports suggest they may have happened earlier as well. The kills typically involve fish that are 2 years old, and they seem to happen when strong winds follow a period of rapid heating.

  Biologists think that the strong winds cause warm surface water to be mixed down into the lake, and the sudden change in temperature disorients the fish. They put too much air in their swim bladders, and this causes them to float rapidly to the water surface where they die.

  This hypothesis is not confirmed, however. The most recent large event was in June 2003 when an estimated 80,000 kokanee died. A small kill of less than 10,000 fish was reported in June 2004. These kokanee kills are also reported in many other large lakes in the Pacific Northwest.

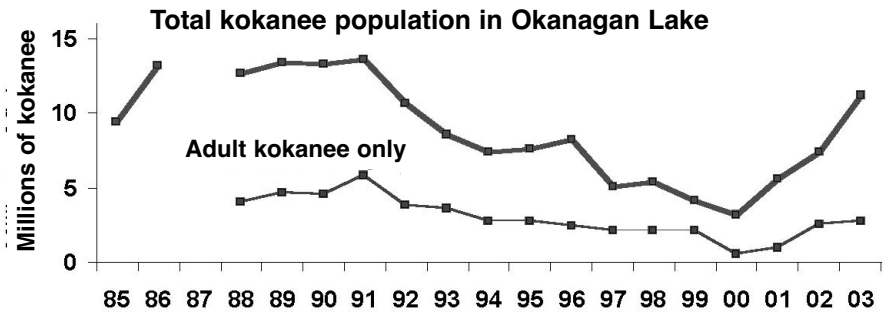


Figure 6. The kokanee salmon population in Okangan Lake, 1985-2003
Data from Matthews 2004

What do we know about fish habitat in Okanagan Lake?

- Shore-spawning kokanee spawn along about one-third of Okanagan Lake's 270-kilometre shoreline. High densities of spawners are found along the section of eastern shoreline from Bertram Park south to the bend in the lake opposite Peachland (Squally Point). Shore-spawners also use the western and eastern shorelines north of Kelowna to the beginning of Armstrong Arm.

  In these locations, however, the selection of sites and the level of use by spawners vary between years and seem to depend on the number and density of spawners. Shore-spawners lay their eggs in substrate in the top one metre of water, and frequently in the top 30-50 centimetres.
  They are highly vulnerable, therefore, to drawdown of water levels while the eggs are incubating.

- *Mysis* shrimps and kokanee salmon both prefer to eat small animals called zooplankton (means floating or wandering animals), and in particular, they both seek *Daphnia* zooplankton. The shrimps are the better competitor for *Daphnia* and graze them to the point that few remain for kokanee to eat.

  Kokanee rely on eating *Daphnia* to gather and store fats that will help them survive through the winter. This is especially important for young fish getting ready to go through their first winter. Biologists suggest that kokanee in Okanagan Lake may not be able to store sufficient fat reserves as a result of food competition.

- Okanagan Lake has naturally low nutrient levels, but nitrogen appears to be even lower than normal during the summer. When a lake has very little nitrogen compared to phosphorus (a low nitrogen to phosphorus ratio), cyanobacteria, or blue-green algae, tend to grow in high numbers.

  Cyanobacteria are a poor food source for zooplankton because they don't have high-quality fats. Zooplankton that feed on cyanobacteria are, in turn, poor quality for fish. Therefore, an unbalanced ratio of nitrogen to phosphorus may be causing a bottleneck where nutrients can't be translated into healthy fish, particularly kokanee.

What impacts and human activities affect fish and fish habitat in Okanagan Lake?

- Introduced species have changed the ecology of Okanagan Lake. Eurasian water milfoil was first observed in the lake in 1970. Eradication was attempted but failed, and after evaluating various methods for control, the plants have since been harvested or uprooted in some locations on an annual basis to prevent it becoming more widespread in the lake.

- *Mysis* shrimps were released into Okanagan Lake in 1966 as an additional food source for fish, particularly kokanee salmon. If the kokanee could find the shrimps, they would be a good food source, but the shrimps migrate deep into the lake during the day when kokanee are feeding closer to the surface. The shrimps swim up to shallower depths at night to feed, but the kokanee can't see them in the dark.

  For several years *Mysis* went undetected, but they finally appeared in sampling nets in 1974. Since then they have increased in abundance to between 150 and 450 per square metre. This equates to between three and six thousand tons of shrimp in the lake.

Biologists believe that the kokanee decline in Okanagan Lake is in part due to impacts from the *Mysis* introduction. Other large lakes in BC and elsewhere have also had *Mysis* introduced to them, and seen subsequent declines in kokanee populations.

- Cyanobacteria dominate the algae component of Okanagan Lake in summer and autumn. Historically, cyanobacteria have always been present but the few records that exist show they were not dominant. They now dominate in summer and autumn, probably because the nitrogen to phosphorus ratio drops very low during this period.

  The lake's nitrogen deficit may be due to the numerous dams on streams and headwater lakes in the watershed. Most nitrogen enters the lake from tributary streams, but dams can trap nutrients by promoting algal growth in the still water behind them and the nutrients are unable to reach the lake. This hypothesis has not been confirmed, but biologists are collecting information to try and find out what has happened to nitrogen inputs to the lake.

- Both shore and stream spawning habitat have been affected. Shore spawning habitat has been reduced by development, particularly the building of houses, roads, and docks. An estimate in the mid-1990s says that 80% of the lake's southwestern and northern shores has been modified in some way. In total, of 1,220 docks have been built around Okanagan Lake; this is 65% of all docks in the province of British Columbia. Stream habitat is discussed in *Chapter 3: Tributary Streams North of Penticton.*

- Flood control in the Okanagan Valley is primarily regulated by releasing water at Penticton Dam on the outlet of Okanagan Lake. Fluctuations in water level have huge impacts on kokanee eggs that are incubating in the gravel along the lake's shoreline. If the water level drops too low in late winter or early spring, the eggs dry out and die.

What do we know about the fishery in Okanagan Lake?

- Historically, Okanagan Lake had a very popular recreational fishery. In 1989, the number of angler days was reported at 72,000, which equates to a value of over $9 million (using today's value of $134 per angler day).

- The primary targets for anglers on Okanagan Lake were kokanee and rainbow trout, but there were also fisheries for burbot and whitefish. The kokanee fishery was closed in 1995 in response to a severe decline in kokanee stocks. Although the lake remains open for rainbow trout and other fisheries, angling effort is thought to have declined markedly since the kokanee fishery closed. Little information has been collected recently due to low angler effort and associated difficulties in collecting information.

What factors limit fish production in Okanagan Lake?

- Kokanee production in Okanagan Lake is limited by competition for food with *Mysis* shrimps, water level fluctuations, shore and stream habitat loss, and possibly also by the quality of food that passes up the food chain.

- The production of rainbow trout in the lake is most likely limited by the kokanee population, since rainbow trout prey mainly on kokanee. Other predatory species, such as northern pikeminnow and burbot, may also be limited by the kokanee population, but no information exists.
- Based on Traditional Ecological Knowledge, the nutrients contributed historically to Okanagan Lake by returning salmon are now lacking.

What gaps exist in our knowledge of fish and fish habitat in Okanagan Lake?

- More information on transfer of nutrients through the Okanagan Lake food web and how species interact with each other, including *Mysis* shrimps, will help determine the size and effect of the potential productivity bottleneck.
- Estimates of how many kokanee survive the winter, especially of young fish going through their first winter, are limited to hydroacoustic and trawl surveys that are conducted every autumn.
- Kokanee eggs spawned at shore sites hatch and emerge from the gravel about two months earlier in spring than their stream-spawned counterparts. The shore kokanee may, therefore, be more vulnerable because less food is available in early spring. It is not known whether higher mortality of juvenile shore kokanee occurs because of limited food supply.
- Climate change will have impacts on the amount and timing of water flow in streams that enter Okanagan Lake. This will affect lake water levels, with consequences for shore-spawning kokanee. Climate changes are hard to predict, but models suggest that peak water flow will occur earlier in the spring and may be smaller in volume during the next 80 years.
- The reasons for the recurring kokanee kill in spring are unclear. It is also unknown whether the fish are a mixture of shore and stream-spawning populations, or are exclusively one or the other variant.
- When the kokanee fishery was open, the bigger stream-spawning fish may have been more easily caught than the smaller shore-spawners. The existence of a catch bias and its size must be determined before the kokanee fishery could be reopened.

What is being done to protect or restore fish and fish habitat in Okanagan Lake?

- The Ministry of Water, Land and Air Protection began an extensive kokanee recovery program on Okanagan Lake in 1996. Their activities include monitoring the lake conditions and kokanee populations to build a database of information, investigating the nutrient levels and unbalanced nitrogen to phosphorus ratio in the lake, and developing ways to fish *Mysis* shrimps from the lake.

  An experimental *Mysis* fishery has been underway since 2000 with the aim of removing as many shrimps from the lake as possible. Large numbers of shrimp can be caught, but success of the fishery depends on finding long-term, high-demand markets to sell the product. The harvest nets have excluders so that kokanee are not inadvertently caught.
- The Ministry of Water, Land and Air Protection, Fisheries and Oceans Canada, and the Okanagan Nation Alliance have been working together closely to fine-tune the release of water through Penticton

Dam. A computer model that incorporates all the available information about impacts from dam operation is under development.

The model should be ready for implementation in autumn 2004, and will greatly improve water managers' decisions to ensure that impacts on fish are minimal.

- The Okanagan Basin Water Board funds a program of Eurasian water milfoil harvesting in summer. From late October to early May, rototillers are also used to uproot the plants and discourage their growth. It is not known whether milfoil harvesting provides any benefits for fish. To the contrary, milfoil harvesters may have a negative effect by disturbing fish habitat and physically injuring or even removing the fish species that use milfoil for cover and feeding.
- The Regional District of Central Okanagan, in partnership with Ministry of Water, Land and Air Protection, the City of Kelowna, and the District of Lake Country, is mapping the shoreline of Okanagan Lake during summer 2004.

  The data being collected includes the type of foreshore, substrate, land use, and vegetation. The project will create an inventory, map, and video that documents the current condition of the shoreline. The information will be used for land use planning, stewardship, and monitoring activities, and will ultimately be accessible on the Internet.

CHAPTER 4.2 SKAHA LAKE

Description

- Skaha Lake is the next lake downstream of Okanagan Lake. It has a length of about 12 kilometres, surface area of 20 square kilometres, and volume of just over half a kilometre cubed. It takes about 15 months for all the water in the lake to be flushed out, commonly known as the water residence time of a lake. The lake's average depth is 26 metres, and the maximum depth is 57 metres.
- Sewage effluent from Penticton caused the lake to have algal blooms each year, and as a result, low oxygen levels deep in the lake were a problem. Improvements to the sewage treatment plant were made in 1972, and the phosphorus load declined, which improved water quality and clarity.

What do we know about fish populations in Skaha Lake?

General

- Nineteen fish species live in Skaha Lake, one of which is blue-listed by the provincial government as being of special concern (chiselmouth), and six of which are not native to the Okanagan.
- The size of the rainbow trout population, which is native to Skaha Lake, has never been estimated.
- Traditional Ecological Knowledge identifies sockeye, coho, chinook, steelhead, and possibly chum and pink salmon, as being present historically in Skaha Lake.

Kokanee salmon

- The kokanee salmon population in Skaha Lake was estimated in 2003 at about 800,000 fish, over half of which were fry, or young-of-the-year.
- Most kokanee spawn in Okanagan River channel upstream of Skaha Lake, towards Okanagan Lake. A few spawn in Ellis and Shingle creeks, and none spawn on the lakeshore. The number of kokanee that spawn increased substantially in the past two years. About 70,000 more fish returned each year in 2002 and 2003 than the average of 8,400 fish in the previous 10 years (Figure 7).

What do we know about fish habitat in Skaha Lake?

- Skaha Lake does not have suitable habitat for salmon to spawn along its shoreline, which is silty and has some large boulders. Kokanee have never been known to shore-spawn in Skaha Lake.
- The lake has moderate productivity and no known problems with unbalanced nutrients, although limited data analysis indicates that nitrogen may be limiting in some years during summer and autumn.
- *Mysis* shrimps are present in Skaha Lake, having come downstream from Okanagan Lake. The abundance of shrimps is lower than in Okanagan Lake, and their impacts on kokanee are not known at this time.

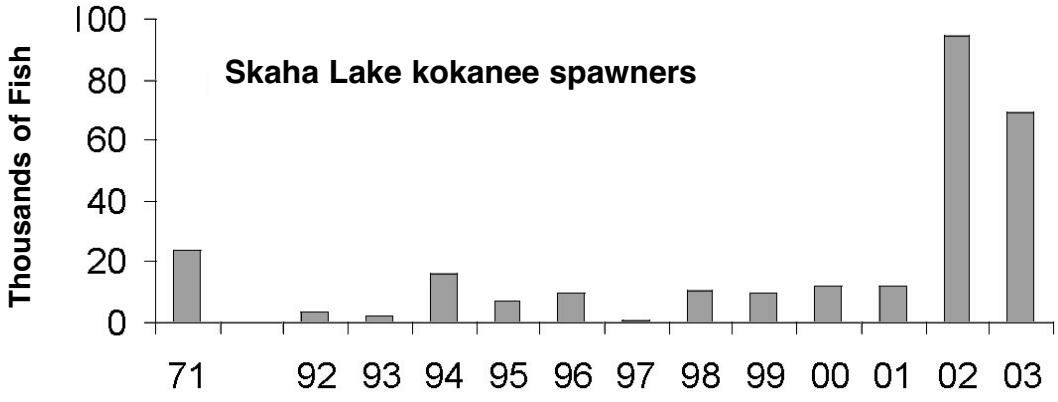


Figure 7. Estimates of kokanee salmon spawners from Skaha Lake, 1971-2003
Data from Northcote et al. 1972, Wilson 2004.

What impacts and human activities affect fish and fish habitat in Skaha Lake?

- Shoreline impacts to Skaha Lake are primarily from a road that runs along its entire eastern shore and the decommissioned railway line that runs along its entire western shore. The banks of the shore were built up with large rocks in several places when the road and railway were built. There is also significant residential development along the lake's shoreline.
- Introduced species in Skaha Lake include fish, many of which were stocked, and *Mysis* shrimps and Eurasian water milfoil, both of which came from Okanagan Lake.
- Phosphorus loading from sewage effluent increased in the mid-1900s in Skaha Lake, but with improvements to sewage treatment, the phosphorus loads declined. Spring levels of total phosphorus dropped by half between 1978 and 2001, while water clarity increased.
- Skaha Dam at Okanagan Falls blocks fish passage; a fish ladder exists but is not used.

What do we know about the fishery in Skaha Lake?

- The Okanagan Nation had a large fishery for sockeye, spring and summer chinook, and steelhead at Okanagan Falls, the outlet of Skaha Lake. This no longer occurs since sea-run fish can swim no further than McIntyre Dam downstream of Vaseux Lake.
- Very limited information is available about the recreational fishery on Skaha Lake. A small spring fishery occurs for rainbow trout, and sporadic efforts are made at angling kokanee throughout the summer. Some angling effort is directed at smallmouth bass from spring through autumn.

What factors limit fish production in Skaha Lake?

- The primary limitation for kokanee production in Skaha Lake is suitable spawning habitat. *Mysis* shrimps may become a limiting factor through food competition, but this has not been documented.
- Based on Traditional Ecological Knowledge, the nutrients contributed historically to Okanagan Lake by returning salmon are now lacking.

What gaps exist in our knowledge of fish and fish habitat in Skaha Lake?

- Fine sediments in Okanagan River channel upstream of Skaha Lake may be affecting the survival of kokanee eggs, but this has not been confirmed.
- The reasons behind the extreme fluctuations in the kokanee population in recent years are unknown. Possibilities include increased in-lake survival, increased egg to fry survival in the river, or fry from Okanagan Lake being flushed over Penticton Dam.
- Only limited Traditional Ecological Knowledge has been collected.
- There is no information on fish production or limiting factors for fish other than kokanee salmon. Angling effort and harvest are also undocumented.

What is being done to protect or restore fish and fish habitat in Skaha Lake?

- In the 1990s, the Okanagan Nation Alliance proposed an experimental reintroduction* of sockeye salmon into Skaha Lake. For three years, they have been collecting information on the risks of introducing new diseases and non-native species. Their conclusions are that the risk of new diseases is low, with some potential issues from a parasite that has recently been discovered in the Okanagan Basin. Specific introduction methods would take this into account.

  The only non-native fish of concern is walleye, which is currently found in the Okanogan River in Washington State and the Columbia River, but has not moved into Canadian waters. The project biologists anticipate that juvenile sockeye reintroduction to Skaha Lake will be successful. Because of its lack of spawning potential, and limited spawning availability between Skaha and Vaseux lakes,

  Skaha Lake may be of greatest benefit to sockeye as a nursery lake. If spawning habitat restoration took place, the lake could also provide important holding habitat for adults prior to spawning.

  A knowledge gap, however, is the interaction of sockeye, kokanee and *Mysis* populations in the lake. The first release of sockeye fry occurred on June 1, 2004. The project will continue for 12 years with monitoring and assessment of species interactions.

* *See footnote regarding sockeye reintroduction terminology on page ii of Summary.*

CHAPTER 4.3 OSOYOOS LAKE

Description

- Osoyoos Lake is the furthest south of the six large Okanagan lakes, and it straddles the border between BC and Washington. The lake has a total length of about 16 kilometres, surface area of 23 square kilometres, and volume of just under half a kilometre cubed. It takes 8-9 months for all the water in the lake to be flushed out, known as the water residence time of a lake. The lake's average depth is 14 metres, and maximum depth is 63 metres.
- Osoyoos Lake is commonly referred to by its three basins, the north and central basins, which are in BC, and the south basin, which is bisected by the international border. About two kilometres downstream of the lake's outlet is Zosel dam, first built in 1927. The dam was built to allow fish passage.
- The levels of nutrients in Osoyoos Lake are higher than in either Okanagan or Skaha lakes, making Osoyoos productive, especially at the bottom of the food web with algal growth. Because of this high productivity, a large amount of organic material (dead algae and microscopic animals) continuously falls to the lake bottom where bacteria decompose it.

  During this decomposition, bacteria use up oxygen in the water to the point that oxygen drops to very low levels at the lake bottom, especially in summer. At the same time, water temperature rises in the surface layers of the lake, and only a narrow band of cool, oxygenated water exists in the middle of the lake. This temperature-oxygen squeeze restricts many fish, particularly salmon and trout, to living in the middle layer (Figure 8).

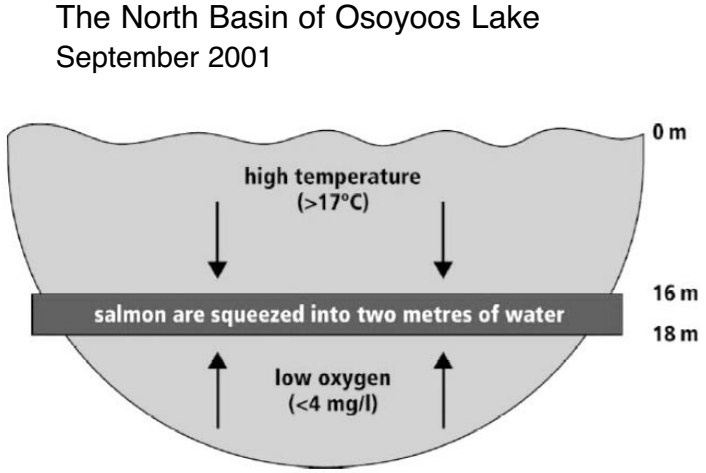


Figure 8. The temperature-oxygen squeeze in Osoyoos Lake.
Data from H. Wright.

What do we know about fish populations in Osoyoos Lake?

General

- Twenty-eight types of fish live in Osoyoos Lake, although presence of five of them is unconfirmed. This number includes sockeye and kokanee salmon as different types, even though they are the same species, and the same for steelhead and rainbow trout.
- Ten introduced fish species are known to be present in Osoyoos Lake, and three more may be present. Most of these introduced fish invaded by swimming upstream from locations where they had been stocked in Washington.
- Population estimates of kokanee in Osoyoos Lake have never been made. In the early 1970s, scientists found that about 40% of the fish catch (from gill nets) in Osoyoos Lake was composed of salmon and trout, with kokanee the dominant species.
- Steelhead trout, the sea-run form of rainbow trout, have been recorded from Osoyoos Lake by anglers in recent years. There are no estimates, however, of how many steelhead actually return to the Okanagan Basin.
- Preliminary evidence gathered by Okanagan Nation Alliance biologists suggests that a resident form of chinook salmon is in Osoyoos Lake, but nothing is known of this life history strategy.

Sockeye

- The Okanagan was chosen as one of the basins to receive sockeye salmon transplants as part of the Grand Coulee Fish Maintenance Program. The goal of this program was to mitigate for the hundreds of kilometers of salmon habitat made inaccessible in 1939 with construction of Grand Coulee Dam on the Columbia River.

  All sockeye and other salmon were collected at Rock Island Dam (further downstream on the Columbia River). The adults were either transported or their eggs were raised in hatcheries and then released into tributaries downstream of Grand Coulee Dam.

  Of all the returning salmon species, only sockeye were transported to the Okanagan Basin during the program's operation from 1939-1943. Sockeye salmon now have passage at Rock Island Dam and return to the Okanagan Basin annually, along with a few chinook and steelhead.

  Because of this transplant program, the Okanagan sockeye are considered to be a composite of sockeye populations that historically returned to the upper Columbia system.
- The sockeye salmon in Osoyoos Lake are one of only two remaining viable stocks, or populations, of Columbia River sockeye. They are referred to as the Okanagan sockeye, with the Wenatchee sockeye being the second remaining stock.
- The lake serves as both a holding area for adult sockeye returning to spawn in Okanagan River, and as a nursery for sockeye fry, or juveniles, to spend the first year of their life before migrating to the ocean. Spending a year in a nursery lake is a crucial stage in sockeye life history. Osoyoos Lake is the only nursery lake available to Okanagan sockeye.

- The number of sockeye fry in Osoyoos Lake varies each year depending on how many adults spawned the previous year. Estimates are that each spawner produces about 70 fry that make it into Osoyoos Lake. The lake has the capacity to support the growth of juveniles from at least 58,000 spawners, which equates to over 4 million fry. The number of spawning sockeye adults has never been this high in the past three decades; sockeye spawners are discussed in *Chapter 6: Okanagan River*.
- Osoyoos Lake's highly productive food web base (algae and microscopic animals) provides ample food for fry. After their nursery year, sockeye fry from Osoyoos Lake are consistently larger than sockeye fry from other nursery lakes in the Pacific Northwest. The larger a fry as it heads to the ocean, the more likely it is to survive and return as an adult.
- When sockeye adults return to spawn in the Okanagan Basin, they spend up to 45 days in Osoyoos Lake waiting for water temperature in Okanagan River to decline to the mid to low teens. During this holding time, the fish can be restricted by the temperature-oxygen squeeze.
- In the early 1970s, a few reports were made of sockeye spawning on the shores of Osoyoos Lake. This has not been reported since, and may have been kokanee or sockeye milling about the shoreline rather than actually spawning.
- Habitat quality or quantity for other fish species has not been assessed. Kokanee, chinook, and presumably some rainbow trout and steelhead, probably spawn in Okanagan River. These species will also be affected by the temperature-oxygen squeeze in Osoyoos Lake.

What do we know about fish habitat in Osoyoos Lake?

- Osoyoos Lake provides critical nursery habitat for sockeye fry. Because of the temperature-oxygen squeeze that occurs in summer, however, the fry are restricted mainly to the north basin of the lake. The low oxygen levels in the bottom waters of Osoyoos Lake are brought about by the high productivity at the base of the food web, but this also provides ample food to the fry, allowing them to grow quickly during their nursery year.
- A 1999 study by Fisheries and Oceans Canada concludes that the amount of rearing habitat does not currently limit fry in Osoyoos Lake, despite the temperature-oxygen squeeze, and that the lake could accommodate more fry.

What impacts and human activities affect fish and fish habitat in Osoyoos Lake?

- Although phosphorus loads to the Okanagan Basin as a whole have since declined, Osoyoos Lake is at the end of the chain and ultimately receives all the effluent from upstream. Osoyoos Lake also receives many diffuse sources of nutrients from agricultural land and septic fields surrounding the lake. Spring phosphorus measurements have declined by 40% since 1978 to levels at or just above water quality objectives.

Nonetheless, the lake continues to be highly productive, probably from resuspension of phosphorus in the bottom waters. This occurs when oxygen levels drop and a chemical reaction releases phosphorus that is normally bound to other elements in the sediment.

The rapid flushing rate of 8-9 months likely helps keep Osoyoos Lake from becoming any more productive, since some nutrients are carried downstream as water exits the lake.

- Introduced species in Osoyoos Lake include fish, which were either stocked or gained access from Washington State, and *Mysis* shrimps and Eurasian water milfoil, both of which came from Okanagan Lake via Skaha Lake. Although Mysis shrimps are present in Osoyoos Lake, they were not detected until the late 1990s, and their numbers are low at about ten times fewer than in Skaha Lake.

  There have not been any reports of *Mysis* competition with kokanee or sockeye in the lake. About 20 years ago, artificial reef habitats were constructed for largemouth and smallmouth bass, which are introduced fish species. The reefs are thought to have been unsuccessful, but they have not been monitored closely.

  Provincial government focus has moved away from habitat restoration measures for introduced species and towards protecting and restoring native species.

- Ten dams exist between the mouth of the Columbia River and Osoyoos Lake. Nine of these are on the mainstem of the Columbia River. The dams are hurdles both for sockeye salmon adults returning to spawn in the Okanagan Basin and for sockeye smolts migrating to the ocean.

- Thirteen vertical drop structures built in Okanagan River upstream of Osoyoos Lake restrict the upstream migration of some fish species, particularly kokanee, from Osoyoos Lake (for more details on the drop structures, see *Chapter 6: Okanagan River*).

- Shoreline impacts to Osoyoos Lake are primarily from urban and agricultural development.

- The water level in Osoyoos Lake is regulated by Zosel Dam on Okanogan River in Washington State. The International Osoyoos Lake Board of Control, under the International Joint Commission (Canada and United States), oversees dam operations, which must maintain Osoyoos Lake between specified water levels that depend on the season and type of year (i.e., drought, normal, wet years).

  In addition, a cooperative plan for trans-boundary flows exists between the BC Ministry of Water, Land and Air Protection and Washington State's Department of Ecology. This plan is a non-binding agreement that outlines water level ranges for Osoyoos Lake and minimum trans-border water flows on a month by month basis for both normal and drought years.

What do we know about the fishery in Osoyoos Lake?

- There is a limited spring fishery for rainbow trout, and minimal fishing effort directed at kokanee during summer. The bass fishery attracts some interest from spring to autumn.

What factors limit fish production in Osoyoos Lake?

- Production of sockeye salmon in Osoyoos Lake may be limited by some factors in Okanagan River (see section on Okanagan River) and dams on the Columbia River. Habitat for juveniles to live in and adults to hold in is also limited in the south and central basins, and in some years, in the north basin. Sockeye depend mostly on the north basin for nursery habitat. In addition to limitations in fresh water, sockeye salmon are subject to numerous impacts during the 1-2 years they spend in the ocean.
- Climate change has the potential to affect water temperature in Osoyoos Lake and may exacerbate the temperature-oxygen squeeze, making it a greater limitation to fish production.
- Fish species other than sockeye will also be limited by the temperature-oxygen squeeze, but little information exists about the quality or quantity of their spawning habitat and other in-lake conditions.

What gaps exist in our knowledge of fish and fish habitat in Osoyoos Lake?

- When surveys are conducted in Osoyoos Lake to count the number of sockeye fry, kokanee fry are also present. The proportion of kokanee to sockeye is unknown, but is thought to be small based on estimates of adult sockeye spawners and subsequent fry in Osoyoos Lake. These estimates of spawners and fry rise and fall in parallel, suggesting that most of the fry result from sockeye spawners.
- The large difference between counts of sockeye salmon at Wells Dam and on the spawning grounds in Okanagan is not well understood.
- The possible presence of a resident form of chinook in Osoyoos Lake is unconfirmed.
- Climate change will have impacts on lake water temperature, but the effects are difficult to predict.
- There is no information about the interaction between large rainbow trout resident in the lake and steelhead trout returning from the ocean.
- Walleye, a predatory fish species introduced from eastern North America to Washington State, is currently established where the Okanogan and Columbia rivers meet. Walleye could, therefore, invade the Canadian portion of the Okanagan Basin.
- Angling effort and harvest are largely undocumented.

What is being done to protect or restore fish and fish habitat in Osoyoos Lake?

- Sewage treatment plants in the Okanagan Valley continue to remove most of the phosphorus from sewage before the effluent is released into the lakes. The Environmental Protection division of the Ministry of Water, Land and Air Protection monitors nutrient levels in Osoyoos Lake each spring and autumn.
- Fisheries and Oceans Canada monitors sockeye fry in Osoyoos Lake on an annual basis.
- The Okanagan Nation Alliance monitors temperature and oxygen conditions in Osoyoos Lake.

- The Osoyoos Lake Water Quality Society is an active community group that is working to improve the environment in Osoyoos Lake through education and protection measures.
- The Regional District of Central Okanagan, in partnership with Fisheries and Oceans Canada and local government, mapped the shoreline of Osoyoos Lake.

  The data collected includes the type of foreshore, substrate, land use, and vegetation.

  The project created an inventory, map, and video that documents the condition of the shoreline. The information is used for land use planning, stewardship, and monitoring activities, and will ultimately be accessible on the Internet.
- The Municipality of Osoyoos is working toward expanding the sewer system coverage to reduce nutrient inputs from septic systems.

Chapter Five

Okanagan: Tributary Streams South of Okanagan Lake

Description

- Tributary streams south of Penticton flow into the Okanagan River, and Skaha, Vaseux, and Osoyoos lakes. Only about half a dozen large streams flow south of Penticton. The largest watershed, Inkaneep Creek, flows into Osoyoos Lake and drains a land area of 186 square kilometres. More details on this stream are given below.
- In a 2003 assessment of focal watersheds, three tributary streams south of Penticton were named as having high or very high significance for fish protection because of the sensitivity of fish stocks (kokanee and sea-run salmon, rainbow trout, and rare species) and the current or potential level of fish production in the stream (Table 6).

Table 6. Ratings assigned to tributary streams south of Okanagan Lake

Creek	Significance for Fish Protection [a]	Habitat Impact [b]	Significance for Habitat Restoration [c]
Inkaneep	Very High	High	Very High
Shingle	High	High	High
Vaseux (McIntyre)	High	High	High
From Matthews and Bull 2003.			

a The ratings of significance for fish protection refer to focal fish species (rainbow trout and rare species) and were obtained by ranking the sensitivity of fish stocks and the current or potential level of fish production in the stream.

b Habitat impact was rated for forestry, agriculture, urban development, low water flow, and temperature. The highest score from any of these impacts was used as the habitat impact for the whole creek or river.

c Significance for habitat restoration was based on the fish protection and habitat impact scores if they were the same and on expert opinion if they differed.

What do we know about fish populations in tributary streams south of Okanagan Lake?

- All the streams have resident rainbow trout that live only in streams, and eight have rainbow trout that live in lakes and spawn in streams. None of the streams has been documented with rare species of fish.
- Kokanee salmon from Skaha Lake spawn in Shingle and Ellis creeks to a limited degree. Kokanee from Osoyoos Lake used to spawn in Inkaneep Creek, but they don't any longer.

  This is likely because of increased water use that has reduced flows, and the build-up of stream sediments to the point that water flows into them rather than over them (sub-surface flow).
- Inkaneep and Vaseux creeks likely provide important spawning and rearing habitat for Osoyoos Lake rainbow trout.
- Sockeye salmon also spawned in Inkaneep Creek historically, but have not been recorded there in recent years. Sockeye have been seen in Vaseux Creek, most recently in 1997.
- Historically, steelhead, chinook, sockeye, and coho likely spawned in these tributaries. The Okanagan name for Shingle Creek is "place where steelhead spawn."
- Warmwater fish, which include many of the introduced species that live in the Okanagan Basin, tend to be rare or absent in the tributary streams because of their low water temperature, low productivity, and steeper channels compared to the Okanagan River mainstem.

What do we know about fish habitat in tributary streams south of Okanagan Lake?

- Riffle habitat, where water moves swiftly over shallow rocks, is common in the tributary streams. Riffles are important spawning and feeding areas. Because of the steep gradient of these streams, side-channel and backwater habitats are rare.
- Two streams, Inkaneep and Vaseux, have suitable habitat for rainbow trout that live in Osoyoos Lake and spawn in streams, and for steelhead trout and chinook salmon. The extent of steelhead and chinook presence is largely unknown, however, in the Okanagan.

What impacts and human activities affect fish and fish habitat in tributary streams south of Okanagan Lake?

- Dams for water storage and water withdrawals from tributary streams affect the amount and timing of water flowing in them. Low water flow and high water temperature have high levels of impact on fish in several streams, including Inkaneep, Ellis, and Vaseux creeks. Vaseux Creek actually goes dry in its lowest section (downstream of the canyon) in late summer, preventing fish from moving up or downstream.
- Water intakes on several streams, particularly Inkaneep and Vaseux, hamper the upstream migration of adult fish and can trap juvenile fish.
- Land use at lower elevations in the stream watersheds includes low to moderate impacts from agriculture and high impacts from urban activities. At higher elevations, impacts vary but most streams are

affected by forestry, agriculture, and urban development.

Roads are extensive in some watersheds, and frequently follow stream channels. These roads affect water runoff patterns and contribute to erosion. Overall habitat impacts for a selection of streams are in Table 6.

What do we know about the fishery in tributary streams south of Okanagan Lake?

- There is little fishing in the lower reaches of these tributary streams.
- A small fishery for rainbow trout takes place in Vaseux Creek canyon and in the upper reaches of the creek.

What factors limit fish production in tributary streams south of Okanagan Lake?

- Fish production in the tributary streams south of Penticton is limited by low water flow and high temperature during migration, and the availability of good quality spawning habitat. The channelization of streams, loss of natural water flow patterns, increases in population growth and land development, and climate change all play a role in limiting the capacity of streams to produce fish.

What gaps exist in our knowledge of fish and fish habitat in tributary streams south of Okanagan Lake?

- A record has never been made of the numbers of spawning fish using habitat in the tributary streams, nor of the numbers of juvenile fish produced by the streams. Little is known about the population size of native species resident in the streams.
- There is a lack of Traditional Ecological Knowledge about past fish assemblages.
- Although water withdrawals from surface waters are licensed by the crown corporation Land and Water BC, there is no system of tracking the quantity of water that license holders actually withdraw. Ground water, which many agriculturalists use as a water source, is not licensed or monitored.

  Ground water feeds into streams from below, so a well dug close to a stream can affect the amount of water that enters the stream. (New ground water regulations introduced by the Ministry of Water, Land and Air Protection in July 2004 focus on water quality and safety.)

What is being done to protect or restore fish and fish habitat in tributary streams south of Okanagan Lake?

- Some stream restoration and planting of streamside vegetation has been done by the Okanagan Nation and its member bands and by conservation groups in the South Okanagan.

- The Ministry of Water, Land and Air Protection installed a fishway in Vaseux Creek about 100 metres upstream from the highway bridge crossing. The fishway provides passage from Okanagan River into Vaseux Creek for rainbow trout, steelhead, and sockeye, provided that the creek has sufficient water flow for fish to migrate into it.

CHAPTER 5.1 VASEUX CREEK

Description

- Vaseux Creek flows into Okanagan River downstream of Vaseux Lake (and also downstream of McIntyre Dam). The creek drains a land area of 128 square kilometres.

What do we know about fish populations in in Vaseaux Creek?

- Rainbow trout, mountain whitefish, suckers, dace, and sculpins are thought to inhabit Vaseux Creek.
- Rainbow trout from Osoyoos Lake, and potentially steelhead trout, use Vaseux Creek for spawning and rearing.
- Sockeye salmon occasionally enter Vaseux Creekduring the spawning period, most recently in 1997.

What do we know about fish habitat in in Vaseaux Creek?

- Vaseux Creek likely provides important spawning and rearing habitat for Osoyoos Lake rainbow trout. The quality of this habitat has been affected by low water flow, particularly in summer when the creek runs dry.

What impacts and human activities affect fish and fish habitat in Vaseaux Creek?

- Water diversions affect water flow in Vaseux Creek, and can also cause fish mortalities where pipes are inadequately screened.
- Low water flow and high water temperature have high levels of impact on fish in Vaseux Creek. The creek goes dry in its lowest section (downstream of the canyon) in late summer, preventing fish from moving up or downstream. A layer of clay was disturbed in the bed of Vaseux Creek and this causes the water to go below the ground surface when water flow is low.

- In two locations, streambed material accumulates and alters water flow. One of these is the result of a dyke that was moved following a flood in the early 1990s, and the other occurs where the South Okanagan Lands and Irrigation District canal crosses the stream.

What do we know about the fishery in Vaseaux Creek?

- There is little fishing in the lower reaches of Vaseux Creek, but a small fishery for rainbow trout takes place in the canyon and upper reaches of the creek.

What factors limit fish production in Vaseaux Creek?

- Fish production in Vaseux Creek is limited by high water temperatures and low water flow in summer. o For the lowest section of the creek, the lack of water flow in late summer eliminates the possibility of fish migration.
- The unscreened intake pipe of the irrigation canal that diverts water from Okanagan River at McIntyre Dam likely traps juvenile fish, particularly rainbow trout and sockeye fry that are migrating downstream to Osoyoos Lake. The dam and canal were originally built from 1919-1921 for the South Okanagan Lands Project.

What gaps exist in our knowledge of fish and fish habitat in Vaseaux Creek?

- The use and importance of Vaseux Creek for rainbow trout spawners from Osoyoos Lake is unknown, but anecdotal reports and observations made by fisheries biologists indicate that there is significant use.
- The capacity of Vaseux Creek for spawning sockeye is unknown.

What is being done to protect or restore fish and fish habitat in Vaseaux Creek?

- The Ministry of Water, Land and Air Protection installed a fishway in Vaseux Creek about 100 metres upstream from the highway bridge crossing. The fishway provides passage from Okanagan River into Vaseux Creek for rainbow trout, steelhead, and sockeye, provided that the creek has sufficient water flow for fish to migrate into it.
- Adequate screening is to be installed by 2005 over the intake pipe of the irrigation canal that diverts water from Okanagan River at McIntyre Dam.

CHAPTER 5.2 INKANEEP CREEK

Description

- Inkaneep Creek flows into Osoyoos Lake on its northeastern shore and drains a land area of 186 square kilometres.

What do we know about fish populations in Inkameep Creek?

- Rainbow trout and the introduced eastern brook trout are found throughout Inkaneep Creek, from its headwaters to its mouth. Prickly sculpin, a native fish, and smallmouth bass, an introduced fish, live in the downstream section closest to Osoyoos Lake.
- Kokanee, sockeye, chinook, and steelhead once used Inkaneep Creek for spawning, but have not been seen there recently.

What do we know about fish habitat in Inkaneep Creek?

- Good habitat exists for fish to rear, or grow, in the lower section of the stream, but all spawning habitat is in poor condition. This lower section is accessible to all fish in Osoyoos Lake, but a natural waterfall about four kilometres above the lake prevents fish from moving further upstream. Inkaneep Creek likely provides important spawning and rearing habitat for Osoyoos Lake rainbow trout.
- A large landslide and debris jam in 1998 changed the shape and characteristics of the stream channel, resulting in less spawning and rearing habitat available for about 20 kilometres of the stream, from Gregoire Creek to Osoyoos Lake.

What impacts and human activities affect fish and fish habitat in Inkaneep Creek?

- Parts of Inkaneep Creek have been modified for flood control, including the removal of streamside vegetation. Roads also follow the creek closely. Agriculture, forestry, and urban development have all had moderate to high impacts on the watershed.
- Water diversions significantly impact the amount of water flowing in Inkaneep Creek. Diversions can also cause fish mortalities where pipes are inadequately screened.

What do we know about the fishery in Inkaneep Creek?

- There is little fishing in the lower reaches of Inkaneep Creek.

What factors limit fish production in tributary streams in Inkaneep Creek?

- Fish production in Inkaneep Creek is limited by high water temperatures, the loss of streamside vegetation, and low water flow in summer. Poor quality spawning habitat prevents kokanee and sockeye salmon from using Inkaneep Creek. Erosion and the input of sediments from landslides in the stream watershed also likely affect the production of fish.

What gaps exist in our knowledge of fish and fish habitat in Inkaneep Creek?

- The use and importance of Inkaneep Creek for rainbow trout and salmon spawners from Osoyoos Lake is unknown.
- The impact of the 1998 landslide and sediment inputs on resident fish production has not been identified.

What is being done to protect or restore fish and fish habitat in Inkaneep Creek?

- In 2001, the Okanagan Nation Alliance conducted restoration work on the lower two kilometres of Inkaneep Creek. The work included stabilizing stream banks, installing log structures in parts of the stream to increase habitat, erecting fences to limit the access of livestock to the stream, and planting native vegetation on stream banks.
- A culvert at Gregoire Creek was replaced by the Ministry of Transport and Highways. Its large size should prevent further debris jams from occurring, such as the one in 1998.

Chapter Six

Okanagan River

Description

- Okanagan River begins at the outlet of Okanagan Lake, and flows through Skaha, Vaseux, and Osoyoos lakes before joining the Columbia River at Brewster, Washington. The total volume of water that flows through Okanagan River each year has been estimated at nearly half a cubic kilometre. The volume was similar before the river became regulated by dams.
- Before it was altered by human activities, Okanagan River flowed through a wide flood plain. Annual flooding was natural, and the many wetlands along the length of the valley from Penticton to Osoyoos absorbed and stored the flood waters. Since human interference, Okanagan River has had a history of flooding communities. Particularly large floods occurred in 1928, 1942, and 1948.

  The 1940s floods prompted the formation of a Joint Board of Engineers. Their report recommended that Okanagan River be straightened into a manageable channel with dykes on either side to confine the water. Work began in 1950 and was completed in 1958.
- The channelized Okanagan River, as it has come to be described, resembles a canal more than a river. Creating the channel shortened the river from 61 to 41 kilometres; the river originally had an area of about 212 hectares and now has an area of 116 hectares. The channelized sections have few, and sometimes no, examples of the key features that define a river: riffles, pools, undercut banks, islands, side channels, eddies, and woody debris.
- About four kilometres of the river (15 hectares) remain in a natural or semi-natural state. Thus, 93% of the natural river no longer exists.
- Between Okanagan and Osoyoos lakes, Okanagan River has three large dams: Okanagan, Skaha, and McIntyre dams. These dams all have fish ladders but they aren't in use because of historical concerns about introduced species. Fish occasionally manage to pass over McIntyre Dam depending on how it is operated. Zosel Dam at the outlet of Osoyoos Lake in Washington State has fish passage.

What do we know about fish populations in Okanagan River?

General

- About 24 types of fish live in Okanagan River, but some are not found in all sections of the river, and the presence of others is uncertain (Table 7). This number includes sockeye and kokanee salmon as different types, even though they are the same species, and the same for steelhead and rainbow trout.
- The section of Okanagan River between Vaseux and Osoyoos lakes is particularly important for sockeye salmon spawning. Other sea-run, or anadromous, fish that return to spawn in Okanagan River are chinook salmon, although in small numbers recently,

and possibly steelhead trout, but reports are unconfirmed. Historically, chum, pink, and coho salmon may have returned to Okanagan River as well. A major impact was the Grand Coulee Fish Maintenance Project where all salmon migrating up into the Columbia River from 1939-1943 were blocked at Rock Island Dam.

Only sockeye were selected to be transplanted back into the Okanagan. It is not known whether the other salmon periodically observed in the Okanagan are strays or a remnant population. The presence of eels, probably Pacific lamprey, was made in early reports, but they have not been seen in recent times.

- As many as 15 native species that remain in fresh water throughout their lives and seven introduced fish species are found in Okanagan River. One native species, chiselmouth, is blue-listed as being of special concern because of its vulnerability to human or natural events. Of all fish species in Okanagan River, the most information is available for sockeye salmon.

Sockeye salmon

- The sockeye that return to Okanagan River are one of only two viable sockeye stocks, or populations, that remain in the Columbia River watershed. Historically, over a dozen sockeye stocks came up the Columbia River but the Grand Coulee and other dams prevented them from reaching their spawning grounds. The two remaining today are the Okanagan and Wenatchee stocks.
- Returning adult salmon navigate nine dams on the Columbia River and Zosel Dam close to the outlet of Osoyoos Lake (Map 3). They then hold in Osoyoos Lake for up to 45 days before swimming up Okanagan River to spawn in October. They spawn along the length of Okanagan River from Osoyoos Lake to McIntyre Dam, which has restricted upstream access since the 1920s.

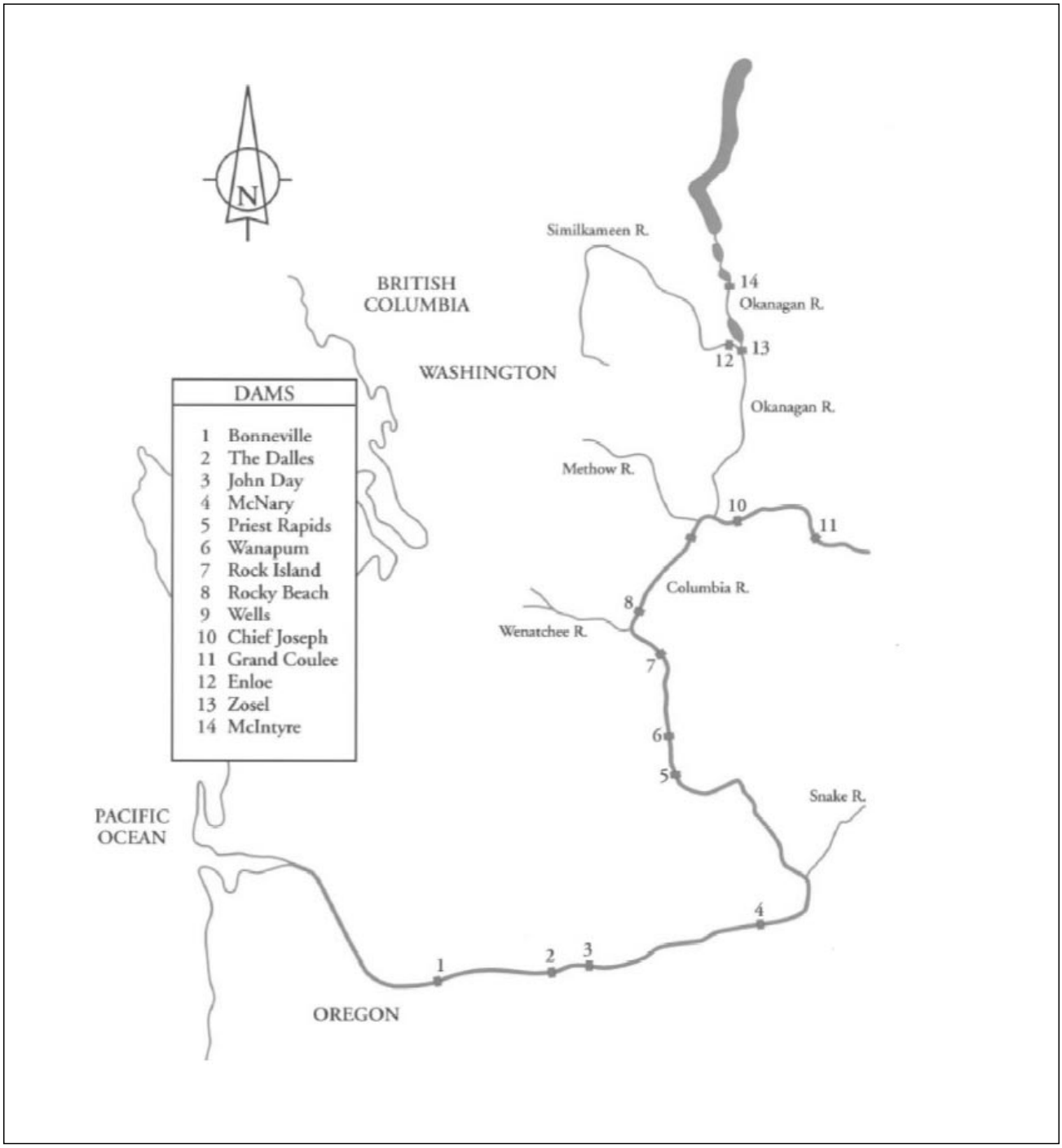
  Occasionally, some sockeye can get above the dam, depending on how it is operated, but a fish ladder built for the dam is inoperable. Most sockeye spawn in the natural and semi-natural sections of Okanagan River, above the town of Oliver (see *Chapters 6.2 and 6.3: Okanagan River sections II and III*).
- Returning sockeye salmon adults are counted on the Columbia River at Wells Dam, the final dam they pass before entering Okanogan River. Since 1961, the number of returning sockeye has varied from a high of 129,557 in 1966 to a low of 1,666 in 1994 (Figure 9 and Table 8). The average from 1961 to 2002 was 33,500 fish. Not all fish make it from Wells Dam to the Okanagan River spawning grounds; mortality ranges from 0-92% with an average of 43%.

Table 7. Presence of fish species in Okanagan River

Entries with a '?' indicate that presence of the species is unconfirmed. Section I , II and III refer to different stretches of Okanagan River; see text for details.

Common name	Okanagan River	
	Section I	Sections II & III
Bridgelip sucker	x?	x
Carp	x	x
Chinook salmon		x
Chiselmouth	x?	x
Eastern brook trout	x?	x?
Kokanee	x	x
Largemouth bass		x
Largescale sucker	x	x
Leopard dace	x?	x?
Longnose dace	x	x?
Longnose sucker	x	x
Mountain whitefish	x	x
Northern pikeminnow	x	x
Peamouth chub	x	x
Prickly sculpin	x	x
Pumpkinseed	x	x
Rainbow trout	x	x
Redside shiner	x	x
Slimy sculpin	x	x
Smallmouth bass	x?	x
Sockeye salmon		x
Steelhead trout		x?
Tench		x
Yellow perch		x

Data from Northcote et al. 1972, Wright et al. 2002, Fish Wizard.



Map 3. The Columbia River and location of dams that sockeye salmon migrate past.
From Bull 2002.

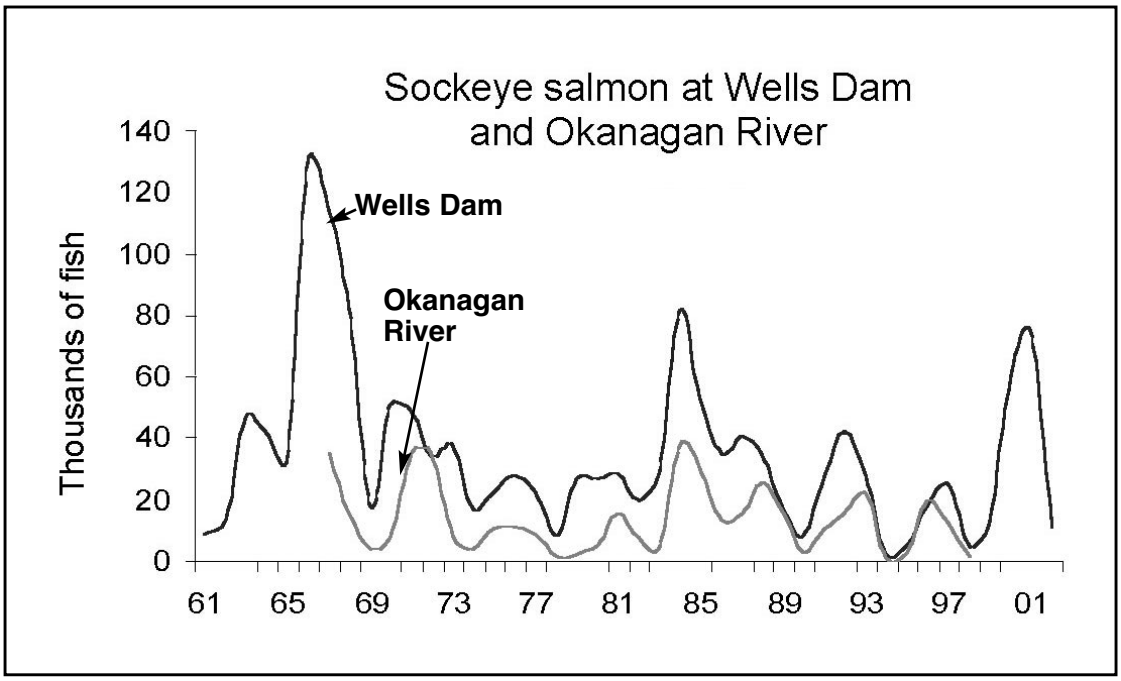


Figure 9 . Okanagan sockeye salmon counted at Wells Dam, 1961-2002, and estimates of spawning sockeye in Okanagan River, 1967-1998

Data from Fryer 1995, Hyatt and Rankin 1999, Stockwell and Hyatt 2003
Wells Dam fish counts website: www.fpc.org/adult_history/YTD-WEL.htm

Table 8. Okanagan sockeye salmon counted at Wells Dam, 1961-2002, and estimates of spawning sockeye in Okanagan River, 1967-1998

Year	Wells Dam	Okanagan River	Year	Wells Dam	Okanagan River
1961	8,505		1982	19,005	7,000
1962	13,218		1983	27,925	3,500
1963	46,299		1984	81,054	37,500
1964	40,590		1985	52,989	30,000
1965	31,722		1986	34,788	13,000
1966	129,557		1987	40,120	15,000
1967	113,232	35,000	1988	33,978	25,000
1968	81,530	15,000	1989	15,976	15,000
1969	17,352	3,500	1990	7,609	2,500
1970	50,667	7,500	1991	27,490	10,000
1971	48,172	35,000	1992	41,951	15,000
1972	33,398	35,000	1993	27,894	21,505
1973	37,178	8,000	1994	1,666	700
1974	16,716	3,500	1995	4,892	2,669
1975	22,286	10,000	1996	17,701	19,000
1976	27,619	11,040	1997	24,621	12,000
1977	21,973	8,475	1998	4,404	1,500
1978	7,644	1,050	1999	12,228	
1979	26,655	2,000	2000	59,944	
1980	26,573	5,000	2001	74,453	
1981	28,234	15,000	2002	10,586	

Data from Fryer 1995, Hyatt and Rankin 1999, Stockwell and Hyatt 2003,
Wells Dam fish counts website: www.fpc.org/adult_history/YTD-WEL.htm

What do we know about fish habitat in Okanagan River?

- Okanagan River no longer has most of the habitat features that were present in the unmodified river. Features that were common – riffles, pools, undercut banks, islands, side channels, eddies, and woody debris – have largely been removed. However, about four kilometres of the river remain in a natural or semi-natural state, and these few kilometres are where the majority of sockeye salmon spawned historically.
- Channelization reduced the river's total length by one third, making the new channel steeper than the original river. Seventeen concrete wiers, known as vertical drop structures, four between Skaha and Vaseux lakes and 13 downstream of Vaseux Lake, were built to ease the steepness and absorb some of the water's energy as it flowed downstream. The drop structures were designed so fish could pass through them, but they limit the movement of some species, including kokanee.
- Dykes flank either side of the engineered channel to contain water flow, and as a result, little streamside vegetation remains. Estimates are that 85% of streamside vegetation was lost when the river was channelized. The most intact and effective streamside vegetation remains in the short natural section upstream of the town of Oliver.

  A key benefit of streamside vegetation is temperature control. In late summer, the water temperature in Okanagan River rises too high for salmon to spawn. The salmon must delay their entry into the river to spawn by holding in Osoyoos Lake until the water temperature drops below the low to mid teens. Peak spawning occurs at 12 oC. Some parts of Okanagan River may have ground water inputs that help to cool the water.
- Okanagan River originally meandered, or twisted, extensively through its flood plain. When the controlled channel was created, these meanders were cut off from the main river channel. However, in the last 5-6 kilometres above Osoyoos Lake, the meanders were left partially attached so that they continue to be charged with water, even though they aren't in the main water flow. These meanders create important wildlife habitat and are also used by several introduced fish species including bass.

What impacts and human activities affect fish and fish habitat in Okanagan River?

- Dams on Okanagan River control the amount and timing of water that flows in the river. Penticton Dam on the outlet of Okanagan Lake controls water flow to the greatest degree. Because of the dams, the natural variability of water flow throughout the year has been altered. For example, the peak water flow in June is now 35% lower than it was before flood control, and the summer months also have lower flows.
- Water withdrawals also affect the volume of water in Okanagan River. McIntyre Dam downstream of Vaseux Lake was built, and continues to be used, to divert water into an irrigation canal. The intake pipe is unscreened, so fish, particularly fry, can be lost down the canal. The dam and canal were built from 1919-1921 for the South Okanagan Lands Project.

- River dredging and straightening has removed large amounts of habitat, both in the river and adjacent to it.
- Seventeen vertical drop structures limit the migration of some fish, including kokanee.
- Land use along the Okanagan River valley consists primarily of urban and agricultural development, including roads and bridges. Increased sediment inputs, changes to water flow patterns, and loss of stream-side vegetation are all impacts associated with these developments.
- In 1970, the amount of phosphorus entering the river from human sources was about twice as high as the amount from natural sources. Improvements in wastewater treatment have since reduced phosphorus inputs.
- The ten dams on the Columbia and Okanogan rivers affect sockeye salmon passage during both upstream and downstream migrations. Also, Okanagan sockeye continue to be caught commercially and for traditional uses in Washington State. Okanagan Nation members in BC take a handful of sockeye each year for food and ceremonial purposes.

What do we know about the fishery in Okanagan River?

- Okanagan Falls was the site of a large traditional fishery for sockeye, chinook, and steelhead. This fishery no longer exists due to the restriction of historical fish access, previous management actions, notably the Grand Coulee Fish Maintenance Project, and numerous habitat and flow alterations.
- There is only a limited recreational fishery on Okanagan River due to several area and timing closures to protect spawning sockeye, kokanee, and rainbow trout.

What factors limit fish production in Okanagan River?

- Limiting factors for sockeye salmon in Okanagan River are numerous and vary slightly depending on the life stage of the fish. Eggs incubating in the river require adequate water flow. Once hatched, the fry move to Osoyoos Lake, but they can be trapped in unscreened water withdrawal pipes along the river.
- For returning adult sockeye salmon, limitations include high water temperature and low water flow. At low water flow, less spawning habitat is available to the salmon. The 13 drop structures downstream of Vaseux Lake are not insurmountable obstacles for sockeye, but they probably increase their physical exhaustion and may delay their upstream migration. Access to spawning grounds further upstream is restricted by dams.
- Limitations on sockeye before they reach the Okanagan Basin include physical stress from navigating dams and catch mortality. In addition, about 50% of the sockeye recorded at Wells Dam on the Columbia River (the last Columbia dam the salmon pass) do not make it to the spawning grounds in Okanagan River.
- Other fish species in Okanagan River are also limited by low water flow, unscreened irrigation pipes, high temperature, and lack of habitat. The vertical drop structures limit or block the passage of smaller fish, including kokanee, in the river.

What gaps exist in our knowledge of fish and fish habitat in Okanagan River?

- The former range of species no longer present in Okanagan River is unclear. These include coho, chum, and pink salmon. The historical and present extent of steelhead trout and chinook salmon are also largely unknown.
- Information is lacking on the fish species, both native and introduced, currently living in or using Okanagan River. Traditional Ecological Knowledge of the historic fish assemblage is limited.
- The contribution of ground water to reducing water temperature or creating small refuges in Okanagan River is unknown.
- Given the extensive changes through land development, channelization, dam construction, and water use in the Okanagan Valley, a significant knowledge gap is how best to minimize the damage and maximize the habitat for fish production. Protection of the small remaining natural stretch of Okanagan River should also be addressed.
- The loss of about half the returning sockeye salmon between Wells Dam on the Columbia River and the spawning grounds in Okanagan River may be due to pre-spawning mortality or counting errors, but has not been confirmed.

What is being done to protect or restore fish and fish habitat in Okanagan River?

- Despite the severe impacts on Okanagan River, considerable potential exists for habitat restoration. A partnership of various agencies and organizations, including provincial and federal governments and the Okanagan Nation, are involved in several restoration projects. These include building artificial riffles (areas of swiftly moving water) to diversify the stream habitat and help absorb the steepness of the river channel, streamside planting of native vegetation, and moving some of the dykes back to allow the river channel more space to move from side to side.
- Fisheries and Oceans Canada and the Okanagan Nation Alliance monitor habitat characteristics, including temperature and water flow, and sockeye adult returns to Okanagan River.
- The Ministry of Water, Land and Air Protection, Fisheries and Oceans Canada and the Okanagan Nation Alliance have been working together closely to fine-tune the release of water through Penticton Dam.

  A new computer model incorporates all the available information about impacts from dam operation, including the effects of low water flow on spawning fish and incubating eggs. The model should be ready for implementation in autumn 2004 and will greatly improve water managers' decisions to ensure that impacts on fish are minimal.

CHAPTER 6.1 Okanagan River: Section I, Penticton Dam to McIntyre Dam

Description

- Section I of the Okanagan River includes three stretches: Penticton Dam to Skaha Lake, Skaha Lake to Vaseux Lake, and Vaseux Lake to McIntyre Dam. These are included together because they are currently inaccessible to sockeye and other sea-run fish species.
- The stretch of river from Penticton Dam to Skaha Lake has been changed dramatically. Dredging and straightening began on the river in 1910 to make navigation easier, and over the years, more and more of the natural river channel was lost (Photos 3 right).

The first dam at the outlet from Okanagan Lake was built in 1914-15. It was replaced at various times in subsequent years to try and control the level of Okanagan Lake and reduce flooding both above and below the dam. The present dam was built in 1954, with updates made in 1978-79.

- The stretch of river between Skaha and Vaseux lakes was straightened during the 1950s and four vertical drop structures were built to lessen the flow along the new, steeper channel. The current Skaha Dam at the village of Okanagan Falls was constructed in the 1950s. The dam prevents fish from moving upstream, but the original falls and cascades may

Photos 3. A section of Okanagan River where it drains into Skaha Lake in 1949 (left) and 1982 (right).
Photos are BC 800:31 (left) and BC 82024: 204 (right).

have been passable. This is supported by Traditional Ecological Knowledge about Okanagan Falls, which was the site of an important fishery for the Okanagan Nation, second only to the fishery at Kettle Falls.

- The section of river from Vaseux Lake to McIntyre Dam is naturally confined by steep terrain on its western bank. McIntyre Dam was built about two kilometres downstream from Vaseux Lake (10 km up from Oliver) in 1920, and modified in 1950, for irrigation purposes. Although the dam was constructed to allow fish passage, it has never been operated this way and would require considerable work to be made operational.

  Initially, the dam was kept closed to fish passage to prevent introduced species, particularly bass, from moving further upstream in the Okanagan Basin. Today, this concern has diminished (bass were stocked into Skaha Lake at a later date), but the dam continues to be operated without fish passage.

What do we know about fish populations in Section I of Okanagan River?

- Up to 18 species of fish live in Okanagan River between Penticton and McIntyre dams and four of these are introduced species. Population estimates and other information are lacking, except for kokanee salmon.
- Kokanee salmon from Skaha Lake use the section of Okanagan River between Okanagan and Skaha lakes for spawning. The number of spawning kokanee varies widely; 94,500 fish spawned in 2002 and 69,000 in 2003, whereas 800-16,000 were recorded from 1992 to 2001 (see Figure 7 in *Chapter 4.2: Skaha Lak*e).
- Traditional Ecological Knowledge suggests that sea-run fish including sockeye and chinook salmon and steelhead trout once migrated as far as Okanagan Lake. Now, these fish can swim no further than McIntyre Dam.

What do we know about fish habitat in Section I of Okanagan River?

- Dykes confine the river channel to widths of 25-30 metres between Penticton Dam and Skaha Lake, and to widths of 40-45 metres between Skaha and Vaseux lakes. A short, undyked stretch is naturally confined just downstream of Skaha Dam. Four drop structures were built in the Skaha to Vaseux stretch to absorb some of the water flow along the steep channel.
- Few habitat features, such as riffles, side-channels, or woody debris, exist in the river. Between Okanagan and Vaseux lakes the river is about 11 kilometres long, but only two kilometres have suitable spawning habitat for salmon.
- The majority of Skaha Lake kokanee prefer to spawn in a 200-metre section of gravel near Penticton Dam. The gravel was added to the channel in 1986 for the use of spawners.

What impacts and human activities affect fish and fish habitat in Section I of Okanagan River?

- Penticton Dam controls the amount of water that flows through Okanagan River.
- Most of the river between Penticton and McIntyre dams has been channelized, with dykes built on

both sides. Streamside vegetation is lacking. Most habitat features no longer exist, and side-channels and river bends have been cut off from the mainstem.

- Recreational use of Penticton channel by boaters and swimmers is heavy in summer, but has generally stopped by the time kokanee enter the river to spawn.

What do we know about the fishery in Section I of Okanagan River?

- There is a small fishery for rainbow trout in a stretch of section I immediately downstream of Skaha Lake.
- Fishing effort in the remainder of section I is very limited due to area and timing closures, and low numbers of popular sport fish species.

What factors limit fish production in Section I of Okanagan River?

- Fish production is likely most limited by the poor habitat available in Okanagan River. This includes changes to natural water flow, high temperatures, and no diversity of habitat.
- The four drop structures between Skaha and Vaseux lakes were designed for fish passage but may prevent some fish from moving upstream.
- When sea-run salmon were no longer able to migrate beyond McIntyre Dam, the river lost the source of nutrients from their rotting carcasses. The input of nutrients, especially ocean nutrients, is important for productivity in salmon streams.

What gaps exist in our knowledge of fish and fish habitat in Section I of Okanagan River?

- The reasons for the large fluctuations in kokanee spawner numbers from Skaha Lake are unknown.
- It isn't known to what degree the four drop structures between Skaha and Vaseux lakes restrict fish passage.
- The status of other resident fish species is unknown.

What is being done to protect or restore fish and fish habitat in Section I of Okanagan River?

- The Ministry of Water, Land and Air Protection counts the number of kokanee that spawn each year in the river between Okanagan and Skaha lakes.
- The Okanagan Nation Alliance counts and samples kokanee spawners that return to Shingle Creek.
- In 1986, the original cobble substrate was removed and replaced with spawning gravel in a 200-metre section of Okanagan River near Penticton Dam. This remains the site where most kokanee from Skaha Lake prefer to spawn.

Chapter 6.2 Okanagan River: Section II, McIntyre Dam to Drop Structure #13

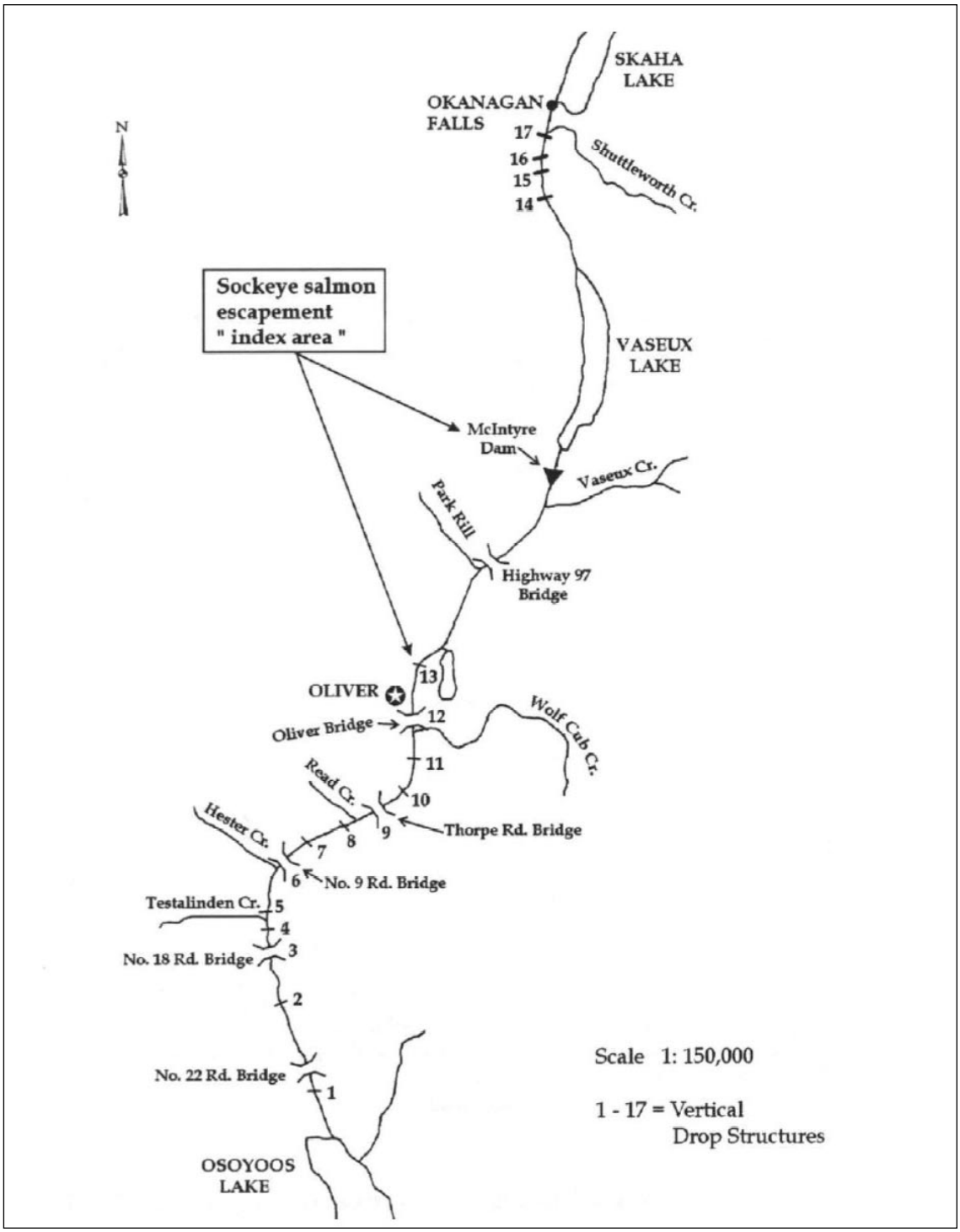
Description

- The total length of the river section from McIntyre Dam to drop structure #13 is about eight kilometres. (The drop structures are numbered up from Osoyoos Lake; Map 4).
- About two kilometres downstream from McIntyre Dam, Okanagan River flows through the only natural stretch of river – about one kilometre – that remains (Photo 4). It is a short distance upstream of the Highway 97 bridge that crosses the river, and is entirely within Osoyoos Indian Reserve. The channel's natural width varies between 20 and 40 metres.
- The river then immediately enters a three-kilometre, semi-natural stretch that was engineered with wider dykes than elsewhere along the river (Photo 4).

  These wider dykes, called set-back dykes, allow the river more freedom to move from side to side in its channel. The channel width ranges from 20 to 50 metres.
- From the end of the set-back dykes to drop structure #13 is a stretch with dykes that confine the river to a channel approximately 30 metres wide.

Photos: C. Bull.

Photo 4. The only remaining natural stretch of Okanagan River.



Map 4. Okanagan River from Skaha to Osoyoos lakes.
From Hyatt and Rankin 1999

What do we know about fish populations in Section II of Okanagan River?

- As many as 24 fish species may live in or use the natural and semi-natural stretches of Okanagan River, but substantial information exists only for sockeye salmon.
- Sockeye salmon have historically preferred spawning in the natural and semi-natural stretches of Okanagan River, even before it was modified.

The percentage of sockeye that spawn upstream of the town of Oliver (referred to as the Index Section) was 45% in 1947, before river channelization, and over 85% from 1951-1953 while channelization was in progress. Since the early 1990s, 70-97% of sockeye have spawned upstream of Oliver (Figure 10).

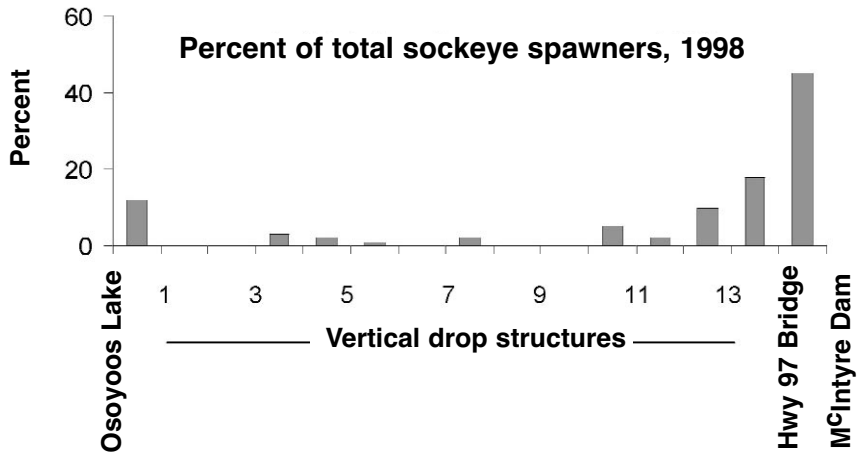


Figure 10. The distribution of sockeye salmon spawners in Okanagan River in 1998.

Refer to Map 4 on the previous page for location of the drop structures.
From Hyatt and Rankin, 1999.

What do we know about fish habitat in Section II of Okanagan River?

- Okanagan River downstream of Vaseux Lake still has the majority of the original spawning grounds for sockeye and other salmon.
- The natural stretch of Okanagan River has a gradient of about 0.5% and the semi-natural stretch is slightly less steep. However, both of these stretches are steeper than further downstream in the river. A steeper gradient allows water to flow more quickly. This is important for bringing oxygen to eggs incubating in the gravel and for removing sediments and wastes that would otherwise clog the gravel.
- A study in 1952, before the channelization was complete, estimated that Okanagan River up to McIntyre Dam had enough available habitat for

approximately 140,000 spawners. A more recent study, in 1999, estimates that the river habitat could support 58,730 spawners (Wells Dam counts) or 29,365 spawners at the peak of visual counts on the spawning grounds. The amount of available habitat depends on the water flow, since less of the river bed is wet when water flow is low.

- Streamside vegetation in the natural stretch was left intact, although the highway to the east limits the width of the vegetation border. In the semi-natural stretch, streamside vegetation is limited and the river can't access its natural floodplain beyond the set-back dykes.

What impacts and human activities affect fish and fish habitat in Section II of Okanagan River?

- Although the natural and semi-natural river stretches remain in their original channels, the river habitat has been fragmented by channelizing the downstream section and eliminating fish passage above McIntyre Dam.
- Urban and agricultural development, as well as roads and bridges, occur near the banks of this river section. Increased sediment inputs, changes to water flow patterns, and loss of stream-side vegetation are all impacts associated with these developments.
- Water management activities can have negative impacts on some fish species, including sockeye and kokanee.
- Because the natural and semi-natural stretches have the greatest number of sockeye spawners, these areas are visited frequently to count sockeye in September and October. Damage may occur to the gravel nests that sockeye lay their eggs in, especially if fisheries personnel walk extensively in the river channel.

What do we know about the fishery in Section II of Okanagan River?

- There is a small fishery targeting rainbow trout in the natural stretch of Okanagan River.

What factors limit fish production in Section II of Okanagan River?

- In years with low water flow, the area of available spawning habitat may be limiting if a large run of sockeye returns.
- In rivers without streamside disturbance, trees and branches are normally carried downstream by high water flows. This woody debris then creates pools and other habitat features where the river deposits it. There is little woody debris available upstream of the natural stretch for Okanagan River to transport downstream. Over time, as current woody debris rots or is swept away, this may limit the diversity of habitat available in the natural stretch of the river.
- The river has more limited access to its floodplain than in historic times, even in the natural section. The floodplain functions as a place for a river to spill into and deposit sediments that would otherwise clog gravel in the river bed.
- The limited ability of the river to flow in its natural course and create natural habitat features in parts of

Okanagan River is a limitation to fish production. From Oliver upstream is considered the highest priority for fisheries protection and restoration.

What gaps exist in our knowledge of fish and fish habitat in Section II of Okanagan River?

- The natural and semi-natural stretches of Okanagan River are extremely important to Okanagan sockeye salmon. Yet, there are no measures in place to ensure that the habitat is protected. How best to go about this could be considered as a significant knowledge gap.
- The quality of spawning gravel in the natural and semi-natural stretches has not been assessed.
- Information is lacking on the fish species, both native and introduced, currently living in or using the natural and semi-natural stretches of Okanagan River.
- The contribution of ground water to reducing water temperature or creating small refuges in Okanagan River is unknown.

What is being done to protect or restore fish and fish habitat in Section II of Okanagan River?

- The stretch of Okanagan River downstream of the set-back dykes to Oliver has particularly high potential for habitat restoration. Various agencies and organizations, including provincial and federal governments and the Okanagan Nation, are working together on several restoration projects in this stretch. A key project involves buying land adjacent to the river channel and pushing back the existing dykes to allow the river more space to move in its floodplain. A proof-of-concept project is currently underway to demonstrate how this can be done.

  Some land has been bought, and other land purchases are being negotiated along about a two-kilometre stretch of the river between the end of the existing set-back dykes and drop structure #13. Construction of the new set-back dykes should begin in 2005.
- Four artificial riffles have been constructed near the town of Oliver. These riffles diversify the stream habitat, and demonstrate how the steepness of the river channel can be reduced through features that are more natural, and likely less costly to maintain, than the drop structures currently in place. The riffles are being monitored for use by fish.
- The Ministry of Water, Land and Air Protection, Fisheries and Oceans Canada and the Okanagan Nation Alliance have been working together closely to fine-tune the release of water through Penticton Dam. A new computer model incorporates all the available information about impacts from dam operation, including the effects of low water flow on sockeye spawners and incubating eggs.

  The model should be ready for implementation in autumn 2004, and will greatly improve water managers' decisions to ensure that impacts on fish are minimal.
- Fisheries and Oceans Canada and the Okanagan Nation Alliance monitor habitat characteristics, including temperature and water flow, and sockeye adult returns to Okanagan River.

CHAPTER 6.3 Okanagan River: Section III, Drop Structure #13 to Osoyoos Lake

Description

- Okanagan River flows for about 17 kilometres through an engineered channel from drop structure #13 to Osoyoos Lake. Dykes confine the channel to a width of 25-35 metres, and the river doesn't have access to its floodplain. The extensive bends that the river once followed have been bypassed, although they are still present and visible in air photos.

What do we know about fish populations in Section III of Okanagan River?

- As many as 24 fish species may live in or use the channel section of Okanagan River, but little information exists.
- Sockeye salmon historically have not spawned in great numbers in the lower 17 kilometres of Okanagan River but some still do and the numbers vary from year to year. Generally, fewer than 25% of sockeye spawn in this section, and often as few as 3-5% use it. In 1947, prior to channelization, about half of sockeye spawners used this section.

What do we know about fish habitat in Section III of Okanagan River?

- The river in the channel is less steep, at only 0.14% gradient, than in the natural and semi-natural stretches. This was also the case historically because of the many meanders, or bends, in the river. Low gradient rivers have slower water flow, and this is less suitable for the life history of salmon.
- The river is now a uniform channel with little habitat variability. It is essentially a long glide, or smooth stretch of water, punctuated only by the 13 drop structures along its length (Photo 5). The channel is considered to have only marginal in-stream habitat. Many of the original meanders remain attached to the river channel as backwater pools with flap-gates that allow some movement of water. These meanders, sometimes referred to as oxbows, provide good habitat for bass, an introduced species.

Photo: Chris Bull

Photo 5. One of 13 vertical drop structures on Okanagan River downstream from Oliver

What impacts and human activities affect fish and fish habitat in Section III of Okanagan River?

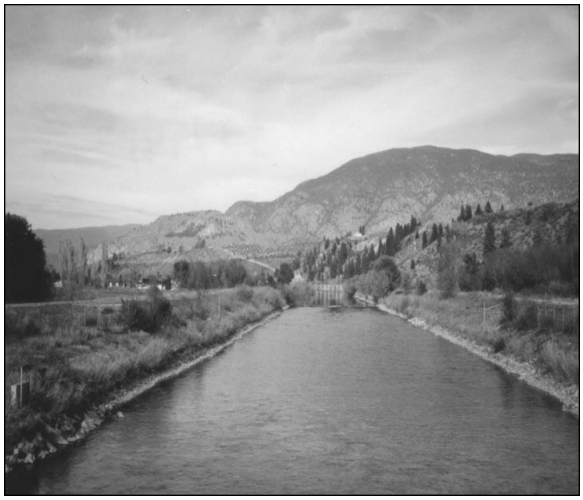
- When the channel was created and the dykes built, all streamside vegetation was removed. Generally, grass grows on the dykes but few bushes or trees grow, and this contributes to the high water temperatures experienced by the river in late summer. Most in-stream habitat was eliminated during the channelization.
- The thirteen drop structures are extra hurdles encountered by migrating sockeye that have already navigated ten dams downstream of Osoyoos Lake. They also limit or block the passage of other fish species, including kokanee.
- Urban and agricultural development, as well as roads and bridges, occur near the banks of the river channel. Water intake pipes for irrigation are frequently left unscreened and these can trap fish.

What do we know about the fishery in Section III of Okanagan River?

- There is a small fishery for smallmouth bass at the lower end of Okanagan River, close to Osoyoos Lake.

What factors limit fish production in Section III of Okanagan River?

- Sockeye are limited in the channelized section of Okanagan River by poor spawning habitat. This was also the case historically, but the habitat quality is now even lower. High water temperature, low water flow, and unscreened water withdrawal pipes will all affect sockeye production. These factors likely also limit other fish species, but information is lacking.



Photos 6. The heavily channelized section of Okanagan River downstream of Oliver.

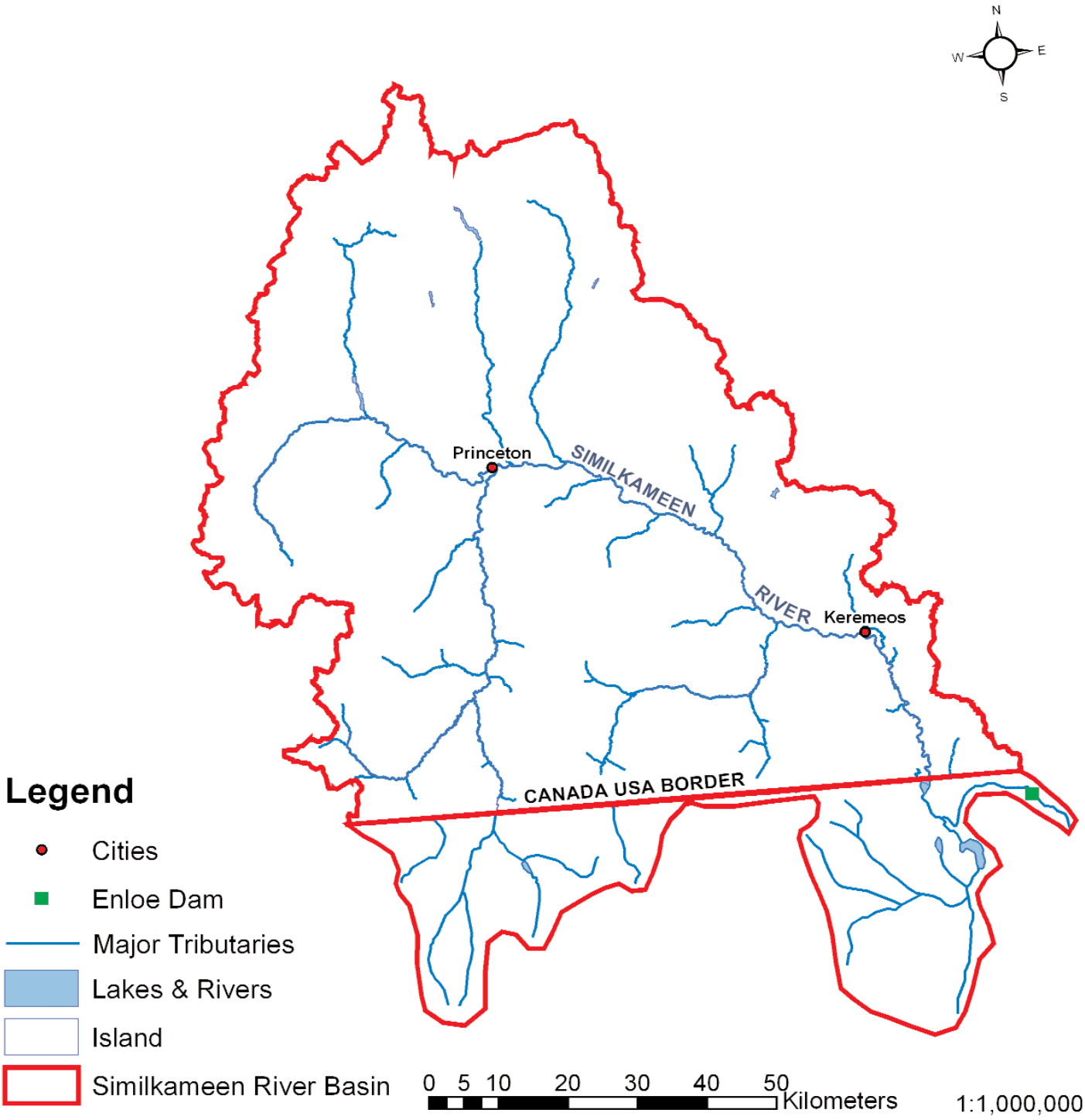
What gaps exist in our knowledge of fish and fish habitat in Section III of Okanagan River?

- Minimal information is available on the fish species, both native and introduced, currently living in or using Okanagan River.
- The former range of species no longer present in Okanagan River is unclear. These include coho, chum, and pink salmon. The historical and present extent of steelhead trout is also unconfirmed.
- Interest has been expressed in re-joining the old meanders to the lake channel to increase wildlife habitat. The impacts on salmon and trout are unknown, but a longer channel could potentially increase their vulnerability to predators.
- The contribution of ground water to reducing water temperature or creating small refuges in Okanagan River is unknown.

What is being done to protect or restore fish and fish habitat in Section III of Okanagan River?

- Fisheries and Oceans Canada and the Okanagan Nation Alliance monitor habitat characteristics, including temperature and water flow, and sockeye adult returns.

Part II: *The Similkameen Basin*



Chapter Seven

Overview of the Similkameen Basin

Description

- The Similkameen Basin includes all the land that surrounds the streams and lakes that ultimately drain into the Similkameen River (Map 5). The basin covers an area of about 7,600 square kilometres in British Columbia. A small portion of the basin (about 20%) is in the United States.
- The Similkameen River flows from its origin in Manning Provincial Park north to Princeton, and then southeast through Keremeos to the international border. Near Oroville, Washington, the Similkameen River joins Okanogan River, which ultimately drains into the Columbia River.
- Enloe Dam was built for hydroelectricity generation on the Similkameen River, about 14 kilometres upstream of its mouth on the US side. The dam operated from 1916 to 1923, and remains today as a barrier to upstream fish migration. Before the dam was built, however, a natural barrier existed at the same location. Therefore, in historic times, sea-run fish did not have access to the Canadian portion of the Similkameen Basin.

  A First Nations' legend tells of Coyote's travels across the land visiting various groups of animal people, who were not yet fully human. At each stop he asked the animal people to give him their daughters in return for salmon. When he visited the area near present-day Oroville, the animal people said they didn't need salmon because they had mountain goat to eat. So, Coyote placed a rock in the Similkameen River and created a waterfall that stopped salmon from moving any further upstream.

What is the origin of streams and lakes in the Simikameen Basin?

- Much of the surface geology present in the Similkameen Basin resulted from large glacial meltwater streams that flowed through the valley as glaciers retreated about 15,000 years ago.

What is the climate of the Simikameen Basin?

- The Similkameen is largely in the rain shadow of the Coast and Cascade mountains. The western part of the basin has a cooler, moister climate than the dry southeast. Precipitation averages 36 centimetres in Princeton and 32 centimetres in Keremeos each year. Air temperature is over 3 oC higher, on average over the year, in Keremeos than in Princeton.
- Climate change may be occurring in the Similkameen Basin and affecting river flow. A study examined water flow in the upper Similkameen River in the 1970s and compared it to water flow at the same location in the late 1980s and early 1990s. In the later years, snow melted earlier in spring, water flow was lower in summer, the low-

flow period in summer lasted longer, and more rain fell in autumn. Indications are that these trends may continue over the next 80 years.

What is the hydrology, or stream flow pattern, in the Simikameen Basin?

- Streams in the Similkameen Basin are fed mainly by snowmelt. The snow that falls each winter melts in spring and enters the streams. The resulting high water flow is called the spring freshet, and accounts for two-thirds of annual stream flow. By July, the freshet has subsided and water flow remains low for the summer, autumn, and winter (see Figure 1 in *Chapter 1: Okanagan Basin*). This means that water flow in creeks is low during the peak irrigation months and during the peak spawning periods for fish. This overlap is greatest in the lower Similkameen valley where most agriculture occurs.

What do we know about fish populations in the Simikameen Basin?

- All fish in the British Columbia portion of the Similkameen Basin are resident fish, meaning that they stay in fresh water throughout their lives (Table 9). Sea-run fish migrate to the base of Enloe Dam, 14 kilometres from the river mouth in Washington, but they can swim no further.
- At least 17 fish species live in the Similkameen Basin, but five of them are not native. These are black bullhead, brook trout, lake trout, cutthroat trout, and kokanee.
- Four rare native species exist in the Similkameen Basin. Umatilla dace are on the provincial red list, meaning that they are or could become endangered or threatened.

  Chiselmouth, mottled sculpin, and mountain sucker are all blue-listed because of their vulnerability to human or natural impacts. Mountain sucker has a particularly small distribution in BC, being found only in two creeks, Otter and Wolfe, that flow into the Similkameen River, and in the North Thompson River basin.
- Several fish species were stocked historically, but now rainbow trout are the principal fish stocked to lakes in the basin.
- The Similkameen River system generally has low productivity because of cool temperatures and few nutrients. Water temperature only rises above 5 oC for about three months each year, so the growth period is short. The tributary streams flow from the mountains and are frequently steep, leaving little chance to accumulate nutrients such as phosphorus and nitrogen that are necessary for plant and animal growth.

  In addition, very high water flow during the spring freshet and low flow in summer limits fish production, as does anchor ice in winter. Anchor ice forms on river and stream beds when water flows and temperatures are both low. The ice scours the bed, and also suffocates eggs incubating and fish overwintering in the gravel.

Table 9. Fish Species in the Similkameen Basin

Common name	Scientific name	Status
Black bullhead	*Ameiurus melas*	Introduced
Bridgelip sucker	*Catostomus columbianus*	Native
Chiselmouth	*Acrocheilus alutaceus*	Native - at risk (blue list)
Eastern brook trout	*Salvelinus fontinalis*	Introduced
Kokanee	*Oncorhynchus nerka*	Introduced
Lake trout	*Salvelinus namaycush*	Introduced
Largescale sucker	*Catostomus macrocheilus*	Native
Leopard dace	*Rhinichthys falcatus*	Native
Mottled sculpin	*Cottus bairdi hubbsi*	Native - at risk (blue list)
Mountain sucker	*Catostomus platyrhynchus*	Native - at risk (blue list)
Mountain whitefish	*Prosopium williamsoni*	Native
Northern pikeminnow	*Ptychocheilus oregonensis*	Native
Rainbow trout	*Oncorhynchus mykiss*	Native
Slimy sculpin	*Cottus cognatus*	Native
Torrent sculpin	*Cottus rhotheus*	Native
Umatilla dace	*Rhinichthys umatilla*	Native - at risk (red list)
Westslope cutthroat trout	*Oncorhynchus clarki lewisii*	Introduced

From IEC Beak Consultants 1983, Bull 2000, SRPC 2001, Fish Wizard 2004.

What is the human population in the Simikameen Basin?

- The Similkameen people originate from the Interior Salish Nations, and have lived in the area for at least 8,000 to 10,000 years. Although sea-run fish did not reach most of the Similkameen River because of a waterfall near the river's mouth, the Similkameen people likely fished resident species at certain times of year.
- In the 1850s, European settlements arose, mainly because of opportunities to mine for gold and, later, copper. Ranching and agriculture also began in the mid to late 1800s, and have increased in intensity since the mid-1900s. Today, forestry, recreation, and tourism are also important to the economy.
- The two largest towns in the Similkameen Basin, Princeton and Keremeos, are both on the shores of Similkameen River, as are smaller communities. In 2001, 9,200 people lived in the Similkameen Basin.

  The population census in BC combines the South Okanagan with the Similkameen (see Figure 2 in *Chapter 1: Okanagan Basin*), and only provides individual statistics on larger communities. Therefore, accurate population growth information is only available for Princeton and Keremeos.

In the 30-year period from 1971 to 2001, the combined population of these towns grew from 3,200 to nearly 4,000 people. The majority of this growth, however, is due to more than a doubling of Keremeos' population from 600 in 1971 to 1,250 in 2001.

What impacts and human activities affect fish and fish habitat in the Similkameen Basin?

- Human activities have had various impacts on the lakes, streams, and rivers in the Similkameen Basin. These activities include land use, water use, flood control, and species introductions.
- Primary land uses are agriculture, forestry, mining, and urban development. These activities frequently occur near lakes and streams, altering shorelines and streambanks. Even when land use activities aren't near water, they can still have impacts. Land alterations affect the way in which water runs across the land, what it carries with it, and what ultimately enters lakes and streams.

  Road and railway building has also had impacts, including dyking the river in some locations, removing streamside vegetation, altering water flow patterns, and increasing accessibility. Dykes were built for flood control along stretches of the Similkameen near Keremeos, and downstream.
- Land use is accompanied by water use for domestic, irrigation, and industrial activities. Water is withdrawn primarily from streams and the Similkameen River, but ground water is also used, particularly in the lower Similkameen valley. By the mid-1980s, most surface water sources in the Similkameen Basin were fully licensed, meaning that they were at their capacity to have water withdrawn for human use.

  In other words, no extra water is available after we have withdrawn water and after the needs of fish and wildlife have been considered. Even without water withdrawals, the low flows that naturally occur in summer and autumn limit fish production and survival. Water withdrawals simply exacerbate this limitation.
- Water flow is naturally low in Similkameen streams in late summer when fish begin to migrate into them. Water withdrawals also tend to be high at this time of year, particularly for irrigation. Climate changes that extend the growing season and alter the timing and volume of water in streams will increase the severity of low stream flow in late summer.
- An additional limitation on water supply in the Similkameen Basin comes from the requirement for downstream water flow to supply water license holders in Washington State.
- Plant and animal species that are not native to an area, also called exotic or introduced species, can have serious consequences for native species. In the Similkameen, four introduced fish are now present. Once established, introduced species can be difficult, or impossible, to eradicate. The main danger of introduced species is competition with native species for food and habitat.

- In the early 1980s, Bonneville Power Administration in the United States was interested in altering Enloe Dam to allow fish passage above the dam. This would enable sea-run fish, including steelhead trout, chinook salmon, and other Pacific salmon species to access the upper Similkameen River.

  An extensive study was carried out to examine the available habitat in the river and several of its major tributaries. This study remains the only comprehensive information available about fish and fish habitat in the Similkameen Basin. Considerable concern was expressed by the Okanagan Nation, the Ministry of Water, Land and Air Protection, and others on the Canadian side of the border and the proposal was shelved.

What do we know about the fishery in in the Simikameen Basin?

- Sport-fishing attracts less people in the Similkameen than in the Okanagan, but nonetheless contributes to the overall $16 million value (direct expenses, year 2000) of fishing in the Okanagan Region (includes Okanagan, Similkameen, Kettle, and Shuswap rivers).
- The majority of fishing effort in the Similkameen Basin is directed at lakes, with some additional fishing for rainbow trout on the mainstem river and a few creeks.

Chapter Eight

Similkameen Lakes

Description

- An estimated 153 lakes are found in the Similkameen Basin. The two largest lakes in the Similkameen Basin, Otter and Missezula, are relatively small with surface areas of 2.9 and 2.6 square kilometres, comparable to the area of Vaseux Lake in the Okanagan. Maximum depth in Similkameen lakes ranges from less than 4 to 74 metres (Missezula Lake).
- Productivity varies in the Similkameen headwater lakes. One measure of lake productivity is the concentration of total dissolved solids, or TDS, in the water. TDS is generally measured in parts per million, ppm. TDS measured for 41 Similkameen lakes ranges from 12 to 403 ppm, with an average of 174 ppm. Kilpoola Lake near Osoyoos is a hyper-saline lake, meaning that it is many times saltier than the sea, with a TDS of about 8,000 ppm.

  Based on average TDS, Similkameen Basin lakes generally have higher productivity than Okanagan Basin lakes (not including the six main valley lakes in the Okanagan).
- Sixty-eight lakes are currently stocked for angling. Yellow Lake on Highway 3 is a particularly accessible and popular fishing lake.

What do we know about fish populations in Simikameen lakes?

- Of the 17 fish species living in the Similkameen Basin, at least nine can be found in the lakes. Little information exists about population sizes. Twenty-six lakes have rainbow trout populations that live in lakes but spawn in streams. Joe and Harry lakes are both alpine lakes that were once stocked with rainbow trout, and now have naturalized shore-spawning populations of these fish. Chiselmouth, which is on the blue list for vulnerability to human and natural impacts, lives in Wolfe and Missezula lakes.
- Of the 68 lakes stocked in 2003, 95% received rainbow trout and the remainder eastern brook trout. In the early 1980s, 323,000 rainbow trout were stocked annually, but this has since declined to 207,250 in 2003. Fish of various sizes are released. Lake trout had previously been stocked into Otter Lake and westslope cutthroat trout into Cathedral Lakes. Otter and Missezula lakes were both stocked with kokanee in the past; a 1984 estimate was made of 125,000 kokanee in total.
- In the early days of the fish stocking program, rotenone and other chemicals were used in some lakes in an attempt to eliminate the native fauna before stocking trout. This practice occurred in 10 Similkameen lakes between 1947 and 1973, but is no longer used.

What do we know about fish habitat in Simikameen lakes?

- Throughout the Similkameen Basin, productivity, or the amount of plant and animal life, decreases with elevation. Higher elevation lakes have cooler water temperatures and shorter growing seasons.
- Twenty-nine lakes have been identified with suitable habitat for the natural spawning of rainbow trout, but others have limited or no habitat.

What impacts and human activities affect fish and fish habitat in Simikameen lakes?

- Land use in the watersheds of Similkameen Basin lakes includes moderate to high impacts from urban and agricultural activities at lower elevations, and moderate to high impacts from forestry at higher elevations. Logging roads are extensive in many watersheds and frequently follow streams up to their headwaters. These roads increase access to headwater lakes, change water runoff patterns, and contribute to erosion.
- *Mysis* shrimps, a species that was introduced into Okanagan Lake in 1966, was later transplanted from Okanagan Lake to Missezula Lake before their harmful effects were realized (see *Chapter 4.1: Okanagan Lake*). The shrimps have never been found since; the lake may be too shallow for them to survive being eaten by fish.

What do we know about the fishery in Simikameen lakes?

- Recreational fishing on lakes accounts for about 85% of all angling in the Similkameen Basin.
- Lakes in the Similkameen Basin contribute to the angling effort on stocked lakes in the Okanagan Region (includes Okanagan, Similkameen, Kettle, and Shuswap basins). In 1995 (the most recent data available), the number of angler days was estimated at nearly 260,000 for stocked lakes in the Okanagan Region. A more recent angler survey in 2000 does not specify angling effort on stocked lakes.

What factors limit fish production in Simikameen lakes?

- The principal limiting factors for fish production in Similkameen lakes are suitable spawning habitat for self-sustaining populations and low water temperature. Low food web productivity limits some Similkameen lakes, but others are so productive, they are unable to support fish through the winter due to low levels of dissolved oxygen in the water.

What gaps exist in our knowledge of fish and fish habitat in Simikameen lakes?

- The Ministry of Water, Land and Air Protection data base contains documentation of fish stock and recreational fishery status on a large number of naturally recruiting and stocked lakes, but information is limited on some priority lakes, or is in need of updating. No basin-wide inventory of native fish populations or fish habitat exists.
- Native fish populations may have been eliminated from a few of the lakes where rotenone and other chemicals were used prior to stocking with trout.

What is being done to protect or restore fish and fish habitat in Simikameen lakes?

- The Ministry of Water, Land and Air Protection gathers information each year about the status of fish stocks in a limited number of the headwater lakes. They also assess the recreational fishery to provide information to assist in developing or modifying management strategies. The number of lakes assessed each year depends on available funds. Lakes are prioritized based on the potential for impacts to wild fish stocks, angler use, fishery status, reported problems or conflicts, and the length of time since a previous assessment.
- The Ministry of Water, Land and Air Protection continues to stock 68 lakes with rainbow trout and eastern brook trout each year. Eastern brook trout are stocked as all-female or sterile fish.
- The Ministry of Water, Land and Air Protection protects wild fish stocks through the use of regulations and access restrictions. Angling regulations are also used to provide a variety of angling opportunities in stocked lakes.
- The Ministry of Water, Land and Air Protection has installed lake aerators in several stocked lakes to increase the levels of dissolved oxygen in the water and improve overwinter survival.

Chapter Nine

Similkameen: Tributary Streams to the Similkameen River

Description

- The Tulameen River is the largest tributary that joins the Similkameen River. Other important tributaries include the Pasayten and Ashnola rivers, and Allison, Hayes, and Otter creeks.

In a recent assessment of focal watersheds, 16 tributary streams were named as having high or very significance for fish protection because of the sensitivity of fish stocks (rainbow trout and rare species) and the current or potential level of fish production in the stream (Table 10).

Table 10. Ratings assigned to streams in the Similkameen Basin.

Creek	Significance for Fish Protection [a]	Habitat Impact [b]	Significance for Habitat Restoration [c]
Allison Creek	High	High	High
Ashnola River	High	Medium	Medium
Asp Creek	High	Medium	Medium
Granite Creek	High	High	High
Hayes Creek	High	High	High
Hedley Creek	High	High	High
Keremeos Creek	High	High	High
Lawless Creek	High	High	High
Otter Creek	High	High	High
Pasayten River	Very High	Low	High
Shrimpton Creek	High	Medium	Medium
Siwash Creek	High	Medium	High
Summers Creek	High	High	High
Tulameen River	Very High	Medium	High
Whipsaw Creek	High	Medium	Medium
Wolfe Creek	High	Medium	High

From Matthews and Bull 2003.

a The ratings of significance for fish protection refer to focal fish species (rainbow trout and rare species) and were obtained by ranking the sensitivity of fish stocks and the current or potential level of fish production in the stream.

b Habitat impact was rated for forestry, agriculture, urban development, low water flow, and temperature. The highest score from any of these impacts was used as the habitat impact for the whole creek or river.

c Significance for habitat restoration was based on the fish protection and habitat impact scores if they were the same and on expert opinion if they differed.

What do we know about fish populations in Simikameen tributary streams?

- At least 17 fish species live in the Similkameen Basin, but not all are necessarily present in every tributary. Five are introduced species, and an additional four are rare native species. The blue-listed (vulnerable to impacts) mountain sucker is found only in Otter and Wolfe creeks.
- All tributaries have rainbow trout populations. Some of these live entirely in streams, but others live in lakes and only enter streams to spawn. In 1983, population estimates for rainbow trout were 19,000 in Tulameen River, 48,000 in Ashnola River, and 7,800 in Pasayten River. These estimates were made between August and October. The highest densities of juvenile rainbow trout have been found in the lower stretches of tributary streams.
- In a 2001 study, two streams were found to have particularly high numbers of rainbow trout compared to other tributaries and to the mainstem river. These streams, Keremeos and Susap, were dry or had low water flow in some sections that prevented fish movement.

What do we know about fish habitat in Simikameen tributary streams?

- The Similkameen Basin boasts about 500 kilometres of fish-supporting rivers and streams. A study in 2001 provided an overview of the habitat available to resident fish in Similkameen tributaries. The streams were considered to be important as spawning, rearing, and overwintering habitat. However, streamside vegetation, which provides important bank stability, shading of the water, nutrient inputs, and in-stream habitat from woody debris, has been removed along many tributary streams.
- Few tributaries in the 2001 study had high quality pool habitat, which was found to be the preferred habitat of rainbow trout and other fish sampled. Low water flows restricted fish movement throughout much of the year. Seven of the larger tributaries contained most of the accessible habitat for fish: Allison, Ashnola, Hayes, Hedley, Keremeos, Tulameen, and Wolfe.
- Streams in the Similkameen Basin generally have low productivity because of cool temperatures and few nutrients. High water flow in spring and low flow in summer limits fish production, as does anchor ice in winter. Anchor ice scours river and stream beds, and suffocates eggs incubating and fish overwintering in the gravel.

What impacts and human activities affect fish and fish habitat in Simikameen tributary streams?

- Land use in the watersheds of Similkameen Basin streams includes moderate to high impacts from urban and agricultural activities at lower elevations, and moderate to high impacts from forestry at higher elevations. Overall habitat impacts for a selection of streams are in Table 10.
- Road and railway building has also had impacts. The Tulameen River, in particular, was affected by the now-abandoned Canadian Pacific railway line that ran along stretches of the river.

- Several streams lack their original streamside vegetation and suffer erosion and trampling from livestock. An extensive list of streams with livestock impacts was compiled in 2001, but locations and the degree of damage were not included.
- Water is withdrawn primarily from streams and the Similkameen River. By the mid-1980s, most surface water sources in the Similkameen Basin were fully licensed, meaning that they were at their capacity to have water withdrawn for human use.
- Water flow is naturally low in Similkameen streams in late summer when fish begin to migrate into them. Water withdrawals also tend to be high at this time of year, particularly for irrigation. Climate changes that extend the growing season and alter the timing and volume of water in streams will increase the severity of low stream flow in late summer.

What do we know about the fishery in Simikameen tributary streams?

- Recreational fishing on streams and the Similkameen River accounts for about 15% of angling in the Similkameen Basin. Rainbow trout are most frequently angled in the streams and river during summer.
- Sport-fishing attracts less people in the Similkameen than in the Okanagan, but nonetheless contributes to the overall $16 million value (direct expenses, year 2000) of fishing in the Okanagan Region (includes Okanagan, Similkameen, Kettle, and Shuswap rivers).

What factors limit fish production in Simikameen tributary streams?

- The principal limiting factors for fish production in tributary streams are cool water temperatures, low levels of nutrients, very high water flows in spring, low flows in summer, and anchor ice in winter. The steepness of some stream channels also limits the amount of habitat available. Disturbance to streamside vegetation and a limited amount of in-stream woody debris affect the amount and quality of in-stream fish habitat.

What gaps exist in our knowledge of fish and fish habitat in Simikameen tributary streams?

- Over 50 fish inventory and habitat assessments have been conducted on individual streams in the Similkameen Basin since 1997, but none of the information in these reports has been compiled. Recent habitat information is available from 2001, but the most recent estimates of fish populations throughout the basin remains a 1983 study. The extent of habitat change or deterioration in the past 20 years is largely undocumented.

What is being done to protect or restore fish and fish habitat in Simikameen tributary streams?

- In 2000, the Similkameen River Planning Committee commissioned a fish habitat assessment (the 2001 study mentioned several times above). Sampling was conducted at four mainstem and seven tributary sites, and fish habitat assessments were conducted on four tributaries. The information collected was then used to identify opportunities for fish habitat restoration.
- In 2002, restoration work was conducted on sections of Allison and Keremeos creeks, as recommended in the Similkameen River Planning Committee report. The restoration focused on building large woody debris and boulder structures to stabilize eroding streambanks. These structures will also provide more fish habitat in the creeks.

Chapter Ten

Similkameen River

Description

- The Similkameen River is 196 kilometres long. It originates in Manning Provincial Park, flows north and is joined by the Pasayten River shortly before flowing over Similkameen Falls, a series of cascades. The Tulameen River enters at Princeton and the river then flows southeast, with the Ashnola River joining upstream of Keremeos. Here, the floodplain has widened and the river meanders south across the international border (Photo 9). It then flows east to join Okanogan River near Oroville, Washington.
- Two impassable barriers to fish are found on the Similkameen River: Enloe Dam in Washington, which was the location of a natural barrier before the dam was built, and Similkameen Falls just downstream of Pasayten River.

What do we know about fish populations in Simikameen River?

- At least 17 fish species live in the Similkameen Basin, but not all are necessarily present in the Similkameen River itself. Four are introduced species and an additional four are rare native species. The river was ranked in 2003 as having very high significance for fish and fish habitat protection because of the sensitivity and production of the fish species.
- Rainbow trout were stocked into the river from Summerland hatchery before the mid-1980s. The stocking was stopped because of possible negative effects on wild rainbow trout populations.
- When fish populations were assessed in 1983, the greatest fish diversity was found below Similkameen Falls, with mountain whitefish and bridgelip suckers the two most common species. Above the falls, only two species were found, rainbow trout and longnose dace.
- In 1983, the mountain whitefish population was estimated at 353,000 fish, 86% of which were in the Similkameen River between Keremeos and Princeton.
- Rainbow trout in the river were estimated at 67,500 fish in 1983, with the highest density only 0.2 fish per square metre. Productive rainbow trout streams in BC generally have densities of two or more fish per square metre. Growth rates were also low in the Similkameen River, with rainbow trout taking four years to reach a length of 20 centimetres.
- Anecdotal evidence says that fishing used to be better than it is now, which indicates a decline in fish production.

What do we know about fish habitat in Simikameen River?

- Habitat for resident fish stocks was assessed at an overview level in 2001. Low water flow throughout much of the year limits the access of fish to

streambank cover and woody debris. These areas are generally only accessible during the spring freshet.

- The lower Similkameen River, from the US border to Hedley, has good side channel habitat which is important both for spawning and juvenile rearing.
- The upper Similkameen River, approximately from downstream of Stemwinder Provincial Park to the Tulameen River, was found to contain most of the highest quality rearing and overwintering habitat for fish. Spawning habitat, however, is limited in the upper section.
- The section of slow moving water between Bromley Rock and Stemwinder Provincial Park contains deep pool habitat that was found in the 2001 study to be particularly important for adult fish. It may also be a site where many fish overwinter.
- The Similkameen River becomes steeper towards its headwaters, especially above Princeton. This limits the availability of spawning and rearing habitat.

What impacts and human activities affect fish and fish habitat in Simikameen River?

- Land use along the Similkameen River is primarily agricultural and urban, including the highway that closely follows much of the river's course. Increased sediment inputs, changes to water flow patterns, and loss of stream-side vegetation are all impacts associated with these developments.
- The Similkameen Basin has a history of mining, mainly for gold, platinum, and copper. The greatest amount of mining in the basin took place in the late 1800s and early 1900s, and was concentrated around Hedley. Some mining continues today. The Ministry of Water, Land and Air Protection monitors water quality at three stations in the Similkameen River for metals that could have been released by past or present mining operations.

  The sites are just downstream of the Tulameen River inflow, just upstream of Hedley Creek inflow, and midway between Cawston and the US border. Monitoring data from 1979-1997 found that water quality meets drinking water guidelines, but that several metals exceed guidelines for aquatic life.

  High concentrations of these metals were measured when turbidity, or suspended material, was also high. The metals are most likely bound to the suspended materials, which means they would not be biologically active.
- In the 1950s, dykes were built for flood control along stretches of the Similkameen River around and downstream of Keremeos. The dykes were set back from the main river channel so that the river continued to have freedom to meander and move from side to side. This is in contrast to the very confining dykes built along much of the Okanagan River.
- Water withdrawals are made for domestic, industrial, and irrigation needs. By the mid-1980s, most surface water sources in the Similkameen Basin were fully licensed, meaning that they were at their capacity to have water withdrawn for human use. Ground water is also used in the Similkameen Basin, but because it is not licensed, there are no estimates of the amount withdrawn. (New ground water regulations introduced by the Ministry of Water, Land and Air Protection in July 2004 focus on water quality and safety.)

What do we know about the fishery in Simikameen River?

- About 15% of sport-fishing in the Similkameen Basin is directed at the Similkameen River (and on some tributary streams). In summer, rainbow trout are angled and in winter, mountain whitefish.
- Sport-fishing attracts less people in the Similkameen than in the Okanagan, but nonetheless contributes to the overall $16 million value (direct expenses, year 2000) of fishing in the Okanagan Region (includes Okanagan, Similkameen, Kettle, and Shuswap rivers).

What factors limit fish production in Simikameen River?

- Fish production in the Similkameen River is primarily limited by cool water temperatures, low levels of nutrients, very high water flows in spring, low flows in summer, and anchor ice in winter. Some areas have only limited habitat and parts of the river have poor quality streamside vegetation.
- Because of the low productivity and slow growth rates of fish, it takes longer for fish to attain large sizes than in other systems. Fish that do grow big are more vulnerable to being caught by anglers, and they could be caught and removed before they have a chance to spawn.

What gaps exist in our knowledge of fish and fish habitat in Simikameen River?

- Current population estimates of the dominant fish species – rainbow trout, mountain whitefish, and longnose dace – have not been made.
- Extent of habitat change or deterioration in the last 20 years has not been documented.
- Although water withdrawals from surface waters are licensed by the crown corporation Land and Water BC, there is no system of tracking the quantity of water that license holders actually withdraw.
- All estimates of angler harvest have been made during the summer. A winter fishery exists for mountain whitefish, but there is no information about the number harvested.

What is being done to protect or restore fish and fish habitat in Simikameen River?

- In 2000, the Similkameen River Planning Committee commissioned a fish habitat assessment. Sampling was conducted at four mainstem and seven tributary sites, and fish habitat assessments were conducted on four tributaries. The information collected was then used to identify opportunities for fish habitat restoration.
- In 2001, the Okanagan Nation Alliance planted native vegetation on three-quarters of a kilometre of bank along the Similkameen River near Chopaka bridge.
- The Ministry of Water, Land and Air Protection places restrictive regulations on anglers to limit the harvest of wild trout stocks.

What Steps Come Next

Lakes, rivers, and streams, and the fish populations living within them, are vital components of the landscape in both the Okanagan and Similkameen basins. Freshwaters in both basins have been affected by human activities, but for the most part, damage has been more severe and is more visible in the Okanagan.

Several large initiatives are currently underway to rehabilitate damaged aquatic ecosystems in the Okanagan, but efforts are clearly lacking in some areas. With certain exceptions, little effort has been made in the Similkameen.

The Okanagan and Similkameen basins differ in a number of ways. Physically, the Similkameen is a less productive system with flashier water flows, cooler water temperatures, and fewer nutrients. Sea-run fish do not have access to the Similkameen.

The Okanagan, on the other hand, has large lakes that store water (although this can give the false impression of a never-ending source), water temperatures that often rise too high, and nutrient levels that in some cases are high and in others low.

Sea-run fish return to the Okanagan but are restricted from accessing their historic range. Similar types of land use occur in the two basins, but rates of development in the Okanagan exceed those in the Similkameen. The human population is also larger in the Okanagan and is growing at a faster rate.

Given projected population increases and anticipated climate changes, the demand for water will continue to grow. Water is scarce and becoming ever more valuable in the Okanagan Valley, despite the large lakes along its length. The Similkameen Valley also faces serious water shortage issues. When water supplies dwindle, fish frequently get forgotten. For them, water shortages are compounded by the often disastrous state of their habitat. Many fish populations are resilient to change, but in several cases, their limits for survival are being approached and they need help.

Developing a Watershed-based Fish Sustainability Plan for the Okanagan and Similkameen basins is a positive first step towards conserving fish populations. Next steps in the WFSP process include determining priority watersheds, and developing action plans and management strategies for these watersheds in conjunction with partners throughout the basins.

This report on the state of fish and fish habitat in the Okanagan-Similkameen should be used as a starting point for identifying priorities in the WFSP. Based on the overview presented here, the following are made as suggestions of activities that need to be considered when developing basin-wide objectives for fish sustainability planning. They are not in any way comprehensive.

Okanagan Basin as a whole

- Continue to minimize the impacts of water releases through Penticton Dam on shore-spawning kokanee in Okanagan Lake and sockeye and other fish in Okanagan River.
- Address shoreline development and fish habitat impacts.
- Conduct further investigations of Traditional Ecological Knowledge about fish and fishing in the Okanagan.
- Address the issue of loss of fisheries for the Okanagan Nation for food and ceremonial purposes.

Okanagan headwater lakes

- Continue fisheries management of these lakes to provide a variety of angling experiences while minimizing angling pressure on wild stocks.

Okanagan tributary streams

- Continue and expand efforts towards stream protection and habitat restoration.

Okanagan Lake

- Continue efforts to address in-lake habitat issues for kokanee, including options for harvesting Mysis shrimps from the lake.
- Determine the overwinter survival rate of kokanee.
- Get a baseline understanding of the rainbow trout population.

Skaha Lake

- Investigate the recent kokanee population fluctuations.
- Investigate interactions between sockeye, kokanee, and *Mysis* in Skaha Lake in the context of the sockeye reintroduction* project.
- Get a baseline understanding of the rainbow trout population.

Osoyoos Lake

- Address the problem of the temperature-oxygen squeeze.
- Monitor the invasion by *Mysis* shrimps.
- Confirm the presence of lake resident chinook and investigate their life history strategy.
- Monitor the interaction between lake resident rainbow trout and sea-run steelhead trout.

Okanagan River

- Continue and expand habitat restoration measures.
- Investigate the loss of sockeye between Wells Dam counts and Okanagan River spawning ground counts.
- Address the issue of McIntyre Dam being operated without fish passage.
- Investigate the current use of habitat by fish other than sockeye.

Similkameen Basin

- Determine the population status of resident species and evaluate whether current angling regulations are adequate.
- Compile information in stream habitat assessment reports to determine if any issues exist and should be addressed.

---

* *See footnote regarding sockeye reintroduction terminology on page ii of Summary.*

Glossary

Algae
Free-floating or attached microscopic plants that grow in lakes and streams. They are the base of aquatic food webs.

Algal bloom
Vigorous growth of algae, often dominated by a single species.

Anadromous
Fish that hatch in fresh water, mature in the ocean and return to fresh water to spawn; often referred to as sea-run.

Blue list for rare species
A provincial government designation for species that are of special concern because of their vulnerability to human or natural impacts.

Blue-green algae
Common name for cyanobacteria, which are bacteria that act like plants in lakes and streams. They can form noxious blooms that taint or even poison drinking water.

Catch bias
When one variant of a fish species is more susceptible to being angled than another variant of the same species.

Channelization
Straightening a river and confining it to a uniform channel for flood control.

Cyanobacteria
Bacteria that act like plants in lakes and streams. They can form noxious blooms that taint or even poison drinking water.

Daphnia
A type of water flea that is the preferred prey of kokanee salmon.

Ecosystem
Plants, animals and the physical environment (water, air, soil, etc.) interacting in a given area.

Escapement
The number of fish in a population that spawn.

Exotic
A species that has been introduced by humans to a location outside its native range.

Extirpated
A species that is locally extinct.

Flushing rate
The time it would take a lake to drain completely if all water inflows were stopped.

Freshet
A sudden and large increase of water flow in streams as a result of snow melt or heavy rains. In the Okanagan-Similkameen, the freshet occurs for a short period in spring.

Fry
Recently hatched fish; sometimes called young-of-the-year.

Glide
A stretch of water in a river with an unbroken surface and a flat bottom, roughly parallel to the surface (i.e., no depressions as in a pool).

Hydrology
The occurrence, distribution and movement of water.

Introduced
A species that has been transferred by humans to a location outside its native range.

Kokanee salmon
A fresh water, resident form of sockeye salmon. Scientific name: *Oncorhynchus nerka.*

Meander
A bend of curve in a river.

Mysis relicta
A shrimp native to eastern North America but introduced to several large western lakes in a failed attempt to provide an additional food source for fish.

Naturalized
A stocked population of fish that becomes self-sustaining.

Nitrogen
One of two key nutrients that usually limit production in freshwater ecosystems. The other is phosphorus.

Nitrogen to phosphorus ratio
A common indicator or nutrient limitations on productivity. If the ratio is low, nitrogen is limiting; if the ratio is high, phosphorus is limiting.

Oncorhynchus mykiss
The scientific name for rainbow and steelhead trout. The former live entirely in fresh water, while the latter migrate between fresh water and the ocean.

Oncorhynchus nerka
The scientific name for kokanee and sockeye salmon. The former live entirely in fresh water, while the latter migrate between fresh water and the ocean.

Oxbows
River bends, or meanders, that have been isolated from the main river channel and form horseshoe-shaped ponds.

Phosphorus
One of two key nutrients that usually limit production in freshwater ecosystems. The other is nitrogen.

Production
The quantity of plant and animal life that an ecosystem can sustain.

Productivity
The rate at which plant and animal life grows in an ecosystem.

Rainbow trout
A fresh water, resident trout. Scientific name: *Oncorhynchus mykiss.*

Rare species
A threatened or endangered species. Blue and red listings are given to rare species in British Columbia.

Red list for rare species
A provincial government designation for species that are, or could soon become, threatened or endangered.

Riffle
An area in a stream where water moves swiftly over rocks or other material and the water surface becomes agitated or broken.

Riparian
The land adjacent to a stream or lake. Vegetation and habitats in a riparian area differ from the surrounding land.

Salmonids
A term commonly used to describe all salmon and trout species.

Set-back dyke
A flood control structure that allows for limited movement of a stream in its flood plain.

Side channels
Areas of quiet water off the main river channel but attached to the channel.

Smolts
A juvenile salmon undergoing physical changes that will allow it to move from fresh water to salt water.

Sockeye salmon
One of six Pacific salmon species that hatch in fresh water, mature in the ocean, and return to fresh water to spawn. Scientific name: Oncorhynchus nerka.

Steelhead trout
One of six Pacific salmon species (despite its common name) that hatch in fresh water, mature in the ocean, and return to fresh water to spawn. Scientific name: Oncorhynchus mykiss.

Stock
A population of fish.

Vertical drop structure
A sill built across a stream to slow water as it flows along a steep channelized river.

Water residence time
The length of time water stays in a lake, or the time it would take a lake to drain completely if all water inflows were stopped.

Watershed
The area of land that drains water to a common location. For example, the Okanagan Lake watershed contains all land where water flows to and eventually enters Okanagan Lake.

Woody debris
Logs and branches that form refuge habitat in streams for fish.

Zooplankton
Small aquatic animals that feed mainly on algae and that either drift or swim weakly. They are eaten by fish.

Sources

The following lists the principal sources of information consulted for each chapter. For a complete bibliography of all material reviewed, refer to Appendix 1.

Chapter 1: Overview of the Okanagan Basin

Authors	Date	Title	Citation
Cederholm CJ et al.	2000	Pacific salmon and wildlife –ecological contexts, relationships, and implications for management.	Special Edition Technical Report, Washington Department of Fish and Wildlife, Olympia, Washington
BC Statistics		http://www.bcstats.gov.bc.ca/	
Cannings RJ, Durance E	1998	Human use of natural resources in the South Okanagan and Lower Similkameen valleys	in: Smith IM, Scudder GGE (eds) Assessment of species diversity in the Montane Cordillera Ecozone. Burlington: Ecological Monitoring and Assessment Network.
Cohen S, Kulkarni T (eds)	2001	Water management and climate change in the Okanagan Basin	Environment Canada & UBC
Conservation Data Centre, Ministry of Sustainable Resource Management		http://srmwww.gov.bc.ca/cdc/	
Earthwild International		http://www.earthwild.ca/	
Ernst A	2000	Aboriginal fisheries information within the Okanagan Basin	Prepared for the ONFC
Fish Wizard		http://pisces.env.gov.bc.ca/	
Hall K, Stockner J, Schreier H, Bestbier R	2001	Nutrient Sources and Ecological Impacts on Okanagan Lake	CD produced by the Institute for Resources and Environment, UBC
Leith R, Whitfield P	1998	Evidence of climate change effects on the hydrology of streams in south-central BC	Canadian Water Resources Journal, 23: 219-230.

Levey JJB, Williams R	2003	2000 Survey of Sport Fishing in British Columbia	Fish and Wildlife Recreation & Allocation Branch, Ministry of Water, Land and Air Protection
Long K	2003	Okanagan Region Fish Species at Risk Status Report	Prepared by ONFC for WLAP (Steve Matthews)
McPhail JD, Lindsey CC	1986	Ch. 16. Zoogeography of the Freshwater Fishes of Cascadia (the Columbia System and Rivers North to the Stikine)	Pages 615-636 in CD Hocutt and EO Wiley, eds. The Zoogeography of North American Freshwater Fishes. Wiley, New York
National Climate data		www.climate.weatheroffice.ec.gc.ca/	
Okanagan Basin Implementation Board	1982	Summary report on the Okanagan Basin Implementation Agreement	
Okanagan Basin Water Board	2000	A proposal for a new partnership for water management in the Okanagan Basin	Prepared by the Westland Resource Group
Okanagan Nation Fisheries Commission	2001	Evaluation of an experimental re-introduction of sockeye salmon into Skaha Lake, Year 1 of 3	Submitted to Colville Confederated Tribes (Year 2 of 3, 2002 and Year 3 of 3, 2003 have same title, etc.)
Outdoor Recreation Council of BC		www.orcbc.ca/	
Roed MA (ed)	1995	Geology of the Kelowna Area and the Origin of the Okanagan Valley, BC	Kelowna Geology Committee
Scherer R, Pike RG	2003	Management activities on streamflow in the Okanagan Basin: Outcomes of a literature review and workshop	Prepared by Forest Research and Extension Partnership (FORREX)
Smith D	2004	Personal communication	Habitat Biologist, Fisheries and Oceans Canada, Penticton
Stockner JG, Northcote TG	1974	Recent limnological studies of Okanagan Basin lakes and their contribution to comprehensive water resource planning	Journal of the Fisheries Research Board of Canada 31: 955-976

Thomson D	1994	The Response of Okanagan Indians to European Settlement	BC Studies 101: 96-117
Tourism BC		www.tourism.bc.ca/	
Vedan A	2002	Traditional Okanagan Environmental Knowledge and FisheriesManagement	Prepared by the Okanagan Nation Alliance
Westland Resource Group	1993	Charting a course for the Okanagan: a review of issues and actions	Prepared for CORD, NORD, OSRD Fish Stock Assessment
Wilson A	2004	Personal communication	Biologist, Ministry of Water, Land and Air Protection, Penticton
Wright H	2004	Personal communication	Fisheries Biologist, Okanagan Nation Alliance, Westbank
Wright H, Hyatt K, Bull C	2002	Possible impacts of exotic species introductions on the indigenous aquatic communities of the Okanagan Valley mainstem lakes	

Chapter 2: Okanagan Headwater Lakes

Anonymous	1980	Fisheries Management Plan for Okanagan Main Valley Lakes	Prepared by Fisheries Staff, Okanagan Region
Brodie B	2004	Personal communication	Land and Water BC, Inc, Kamloops
Bull CJ	1983	Okanagan Region Fisheries Management Statement.	Fish & Wildlife Program, Ministry of Environment
Bull CJ, Kendall K, Scott L	1981	Review of Okanagan Basin Study recommendations relating to headwater lakes	Fish & Wildlife Program, Ministry of Environment
Jantz B	2004	Personal communication	Fisheries Biologist, Ministry of Water, Land and Air Protection, Penticton
Koshinsky GD, Andres JE	1972	The Limnology - Fisheries of the Okanagan Headwater Lakes	Task 66B, Canada-BC Okanagan Basin Agreement

Matthews S, Bull C	2003	Selection of focal watersheds for the protection and restoration of fish stocks and fish habitat in the Okanagan Region	
McBeath A	2000	1995 Survey of Sport Fishing in British Columbia, Okanagan Region Profile	BC Fisheries
Shepherd BG	1990	Okanagan Lake Management Plan, 1990-1995	Ministry of Environment, Penticton
Stringer GE	Late 1970s?	History of Lake Rehabilitation in Thompson-Okanagan Region from 1947-1975.	Ministry of Environment, Penticton

Chapter 3: Okanagan Headwater Lakes

Andrusak H et al.	1999, 2000, 2001, 2002	Okanagan Lake Action Plan reports from Years 4-7	Province of British Columbia, Fisheries Project report Nos. RD 83, 88, 96, 106.
Cohen S, Kulkarni T (eds)	2001	Water management and climate change in the Okanagan Basin	Environment Canada & UBC
Gaboury M, Slaney P	2003	Mission Creek Habitat Restoration Feasibility	Prepared by LGL Ltd for MWLAP
Harper WL	1985	Kokanee management plan for the Okanagan Main Valley lakes	Ministry of Environment, Victoria
Leith R, Whitfield P	1998	Evidence of climate change effects on the hydrology of streams in south-central BC	Canadian Water Resources Journal, 23: 219-230.
Matthews S	2004	Personal communication	Senior Fisheries Biologist, Ministry of Water, Land and Air Protection, Penticton
Matthews S, Bull C	2003	Selection of focal watersheds for the protection and restoration of fish stocks and fish habitat in the Okanagan Region	

Northcote TG, Halsey TG, MacDonald SJ	1972	Fish as indicators of water quality in the Okanagan Basin lakes, British Columbia	Rep#22, Canada-BC Okanagan Basin Agreement
Northwest Hydraulic Consultants	2001	Hydrology, water use and conservation flows for kokanee salmon and rainbow trout in the Okanagan Lake basin, BC	Prepared for Fisheries Management Branch, WLAP
Okanagan Basin Water Board	2000	A proposal for a new partnership for water management in the Okanagan Basin	Prepared by the Westland Resource Group
Rensel Associates	1998	Water Quality of Osoyoos Lake during 1997, fourth annual report	Prepared for PUD no 1 of Douglas County
Rensel Associates	1998	Nutrients, phytoplankton and zooplankton assessment of Osoyoos Lake, 1994-1996	Prepared for PUD no 1 of Douglas County
Scherer R, Pike RG	2003	Management activities on streamflow in the Okanagan Basin: Outcomes of a literature review and workshop	Prepared by Forest Research and Extension Partnership (FORREX)
Shepherd BG	1990	Okanagan Lake Management Plan, 1990-1995	Ministry of Environment, Penticton
Smith D	2004	Personal communication	Habitat Biologist, Fisheries and Oceans Canada, Penticton
Wallis M	1987	1985-1986 Okanagan Valley eurasian water milfoil control program	Ministry of Environment and Parks, Victoria
Wightman JC, Sebastian DC	1979	Assessment of Mission Creek rainbow trout carrying capacity (Aug 1978)	Ministry of Environment, Victoria.
Wildstone Resources	1992	Okanagan Lake Tributaries Plan. Vol 1. Mission Creek Management Plan	Volume 1 of 7.
Wilson A	2004	Personal communication	Fish Stock Assessment Biologist, Ministry of Water, Land and Air Protection, Penticton
Wright H	2004	Personal communication	Fisheries Biologist, Okanagan Nation Alliance, Westbank

Chapter 4: Okanagan – Main Valley Lakes

Andrusak H et al.	1999, 2000, 2001, 2002	Okanagan Lake Action Plan reports from Years 4-7	Province of British Columbia, Fisheries Project report Nos. RD 83, 88, 96, 106.
Armour G	2004	Personal communication	Okanagan Basin Water Board
Ashley K et al.	1998, 1999	Okanagan Lake Action Plan reports from Years 1-3	Province of British Columbia, Fisheries Project report Nos. RD 73, 78
Bull C	1999	Fisheries habitat in the Okanagan River Phase 1: Options for protection and restoration.	Prepared for Public Utility District No. 1 of Douglas County, Washington.
Bull C	2000	Sockeye salmon habitat assessment in Okanagan River upstream of McIntyre dam	Prepared for ONFC
Butler S	1974	Historical Fisheries Information	Ministry of Environment
Cashin T	2004	Personal communication	Regional District of Central Okanagan
Clemens WA, Rawson DS, McHugh JL	1939	A biological survey of Okanagan Lake, British Columbia	Fisheries Research Board of Canada, Bulletin No. LVI
Dean A, Rowe S	2004	Personal communication	Land and Water BC
Ernst A	1999	Okanagan Nation Fisheries Commission Dam Research	Prepared for ONFC by Running Horse Consulting
Fish Wizard		http://pisces.env.gov.bc.ca/	
Gustafson RG, et al.	1997	Status review of sockeye salmon from Washington and Oregon	NOAA Technical Memorandum NMFS-NWFSC-33
Houston C	1983	Historic Stocking Records, Books 1 and 2 of 2	Ministry of Environment
Hyatt KD, Rankin DP	1999	A habitat based evaluation of Okanagan sockeye salmon escapement objectives	Fisheries and Oceans Canada, Nanaimo

Jensen V	2004	Personal communication	Ministry of Water, Land and Air Protection
Levey JJB, Williams R	2003	2000 Survey of Sport Fishing in British Columbia	Fish and Wildlife Recreation & Allocation Branch, Ministry of Water, Land and Air Protection
Matthews S	2004	Personal communication	Senior Fisheries Biologist, Ministry of Water, Land and Air Protection, Penticton
Ministry of Water, Land and Air Protection	2004	2004-05 Freshwater Fishing Regulations Synopsis	Ministry of Water, Land and Air Protection
Northcote TG	1996	Effects of human population growth on the Fraser and Okanagan River systems, Canada: a comparative inquiry	GeoJournal 40(1-2): 127-133
Okanagan Basin Implementation Board	1982	Summary report on the Okanagan Basin Implementation Agreement	
Okanagan Nation Fisheries Commission	2001	Evaluation of an experimental re-introduction of sockeye salmon into Skaha Lake, Year 1 of 3	Submitted to Colville Confederated Tribes (Year 2 of 3, 2002 and Year 3 of 3, 2003 have same title, etc.)
International Osoyoos Lake Board of Control		www.wa.water.usgs.gov/IJC/Osoyoos/osoyres.htm	
Patalas K, Salki A	1973	Crustacean plankton and the eutrophication of lakes in the Okanagan Valley, British Columbia	Journal of the Fisheries Research Board of Canada 30: 519-542
Peters CN, Bernard DP, Marmorek DR	1998	Should sockeye be re-introduced to Okanagan Lake? An exploration of potential benefits, impacts and uncertainties	Prepared by Essa Technologies for the participants of the Okanagan Sockeye Workshop hosted by ONFC
Pinsent ME, Stockner JG (eds)	1974	Limnology of the major lakes in the Okanagan Basin	Technical supplement V, Canada-BC Okanagan Basin Agreement
Sebastian D	2004	Personal communication	Ecosystem Specialist, Ministry of Water, Land and Air Protection, Victoria.
Shepherd BG	1990	Okanagan Lake Management Plan, 1990-1995	Ministry of Environment, Penticton

Stockner JG, Northcote TG	1974	Recent limnological studies of Okanagan Basin lakes and their contribution to comprehensive water resource planning	Journal of the Fisheries Research Board of Canada 31: 955-976
Stockwell MM, Hyatt KD	2003	A summary of Okanagan sockeye salmon (Oncorhynchus nerka) escapement survey observations by data and river segment from 1947 to 2001	Fisheries and Oceans Canada, Nanaimo, Canadian Data Report of Fisheries and Aquatic Sciences 1106
Taylor EB, Harvey S, Pollard S, Volpe J	1997	Postglacial genetic differentiation of reproductive ecotypes of kokanee *Oncorhynchus nerka* in Okanagan Lake, British Columbia	Molecular Ecology 6:503-517
Wilson A	2004	Personal communication	Fish Stock Assessment Biologist, Ministry of Water, Land and Air Protection, Penticton.
Wright H	2004	Personal communication	Fisheries Biologist, Okanagan Nation Alliance, Westbank.
Wright H, Hyatt K, Bull C	2002	Possible impacts of exotic species introductions on the indigenous aquatic communities of the Okanagan Valley mainstem lakes	

Chapter 5: Tributaries South of Okanagan Lake

Alex H, Long K	2002	Inkaneep Creek Fish Habitat Restoration	Prepared for ONFC
Bull C	2004	Ecosystem Diagnosis and Treatment ratings for the Canadian portion of the Okanagan Subbasin	Unpublished manuscript submitted to the Colville Confederated Tribes, Washington
Geostream Environmental Consulting	2001	Restoration Plan for the Inkaneep Creek Watershed	Prepared for Osoyoos Indian Band
Long K	2000	Inkaneep Creek Fish Inventory and Fish Habitat Assessment	Prepared for ONFC

Matthews S, Bull C	2003	Selection of focal watersheds for the protection and restoration of fish stocks and fish habitat in the Okanagan Region	
Northwest Hydraulic Consultants	2001	Hydrology, water use and conservation flows for kokanee salmon and rainbow trout in the Okanagan Lake basin, BC	Prepared for Fisheries Management Branch, WLAP
Smith D	2004	Personal communication	Habitat Biologist, Fisheries and Oceans Canada, Penticton
Wilson A	2004	Personal communication	Fish Stock Assessment Biologist, Ministry of Water, Land and Air Protection, Penticton.
Wright H	2004	Personal communication	Fisheries Biologist, Okanagan Nation Alliance, Westbank.

Chapter 6: Okanagan River

Atwood LB, Scott LK	1997	Riparian and wetland restoration of the Okanagan River channel: feasibility study	Prepared for WLAP (Orville Dyer)
Bull C	1999	Fisheries habitat in the Okanagan River Phase 1: Options for protection and restoration.	Prepared for Public Utility District No. 1 of Douglas County, Washington.
Bull C	2004	Ecosystem Diagnosis and Treatment ratings for the Canadian portion of the Okanagan Subbasin	Unpublished manuscript submitted to the Colville Confederated Tribes, Washington
Bull C, Gaboury M, Newbury R	2000	Okanagan River Habitat Restoration Feasibility	
Dyer O	2004	Personal communication	Wildlife Biologist, Ministry of Water, Land and Air Protection, Penticton
Ernst A	1999	Okanagan Nation Fisheries Commission Dam Research	Prepared for ONFC by Running Horse Consulting
Fish Wizard		www.pisces.env.gov.bc.ca/	

Fryer JK	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
Gangmark HA, Fulton LA	1952	The present status of Columbia River blueback salmon runs	Special Scientific Report, United States Dept of the Interior
Glenfir Resources	2002	A discussion paper concerning restoration of the Okanagan River and its riparian habitats	Prepared for South Okanagan Similkameen Conservation Program
Gustafson RG, et al.	1997	Status review of sockeye salmon from Washington and Oregon	NOAA Technical Memorandum NMFS-NWFSC-33
Hourston WR et al	1954	The salmon problems associated with the proposed flood control project on the Okanogan River in BC, Canada	US Fish &Wildlife Service, Washington State Dept of Fisheries, Dept of Fisheries Canada
Hyatt KD, Rankin DP	1999	A habitat based evaluation of Okanagan sockeye salmon escapement objectives	Fisheries and Oceans Canada, Nanaimo
Koshinsky GD, Willcocks TJ	1973	Fishery Potentials in the Okanagan Basin	Canada-BC Okanagan Basin Agreement
Matthews S	2004	Personal communication	Senior Fisheries Biologist, Ministry of Water, Land and Air Protection, Penticton
Stockwell MM, Hyatt KD	2003	A summary of Okanagan sockeye salmon (Oncorhynchus nerka) escapement survey observations by data and river segment from 1947 to 2001	Fisheries and Oceans Canada, Nanaimo, Canadian Data Report of Fisheries and Aquatic Sciences 1106
Summit Environmental Consultants	2002	Reconstruction of the natural hydrograph of Okanagan River	Prepared for ONFC
Symonds BJ	2000	Background and history of water management of Okanagan Lake and River	Ministry of Environment, Lands and Parks, Penticton
Underwood McLellan Ltd	1985	Report on the Okanagan River channel enhancement project	Prepared for Min of Environment, Penticton

Wilson A	2004	Personal communication	Fish Stock Assessment Biologist, Ministry of Water, Land and Air Protection, Penticton.
Wright H	2004	Personal communication	Fisheries Biologist, Okanagan Nation Alliance, Westbank.

Chapters 7-10: Similkameen Basin, Tributaries, Lakes and River

Anon.	1984	Similkameen Strategic Environmental Plan	Ministry of Environment
BC Statistics		www.bcstats.gov.bc.ca/	
Bull C	2000	Similkameen Watershed Fisheries Information and Action Plan	Prepared for the Similkameen River Planning Committee & Fisheries Renewal BC
Bull C	2004	Personal communication	Glenfir Resources
Cohen S, Kulkarni T (eds)	2001	Water management and climate change in the Okanagan Basin	Environment Canada & UBC
Conservation Data Centre		www.srmwww.gov.bc.ca/cdc/	Ministry of Sustainable Resource Management
Fish Wizard		www.pisces.env.gov.bc.ca/	
IEC Beak Consultants	1985	Enloe Dam passage project annual report 1984, Vol 1	Prepared for Bonneville Power Administration, Project No. 83-477
IEC Beak Consultants	1984	1983 Similkameen River habitat inventory for Enloe Dam passage Vol 1 report	Prepared for Bonneville Power Administration, Project No. 83-478
Jantz B	2004	Personal communication	Fisheries Biologist, Ministry of Water, Land and Air Protection, Penticton
Leith R, Whitfield P	1998	Evidence of climate change effects on the hydrology of streams in south-central BC	Canadian Water Resources Journal, 23: 219-230.

Levey JJB, Williams R	2003	2000 Survey of Sport Fishing in British Columbia	Fish and Wildlife Recreation & Allocation Branch, Ministry of Water, Land and Air Protection
Matthews S, Bull C	2003	Selection of focal watersheds for the protection and restoration of fish stocks and fish habitat in the Okanagan Region	
Ministry of Energy and Mines		www.em.gov.bc.ca	
National Climate data		www.climate.weatheroffice.ec.gc.ca/	
Northwest Hydraulic Consultants	2001	Hydrology, water use and conservation flows for kokanee salmon and rainbow trout in the Okanagan Lake basin, BC	Prepared for Fisheries Management Branch, WLAP
Okanagan Basin Water Board	2000	A proposal for a new partnership for water management in the Okanagan Basin	Prepared by the Westland Resource Group
Regional District of Okanagan-Similkameen		www.rdos.bc.ca	
Smith D	2004	Personal communication	Habitat Biologist, Fisheries and Oceans Canada, Penticton
Vedan A	2002	Traditional Okanagan Environmental Knowledge and Fisheries Management	Prepared by the Okanagan Nation Alliance
Wahl D	2001	A reconnaissance evaluation of livestock, riparian habitat and fish-streams, Similkameen River watershed, Pilot Project	Prepared for Ministry of Agriculture, Food & Fisheries
Webber TN, Stewart A .	2001	State of Water Quality of the Similkameen River, 1979-1997	Canada-BC Water Quality Monitoring Agreement, Ministry of Environment, Lands and Parks, and Environment Canada
Wildstone Engineering Ltd.	2001	Lower Similkameen River Watershed Overview Fisheries Habitat Assessment and Restoration Plan.	Prepared for the Similkameen River Planning Committee