OKANAGAN LAKE ACTION PLAN

YEAR 10 (2005) REPORT

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northwest hydraulic consultants

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Ecosystems Branch
Ministry of Environment
Province of British Columbia

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ABSTRACT

The Okanagan Lake Action Plan (OLAP) has now completed a decade of investigations into reasons why there was such a precipitous decline in kokanee during the 1970s through the 1990s. This report is the ninth technical publication written by OLAP participants involved in the 2005 work. Early study years focused on gaining a better understanding of whole lake biological relationships, as well as identifying limiting factors and remedial measures that should result in recovery of the lakes' kokanee populations. Loss of kokanee spawning habitat, lake water nutrient imbalance resulting in a decline of lake productivity and mysid competition with kokanee for preferred macrozooplanktors have jointly caused a dramatic decline of Okanagan Lake's kokanee population over the last three decades.

Fundamental to recovery of kokanee has been protection and restoration of kokanee spawning habitat. OLAP investigators recognized that a combination of lake and stream restoration measures were required if a long term kokanee recovery was to be achieved. Several restoration projects have been completed as a result of the first phase of Okanagan Lake studies. The first and most obvious step has been recovery of water for fish spawning in tributaries flowing into Okanagan Lake. Progress has been made, particularly for the largest stream, Mission Creek, but further efforts are required on several other spawning streams. Aside from Mission Creek, Trout Creek has been singled out as having the greatest potential for kokanee restoration. On these streams some flow improvements have been achieved by working with the large water users. Extreme heat and drought conditions from 2003-2005 underscored the importance of working towards adequate water flow in fish spawning streams. During these years several of the smaller streams that are over used by public consumption (domestic and agricultural) were virtually dry at the time of kokanee spawning. Stream habitat restoration has also begun, again mostly in Mission and Trout Creek watersheds and recently in Penticton Creek.

Kokanee escapement data over several decades indicates that in-lake survival has often been low resulting in fewer spawners than their parental numbers. Poor kokanee fry-to-adult survival indicates that the quality and or quantity of food in the lake have been responsible for continued low spawner numbers. For this reason, the second phase of OLAP that began in 2001 has focused on understanding the N:P imbalance in the lake and how it may impact primary and secondary production. Limnological monitoring over a number of years indicated that Okanagan Lake appeared to be primarily nitrogen limited during the growing season. From 2003-2005 Okanagan Lake suffered drought conditions and the limnological data indicated a considerable decrease in nutrient concentrations that resulted in extremely low algal production. Okanagan Lake is somewhat unusual as the lake becomes depleted of NO_3 in the epilimnetic zone by early summer. The last nine years of data indicates that the N:P ratio is out of balance for growth of algae preferred by macrozooplanktors (especially *Daphnia*) that are in turn preferred by kokanee.

A very low NO_3:TDP ratio (<2.0) caused by the disappearance of dissolved inorganic N from the growing layers of the lake in late spring results in a prevalence of blue-greens in Okanagan Lake. Blue-green algae, or least the N_2–fixing forms, thrive under such conditions hence their dominance in Okanagan Lake. These phytoplanktors grow very well when nitrogen is limiting while other types of phytoplankton species do not, and they are generally unpalatable to zooplankton potentially limiting their populations. In 2003 and even more so in 2004, all algal forms including blue-greens decreased to near collapse status. This phytoplankton "collapse" is believed to have occurred due to chronic nutrient depletion of both N and P, most likely due to the low inflow years observed in 2003 and 2004 (hence, less nutrients). In 2005, growing conditions returned to a more "normal" level, albeit comparatively low. Primary productivity measurements made in 2004 and 2005 confirm microplankton grows better in Okanagan Lake than nanaoplankton that are preferred by zooplankters. This work also found that Okanagan Lake is far less productive than nearby Arrow Lakes Reservoir and Kootenay Lake. Zooplankton data also indicates that cladocerans densities are comparatively lower than nearby Arrow Lakes Reservoir and Kootenay Lake. OLAP researchers have also noted there has been a gradual decline in Okanagan Lake cladocerans over the last three decades. Not surprisingly, mysid densities in Okanagan Lake are much higher than Arrow Reservoir or Kootenay Lake.

Experimental introduction of nitrate to a portion of the lake has been considered by OLAP participants to understand if this would improve production of algae that macrozooplanktors prefer. This proposal has met with some concern since the public often equates nutrient addition to water pollution. If the experiment were to proceed and is effective OLAP views addition of nitrate through direct introduction by boat or barge to be a temporary solution. A more long term possibility is that of utilizing the existing sewage treatment plants to assist in re-balancing the N:P ratio. Technical analysis indicates that it would be feasible to modify the sewage treatment plants on the lake to permit release of nitrate into the hypolimnion. It is believed that manipulation of the N:P ratio is necessary to increase the lake carrying capacity, a key problem identified at the onset of OLAP.

Public uneasiness over nitrate introduction has made OLAP participants move very cautiously and a high priority commitment has been to keep the public well informed. Three internationally renowned scientists were asked to review the science behind experimental nitrate addition and were asked to provide their opinion on level of risk associated with such an experiment. All three expressed their opinion (s) that the risk to water quality was low. However, research conducted in 2004 and 2005 has led to the realization that P as well as N limits algal production, at least in dry, low run off conditions that have prevailed in recent years. Introduction of P has never been contemplated and aside from probable public opposition, the cost of doing so would be prohibitive.

While the nutrient imbalance issue has recently been the primary focus of OLAP, other lake and stream restoration measures are also critically important for increasing the kokanee population. For example, shore spawning kokanee are known to utilize a very narrow band of the shoreline with most spawning occurring at water depths of 0.25-0.75 m of water. Until recently, lake drawdown often negatively impacted shore spawning kokanee eggs that were deposited in depths < 0.25 m. Field study results during the 2000s refined the data on timing and depth of egg deposition and actual stage of development during the winter months. This information has provided fish and water managers with greater certainty as to how much and when lake drawdown would result in minimal impact to incubating eggs.

With the prospect that nutrient addition is unlikely, at least during low runoff years, OLAP researchers have turned to mysid removal as the best way of increasing kokanee numbers. Mysids have been implicated by OLAP biologists for the significant decline in the Okanagan lake kokanee population because they compete directly with kokanee for the same food source. A somewhat novel approach has been initiated by OLAP to restore kokanee numbers. Commencing in 1999, experiments were conducted to harvest mysids with the long term objective of removing enough mysids to provide kokanee with a competitive advantage. After a year of experimental fishing it was realized that this approach not only worked but there was a commercial value associated with the catch. During the last six years two commercial fishing interests have been harvesting mysids with annual harvests ranging from ~30-80 tons (wet weight). By-catch of kokanee has been a concern and OLAP has insisted on monitors accompanying the mysid harvesters. To date, the by-catch has been very low and not a real concern.

The question of how much of a harvest is required to impact the mysid population has been addressed. A model has been developed to estimate the theoretical harvest rate required to impact the mysid population. The model indicated that a minimum 30% harvest rate was required before any downward measure of change in mysid biomass would occur. Mysid biomass estimates for the lake have ranged from 2,700-5,700 metric tonnes therefore minimum annual harvest needs to exceed 1,000 metric tonnes. The harvest rate to date has been restricted by market demand but a breakthrough in the market occurred in late 2005. With new markets for mysids, the target harvest for 2006 was conservatively set at 250 tonnes.

The 2005 kokanee escapements were the highest in two decades but still far below the levels recorded in the 1970s and early 1980s. Shore spawner counts continue to be problematic but the 2005 results were encouraging with a sizeable increase recorded. These results contradict the limnological data that suggest poor growing conditions prevail in the lake. Although entirely speculative, increased numbers of kokanee during the last three years may be due to decreased mysid numbers during 2002-2004. The 2005 mysid densities were again quite high so the 2006 kokanee escapements should be quite informative.

The acoustics and trawl survey data conducted consistently for well over a decade provides the best data on status of Okanagan Lake kokanee. The 2005 results (~10 million) indicate a continuing trend of increased numbers in the lake. Total numbers have previously been < 8 million but in the last 5 years this estimate has increased to between 8-10 million. The age 1-3 component in 2005 suggests there should be a large escapement in 2006. Despite this apparent improvement these estimates remain less than half those made in the late 1980s.

Comparative analysis of study results from Okanagan Lake with those from nearby Arrow Lakes Reservoir and Kootenay Lake are quite useful and informative. These latter systems are currently the subject of experimental fertilization (N and P) to restore lake productivity to pre-impoundment levels. To date the data suggests that Okanagan Lake produces far fewer kokanee compared to either Arrow or Kootenay Lake.

TABLE OF CONTENTS

OKANAGAN LAKE ACTION PLAN

YEAR 10 (2005) REPORT

by

H. Andrusak[1]

INTRODUCTION

In 1995, the popular Okanagan Lake sport fishery for kokanee was closed due to a continued downward trend in spawner numbers. Clearly, something was wrong with the kokanee population that the public and biologists alike could readily see for themselves. The year following the fishing closure, a plan was assembled to investigate the problems faced by the kokanee population, propose solutions, and work towards addressing the problems. The plan is known as the Okanagan Lake Action Plan (OLAP) and has been implemented over the last ten years. This report includes all the results of the work done by OLAP in 2005, and compares the data with the results of previous years.

Okanagan Lake kokanee have been intensively studied over the last 10 years due to the realization that their sharp decline in the 1980s was a risk not only to existing sport fisheries but also to all predator populations that rely on them. They have been the primary focus of a long term investigation of the lake ecosystem and its watershed. In reality, the kokanee population has been in decline since the early 1970s, although minimal data exists for the earlier decades. In the late 1980s and early 1990s, already into the decline, the total kokanee population was estimated at about 12 million individuals. By the year 2000 the number had dropped to 3.1 million. Most recently numbers have increased but are far less than those recorded in the 1970s. OLAP has identified a number of factors that influence the kokanee population and these are addressed in this report.

BACKGROUND TO OKANAGAN LAKE

There is a great deal of fisheries related work currently underway on several of British Columbia's southern large lakes. Comprehensive multi-disciplinary investigations have been implemented on Kootenay Lake (Ashley et al. 1999), Arrow Lakes Reservoir (Pieters et al. 2003) and Okanagan Lake (Andrusak et al. 2005) for over a decade and commencing in 2005 on Quesnel Lake. Somewhat surprising is that it was not until the late 1960s that any work had been done on Okanagan Lakes' fish populations. Initial studies by Northcote et al. (1972) and Halsey and Lea (1973) identified the existence of two kokanee populations and raised questions about their status. In the late 1980s, annual whole lake population estimates began using hydroacoustic techniques, and although historical kokanee abundance estimates were not obtained, over a decade of decline in the population was measured. Several studies have been conducted to find

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out the causes of the kokanee decline (e.g., Northcote et al. 1972, Smith 1978, Matthews and Bull 1981, Andrusak and Sebastian *in* Andrusak et al. 2000), with OLAP being the largest and most coordinated of these efforts. Kootenay, Arrow, Quesnel and Okanagan lakes are reasonably comparable having similar levels of productivity for their size and all have experienced recent declines in kokanee abundance. The causes of these declines vary among the lakes and are not entirely understood. In all cases however, kokanee are recognized as the “engines” that drive much of the ecosystem, particularly the dynamics of many other fish species. Piscivorous rainbow trout, bull trout, lake trout, burbot, sturgeon, and likely other lesser-known fish, depend heavily on kokanee as prey. Kokanee, therefore, are excellent indicators of the health of these lake ecosystems and their fish populations are thus, restoration efforts to benefit kokanee will ultimately improve the whole ecosystem.

In some cases the issues affecting kokanee in Okanagan Lake are similar to those in other British Columbia lakes, while in others, the issues are quite different. The introduced mysid shrimp, *Mysis relicta*, is found in Kootenay, Arrow, and Okanagan lakes. This shrimp was released into these lakes in the 1960s as a food source for rainbow trout and kokanee, but in reality kokanee only occasionally utilize them and instead the shrimp compete with kokanee for food (Northcote 1991). Kokanee prefer to eat daphnid zooplankton, which the shrimp also consumes. The mysid population has increased dramatically in southern BC lakes and competes effectively for the zooplankton (see Whall and Lasenby 2000 *in* Andrusak et al. 2000).

Kootenay and Arrow lakes both had problems with reduced lake production and are currently having nutrients added to them to help increase their productivity. The program of nutrient additions, primarily of phosphorus, has stimulated the food web from the bottom and increased food availability for kokanee (Wright et al. 2002; Pieters et al. 2003). Okanagan Lake is in a different situation. The lake also has low production but the two main nutrients, nitrogen and phosphorus, in the lake appear to be unbalanced with nitrogen often too low for the levels of phosphorus. A low ratio of nitrogen to phosphorus promotes growth of blue-green algae that uses nitrogen from the air rather than nitrogen in the water. These nitrogen-fixing algae are a poor food source for the zooplankton that are then fed on by kokanee. Therefore, it is suspected that the problem in Okanagan Lake is low quality food, which causes a food web bottleneck. This bottleneck reduces the flow of energy from prey to predator and results in low productivity (see Rae & Ashley *in* Andrusak et al. 2004).

In an area that has a very dry climate and where water is in such high demand for urban development and agriculture, it should not be a surprise that Okanagan Lake fish and fish habitat are constantly threatened. Water is a precious commodity in the Okanagan Valley and efficient and responsible water use is crucial, but has not always taken place. The population continues to grow in the Okanagan at one of the highest rates in the province. This growth is placing even greater pressure on the land and water resources in the basin.

An important task of OLAP has been to recover stream water for fish and to improve the kokanee and stream flow database. This information will be invaluable to public stewardship groups and fisheries biologists in making a strong case for kokanee in the face of crushing demand for water and land adjacent to kokanee spawning habitat.

In the context of these numerous issues, the Okanagan Lake Action Plan aims to study and address limitations to kokanee production. Data collected during the first 10 years of OLAP has provided a great deal of information about water quality, kokanee and other organisms, such as mysid shrimp. These results are being transferred into new management strategies and restoration measures that are aimed at kokanee recovery. The results of kokanee population estimates from the past five years show that the population has increased somewhat from its lowest-recorded level in 2000 (Sebastian et al. in this OLAP report).

BACKGROUND AND PROGRESS WITH THE OKANAGAN LAKE ACTION PLAN

A major concern of fisheries scientists and the public since the early 1980s has been the observed decline in kokanee abundance in Okanagan Lake. Numerous articles in the local media, submissions to government by the BC Wildlife Federation and individual letters to government heightened during the early 1990s, ultimately led to government action. A public meeting was held in 1995 to discuss the decline and how best to address it, and the result was the formation of the OLAP. The vision was a multi-disciplinary plan that would examine and address the capacity of Okanagan Lake to support kokanee and other species. The plan was designed for a 20 year period, during which the biological and physical aspects of the lake and its watershed would be studied, with emphasis on three specific issues: habitat deterioration, competition for food between kokanee and mysid shrimp, and nutrient levels in the lake. The action plan is to-date, the largest freshwater fisheries management project in British Columbia's history.

OLAP's long term objective, as stated in the report from the initial public meeting, is *to rebuild and maintain the biodiversity of the wild kokanee stocks in Okanagan Lake. The plan seeks to determine the biological relationships, define causal problems and implement innovative solutions to remediate the declining kokanee population* (Ashley and Shepherd 1996). At a follow-up public meeting in 2001 to discuss OLAP's progress, there was strong support for expanding the objective from kokanee restoration to whole watershed restoration (Andrusak and McGregor 2001). OLAP supports this goal, however, it is beyond the scope of the initial plan and its primary funding source, the Habitat Conservation Trust Fund. Another public meeting was held in April 2004 in which the public was updated on the progress and direction of OLAP and support was expressed for its current direction (Rae and Andrusak 2004).

The scientific basis and direction of OLAP originated from a simulation model developed by Dr. Carl Walters (Walters 1995). The model was built to test the lake carrying capacity hypothesis, of the lake having insufficient food for the kokanee population. This situation could be the result of competition between kokanee and mysid shrimp for food, and/or a decline in nutrient levels in the lake, resulting in low production at the base of the food web. The model suggested that competition for food was the primary reason for the kokanee decline (Walters 1995, Ashley et al. 1999). In 2003, the simulation model was re-examined using the data collected by OLAP during its first seven years. With the additional data, the model concluded that both competition for food and low nutrient levels contribute significantly to the depressed kokanee population (Walters and Korman *in* Andrusak et al. 2004).

OLAP work from its inception has been viewed as a long term project and from the onset the principle biological working group divided the program into four phases of five years each. The first phase (1996-2000), focused mainly on conserving native fish stocks, protecting habitat, and collecting baseline information about Okanagan Lake. In the second phase, 2001-2006, lake monitoring continues but not as intensively as during the first five years. With the knowledge gained from monitoring Okanagan Lake, so far the focus now has shifted to implementing restoration measures to increase the kokanee population. Restoration measures have been developed through research and large-scale experiments. Phase three (2006-2010), continues to monitor key characteristics of the lake and build on restoration that is underway and or proposed. Phase four, (2011-2015), is proposed to continue at a reduced level for the long term monitoring while applying new information and techniques into restoration activities identified from the ongoing research and large-scale experiments.

The ecological complexities of Okanagan Lake necessitate kokanee recovery efforts to be directed at both lake and stream restoration measures, which combined, will offer the best chance of long term kokanee improvement. Several restoration measures are now in progress as a result of the initial phases of investigations on Okanagan Lake. The first and most obvious step has been to recover water for fish spawning in the streams that flow into Okanagan Lake. Progress has been made, particularly for the largest streams including Mission, Penticton, and Trout creeks, but further efforts are required with many of the other numerous kokanee spawning streams. Equally important are the measures undertaken to restore the lake carrying capacity as the kokanee population(s) rely on the growth and rearing habitat the lake provides. Since 2000 mysids have been harvested in the lake with the objective of reducing food competition with kokanee. This technique is proving to be successful and up until 2004 has been increased each year as the commercial market expands. Efforts are continuing to further expand the mysid fishery with the fishery companies aggressively pursuing new market opportunities.

Nutrient levels and periodic nutrient imbalance has been the focus of considerable work during the last four years. Specifically, it has been observed that the balance of nitrogen to phosphorus is low (Rae and Ashley *in* Andrusak et al. 2004). This imbalance encourages growth of algae that are unpalatable to grazing zooplankton, the main food source for kokanee. A workshop was held in February 2003 with scientists both within and outside the OLAP team to discuss the nutrient balance issue and the efficacy of experimentally introducing some nutrients to the lake (Andrusak et al. 2003b). An experiment was conducted in summer 2003 to test the hypothesis that a higher nitrogen:phosphorus (N:P) ratio would promote the growth of more palatable algae (Rae and Ashley *in* Andrusak et al. 2004). Further research into the feasibility of manipulating the nitrate levels to restore the N:P ratio continued through 2005 and the results are described by Rae and Ashley (in this OLAP report). Public concern over possible changes to water quality if nitrate additions were to proceed has led to outside reviews of the concept by three independent leading experts in the field. In short, their assessment indicates that there is little risk associated with such a proposal (Wilson *in* Andrusak et al. 2005). However, in the summer 2005 it was also determined that P as well as N limited growth of preferred algal forms (Rae and Wilson *in* Andrusak et al. 2005) at least during certain climatic conditions. Adding phosphorus as well as Nitrogen has not been considered by OLAP and such a prospect would be far too expensive.

With nutrient addition unlikely to be successful, at least during years of dry, low runoff conditions, OLAP intends on focusing on other restorative measures. Stream habitat restoration and improvements, mysid removal and further study of nutrient inputs and removal will be emphasized during phase 3.

To ensure that OLAP activities are meeting the overall program objective an outside review was implemented in 2004 by Dr. D. Bennett. His report is included in Andrusak et al. (2005).

YEAR 10 (2005) OF OLAP

Reports are produced each year with details of the work done for OLAP and the results obtained. This report includes information for 2005, and is presented in the following chapters:

1. Priority Remedial Measures
2. Monitoring Program
3. Functional Studies
4. Public Communications

The list of participants in 2005 OLAP activities shows the diversity of experts who have contributed to Okanagan Lake kokanee recovery (Table 1).

Table 1. Okanagan Lake Action Plan participants, activities and affiliation for Year 10 (2005).

Name	Function	Affiliation
Kevin Ade	Kokanee enumeration	Biological Contractor, Kelowna
Fabian Alexis	Shore spawner counts	Okanagan Nation Alliance, Fisheries Department
Harvey Andrusak	Editor	Contractor, Redfish Consulting Ltd., Nelson
Dr. Ken Ashley	Scientific Advisor	Fisheries Research, Biodiversity Br., MOE, UBC
Dr. Michael Brett	Nutrient studies, lipid analyses	Researcher, University of Washington
David Cassidy	Spawner enumeration, field data	BCCF Biological contractor, Kelowna
Barry Chilibeck	Hydrological engineer	Northwest Hydraulic Consultants, Vancouver BC
Melinda Coleman	OLAP contract administrator	BC Conservation Foundation, Surrey BC
Dr. Ted Down	Scientific Advisor	Manager, Biodiversity. Br, MOE, Victoria
Phil Epp	Hydrologist/advisor stream flows	Regional Hydrologist, MOE, Penticton BC
Randy Erbacker	Kokanee enumeration	Biological Contractors, Chara Consulting, Penticton
Marc Gaboury	Mission Creek Restoration Plan	LGL, Nanaimo
Lee Granberg	Mysid harvesting	Commercial Harvester, Piscine Energetics, Vernon
Shannon Harris	Primary productivity analysis	UBC Graduate Student
Nick Ipatowicz	Boat operator	BCCF Contractor, Penticton
Brian Jantz	Kokanee enumerations	MOE Fisheries Biologist, Penticton
Tom Johnston	Stock Assessment – harvest model	Fisheries Science Sect. Ecosystems Br, MOE, UBC
Dr. David Levy	Public workshop facilitator	Contractor, Levy Research Services West Vancouver BC
Keith Louis	Shore spawner counts	Okanagan Nation Alliance Fisheries Department
Deana Machin	Shore spawner studies	Okanagan Nation Alliance Fisheries Department
Dave Mahovolic	Shore spawner studies	Freshwater Fisheries Society of BC
Steve Matthews	Program coordination, logistics	Regional Fisheries, MOE, Penticton
Vince McGee	Mysid harvesting	Commercial Harvester, M & M Trading Ltd.
Jerry Mitchell	Kokanee enumeration	Biological Contractor, Penticton
Ron Ptolemy	Stream flow analyses	Flow specialist, Biodiversity Br, MOE, Victoria
Rowena Rae	Limnologist	Sumac Writing & Editing, Summerland BC
Joe Ravet	Nutrient studies, lipid analyses	Graduate Student, University of Washington
George Scholten	Hydroacoustic and trawl surveys	Fisheries Science Sect. Ecosystems Br, MOE, Victoria
Dale Sebastian	Program coordination, acoustics	Fisheries Science Sect. Ecosystems Br, MOE, Victoria
Dr. John Stockner	Phytoplankton analyst	Adjunct Professor, Fisheries Centre, UBC
Brian Symonds	Lake level management	Engineering Section, Water Mgmt. Br, MOE, Pent.
Dr. Lidija Vidmanic	Zooplankton and mysid analyses	Contract Scientist – UBC
Jason Webster	Spawner enumeration, field data	Biological Contractor, BCCF, Penticton
Andrew Wilson	Kokanee population assessments	Stock Assessment Biologist, Penticton BC
Dr. R. Withler	Kokanee genetic analysis	DFO Pacific Biological Research Station, Nanaimo BC
Patricia Woodruff	Kokanee Acoustics analyst / database	BCCF Biological Contractor - Victoria
Howie Wright	Shore spawner studies	Okanagan Nation Alliance, Fisheries Department

BUDGET FOR YEAR 10 (2005 - 2006) OLAP

Approximately half of the OLAP funding in Year 10 was provided by the Habitat Conservation Trust Fund (HCTF), with significant funding provided by the Ministry of Environment through direct funding of water quality analyses and through in-kind support of ministry staff. Canadian Lake Plankton and Piscine Energetics companies continued to provide equipment and labour for mysid harvesting and research into developing markets. A continuing partnership with Douglas County Public Utility District in Washington State resulted in total contributions of approximately $215,000.

Table 2. Estimated cost of Okanagan Lake OLAP by fiscal year for Phases 1 and 2.

Year	Amount requested of HCTF	Amount approved by HCTF	Expended	Funding additional to HCTF
1996/1997	$ 200,000	$ 200,000	$ 200,000	$ 159,000
1997/1998	$ 268,600	$ 268,600	$ 268,600	$ 110,000
1998/1999	$ 285,000	$ 269,000	$ 256,000	$ 177,000
1999/2000	$ 353,400	$ 310,000	$ 323,000[1]	$ 219,000
2000/2001	$ 351,500	$ 351,500	$ 319,400	$ 163,000
Phase 1	**$ 1,458,500**	**$ 1,399,100**	**$ 1,367,000**	**$ 828,000**
2001/2002	$ 265,000	$ 200,000	$ 186,300[2]	$ 276,000
2002/2003	$ 324,000	$ 290,000[3]	$ 263,200[4]	$ 260,000
2003/2004	$ 326,500	$ 326,500	$ 346,500[5]	$ 249,000
2004/2005	$ 325,500	$ 325,500	$ 321,155[6]	$ 396,000
2005/2006	$ 322,000	$ 322,000	$ 228,845[7]	$ 340,500[8]
Phase 2	**$ 1,563,000**	**$ 1,464,000**	**$ 1,342,745**	**$ 1,521,500**

[1] 1999-2000 expenditures include $13K carryover from 1998.
[2] 2001-2002 expenditures include $32.1K carryover from 2000.
[3] Approved $260K plus $30K boost to begin nutrient studies.
[4] 2002-2003 expenditures include $45.8K carried over from 2001 to complete Year 6 contracts.
[5] 2003-2004 expenditures include $72.6K carryover from 2002 to complete Year 7 tasks including the Year 7 report, an adaptive management workshop held in September 2003 and ongoing *mysis* test fishery monitoring and updating of OLAP databases.
[6] 2004-2005 expenditures include $52,600 carryover to complete Year 8 tasks including a strategic planning meeting in April 2004, an outside (independent) technical review of the OLAP program and the annual technical report.
[7] 2005-2006 expenditures include $56,945 carryover to complete Year 9 tasks including completion of the phase 2 Year 4 technical report, continued development of genetic ID tools and completion of primary production studies undertaken in 2004-05.
[8] Phase 2, Year 5, additional funding was provided as follows: approximately $215K from Douglas County Public Utility District (Washington State) for restoration and monitoring activities on Okanagan River sockeye and Okanagan Lake kokanee including development and monitoring of a river flow and lake level management model to assist in flood management., $11.5K from WLAP for water quality analyses, $10K from the Recreational Inventory and Stewardship Program, BC Conservation Foundation, toward kokanee spawner sampling and enumeration of Okanagan Lake tributaries, $4K from Fish and Wildlife Allocation (WLAP region 8) for low flow studies, and **in-kind** contributions of approximately $100K by MOE Fish and Wildlife Allocation and Biodiversity Branches through continued staff involvement on the Okanagan Lake Action Plan.

Efforts in Year 10 (2005-2006) concentrated on continuation of baseline monitoring, completion of studies address the concerns of the N:P limitation and proposed nutrient addition, and finalization of a 10 year report summarizing the Okanagan Lake Action Plan activities and progress in non-technical language suitable for the public and client groups. Genetic work continued through a partnership with DFO to develop stock separation techniques for distinguishing stream and shore spawning stocks of kokanee.

Table 3. Approximate expenditure in 2005/2006 by major components for Phase 2, Year 5 of OLAP.

ACTIVITY	EXPENDITURE
Monitoring	$ 115,500
Comparative Analyses	$ 0
Large-Scale Experiment (Mysis Removal)[1]	$ 24,000
Priority Remedial Measures	$ 3,500
Applied Research (N:P manipulation experiments)	$ 29,400
Functional Studies	$ 0
Communication	$ 12,200
Reporting	$ 29,500
Stock Assessment and Database Development	$ 8,000
Miscellaneous Administrative (Report Printing)	$ 7,750
Total Expenditures in 2005-06	**$ 228,850**
Carry-over to complete 2005-2006 tasks in progress	$ 62,800
Returned to HCTF – nutrient addition not required	$ 87,298
Total approved for Phase 2, Year 5 (2005-2006)	**$ 378,948**

[1.] Includes by catch monitoring and seasonal estimates of mysid distribution and abundance.

DISCUSSION OF 2005 RESULTS

This report summarizes the 10th year (2005-2006) of OLAP activities directed at Okanagan Lake kokanee recovery. A brief synopsis of some of the key findings from work conducted in 2005 is provided over the next few pages. The reader is directed to individual reports in the five chapters following this discussion for more detail.

A number of major initiatives have been underway for several years that collectively are aimed at achieving the primary objective of restoring Okanagan Lake kokanee. Data from water chemistry, phytoplankton, zooplankton and kokanee investigations provide greater insight into Okanagan Lake trophic levels and the relationships that exist between them. While most of the OLAP work has been directed towards kokanee, the data collected to date is also of considerable value to protection and maintenance of all fish and other aquatic organisms. It is important to emphasize that adding and improving the baseline data set is fundamental to long term success in rebuilding the Okanagan Lake kokanee populations.

OLAP is a major undertaking that involves many professionals as well as First Nations and the public. Often overlooked in such a major scientific program is the broad based scientific support provided by the universities. The Universities of Victoria, Okanagan, and British Columbia all provide technical support and advice to the OLAP biologists and engineers. This multi-disciplinary approach is essential since the problems facing kokanee as well as other fish species in Okanagan Lake are complex, interrelated, and not readily resolved. As previously stated, examination of all aspects of Okanagan Lake limnology, biology, and impacts of humans to this ecosystem is expected to lead to some (eventual) practical solutions. In the broadest terms, results from the 2005 field season again point towards the concept that lake nutrients and mysids are most likely the reasons why kokanee have not been able to rebuild, despite the determination that quality spawning habitat exists (i.e., good spawning habitat remains vacant indicative that factors in the lake limit kokanee numbers).

Habitat Protection and Restoration

Human settlement in the Okanagan Valley has resulted in most streams flowing into Okanagan Lake being substantially modified to accommodate residential and agricultural development. Major withdrawals of water have occurred and habitat protection biologists acknowledge that many tributaries might not be restored to historic flow conditions. However, there is certainly room for improvement through more rigorous protection of existing stream flows and working with water licensees to reduce water use. Protection of remaining stream habitat has been the focus of considerable energy within OLAP and it is an on-going function requiring continuous effort to retain what remains of key fish habitat after decades of destructive, human induced impacts. This work is the least noticeable part of the OLAP yet it is by far the most important. A report was completed in 2002 on required fish flows for each of the important fish bearing streams. In 2004, Trout Creek issues were the focus of more detailed investigation, including preliminary negotiations with the Municipality of Summerland for improved flows for fish. In this regard, Trout Creek has been identified as the stream with the greatest potential for recovering flows for fish and habitat restoration. The importance of Trout Creek for water users and fish was underscored by the provincial government announcing in 2005 additional funds for improved water conservation for this system. Mission Creek appears to have sufficient flows for fish but requires multi-agency cooperation in planning for some major stream restoration projects.

A report by Gaboury and Slaney (*in* Andrusak et al. 2003b) provides a blueprint for restoration of Mission Creek and it is OLAP's expectation that stewardship groups in Kelowna will use it as a guide. As part of this work a key parcel of land was purchased by HCTF funds in 2004 that will provide the opportunity for stream restorative prescriptions in the lower reach. Additional parcels of riparian land are becoming available and OLAP has put forward proposals to a number of potential partners to purchase some of these key sites. There are a number of stream stewardship groups actively involved in restoration planning and implementation on Okanagan Lake tributaries. In some cases, these groups are working in conjunction with the regulatory agencies as part of watershed planning/restoration roundtables. These include, but are not limited to:

- Trout Creek Watershed Roundtable – Trout Creek
- Penticton Flyfishers/Penticton Shooting Sports – Penticton Creek
- Naramata Citizens Association – Naramata Creek
- Peachland Sportsman's Association – Peachland Creek and Powers Creek
- Trepanier Creek Linear Park Society and Peachland Sportsman's Association – Trepanier Creek
- Okanagan Nation Alliance – Equisis Creek
- City of Kelowna - Kelowna (Mill) Creek, Mission Creek
- Kelowna and District Fish and Game Club – Bellevue Creek

Habitat protection work has also been directed at the lake itself. It is believed that the majority of Okanagan Lake kokanee spawn on certain parts of the shoreline. These beach spawning kokanee are known to utilize a very narrow band of the shoreline with most spawning occurring at water depths of 0.25-0.75 m of water. Until recently, lake drawdown often negatively impacted shore spawning kokanee eggs that were deposited in depths <0.25 m. Predicting in advance the probable inflow volume to the lake could result in designated lake levels being adjusted early in the fall to be more favorable to shore spawning kokanee. A detailed investigation in 2005 of shore spawning kokanee has provided fish and water managers with greater certainty about the actual depth that these spawners deposit their eggs.

Limnology

A key component of OLAP has been establishment of a good baseline of limnological data. Long term limnological data provides important information on the lake's trophic status, limitations to lake productivity and relationships between trophic levels. Monthly samples have now been collected by OLAP for 10 years (1996-2005). From a limnological perspective, Okanagan Lake is quite interesting because most of the lake is rather unproductive or oligotrophic. However, Armstrong Arm and a portion of the north end of the lake are actually moderately productive (mesotrophic) and therefore, offer some marked contrasts to main lake productivity.

The surface waters of the lake often warm up as early as April and generally water temperatures peak in early July at ~20°C. The thermocline is usually at ~10-15 m although in 2005 it extended to 18 m. Surface temperatures occasionally reach 25°C as was the case in July 2003 and 2004 but not in 2005. The lake mixes each spring and late fall and becomes isothermal by November, commencing to stratify in early April. Armstrong Arm warms earlier than the main body of the lake and stratifies earlier at a shallower depth (Rae et al. in this OLAP report). The lake is well oxygenated displaying orthograde profiles typical of low productivity lakes. The exception is in Armstrong Arm where dissolved oxygen concentrations can be < 8 $mg \cdot L^{-1}$ at 40 m compared to 10 $mg \cdot L^{-1}$ in the main lake. As in previous years, in October 2005 the hypolimnion of Armstrong Arm became oxygen deficient with concentrations measured by Rae and

Wilson (in this OLAP report) at < 1 mg·L^{-1}. High nutrient inputs from human activities elevate primary and secondary production. Oxidation of organics from this elevated production in the sediments of Armstrong Arm probably accounts for the oxygen depletion that exists for up to 1-2 months before fall turnover in November. Interestingly, each fall the mysid population in Armstrong Arm declines to zero, probably due to low oxygen levels and higher surface water temperatures (Rae and Wilson in this OLAP report).

Okanagan Lake is slightly alkaline with pH readings ranging 7.6-8.6. Water clarity as measured by Secchi disk has decreased over the last two decades with much of this attributable to the types of phytoplankton that grow in the lake. The average reading today is 6.6 m compared to nearly 12 m in the late 1980s (Jensen *in* Ashley et al. 1999). Armstrong Arm Secchi values are about half that of the rest of the lake.

The nutrient content of the lake has been of particular interest to limnologists, especially during the OLAP study years. Since the inception of OLAP, the lake has been described as oligotrophic since the total phosphorus (TP) values have ranged from 0.004-0.010 mg·L^{-1}. However, in the last three years, the lake has moved towards ultra-oligotrophic status with TP values <0.004 mg·L^{-1}. This change has been largely attributed to exceptionally low inflows due to extremely dry conditions that prevailed in the Okanagan valley. Low spring runoff events appear to result in epilimnion phosphorus and nitrogen limitation to primary production. During these years the nitrate-nitrogen concentrations in the eplimnion were depleted below detection limits as was TDP at times resulting in N:P ratios (as NO_{2+3}:TDP) < 2:1 in the summer months. Such low ratios seem to favor growth of cyanobacteria in the phytoplankton community, although in 2004 even these failed to respond, resulting in the lowest phytoplankton production recorded (Stockner *in* Andrusak et al. 2005). In 2005, phosphorus and chlorophyll *a* levels were amongst the lowest recordings in the last decade so once again the lake was co-limited (N&P). It is known that cyanobacteria excel when nitrogen is limiting other phytoplankton species but cyanobacteria are generally unpalatable to zooplankton, limiting their growth (Stockner and Shortreed 1989) and hence, the nutritional value for fish (Brett and Muller-Navarra 1997). In 2003-2004 and to a lesser extent in 2005, the Okanagan Basin suffered drought conditions and the limnological data indicates an overall reduction in nutrient inputs from tributary streams resulted in lower algal production that in turn impacts zooplankton and kokanee. Regardless of mechanism or species involved, lower phytoplankton production is bound to negatively impact kokanee production (see Rae and Wilson in this OLAP report for more details).

Phytoplankton

Okanagan Lake is considered to be oligotrophic owing to its low nutrient content producing comparatively low phytoplankton abundance and biomass. The most unusual characteristic about the lake is the domination by blue-green algae that are typically found in far more productive mesotrophic or eutrophic lakes. Major blue-green algal blooms have been documented by Stockner (*in* Andrusak et al. 2004; 2005) but in 2003 and again in 2004, there were major deviations in the seasonal patterns with blue-greens "blooming" very early followed by major depressions in total abundance of all phytoplanktors. Stockner (*in* Andrusak et al. 2004; 2005) initially reported that the 2003 growing season was very atypical from previous years. Large blooms of blue-greens were detected in Armstrong Arm during February to March but the typical "bloom' in the main lake did not materialize to the extent measured in previous years. This decline or depression persisted to an even greater extent in 2004 but a more typical pattern was observed in 2005 (Stockner, in this OLAP report).

Seasonal dominance of blue-greens in Okanagan Lake is caused by the disappearance of dissolved inorganic N from the growing layers of the lake in late spring that results in a very low NO_3:TDP ratio (<2.0) (Stockner *in* Andrusak et al. 2005). Blue-green algae, or at least the N_2 fixing forms, thrive under such conditions, hence, their domination in Okanagan Lake. These phytoplanktors grow very well when nitrogen is limited while other types of phytoplankton species do not, and they are generally unpalatable to zooplankton potentially limiting their populations (Stockner and Shortreed 1989). Results from 1999-2002 showed that blue-greens were dominant throughout the spring, summer, and fall but in 2003 and particularly in 2004, all algal forms including blue-greens decreased in late summer. This phytoplankton "collapse" is believed to have occurred due to chronic nutrient depletion of both N and P, most likely due to the low inflow observed in 2003 and 2004 (hence, less nutrients). In 2004, it was very clear that there was nutrient co-limitation (N and P) exacerbated by extreme climatic conditions. In 2005, the more typical spring succession occurred with a diatom bloom in May followed by a mix of flagellates that declined somewhat in the summer followed by growth of blue-greens that were moderately abundant in late summer to early fall.

Except in 2003 and 2004, algal growth appears to have remained fairly constant over the last three decades with blue-greens dominate during the summer months and their annual abundance slowly increasing over time. Stockner (in this OLAP report) has theorized that because blue-greens are a poor food source for macrozooplankton (e.g., *Daphnia*) this may be one explanation why kokanee have declined (poor growth due to lack of preferred macrozooplanktors).

Over the last seven years water chemistry data indicates that the N:P ratio is out of balance for growth of algae preferred by macrozooplanktors (especially *Daphnia*) that are in turn preferred by kokanee. OLAP scientists have felt that manipulation of the N:P ratio may be necessary to increase the lake carrying capacity, a key problem identified by Walters (1995) at the onset of OLAP and recently reconfirmed by Walters (*in* Andrusak et al. 2004).

The compelling question is, if nitrogen (nitrate) is limiting lake production is it possible to "re-introduce" it to improve the N:P ratio and in turn create a better growing environment for the more preferred algae? As noted in Andrusak et al. (2004) there were varying opinions within the scientific community as to whether or not the N:P ratio is that crucial to the state of productivity of Okanagan Lake. A proposal to experimentally introduce nitrate to a portion of the lake on a limited but carefully controlled basis has been considered by OLAP (Andrusak et al. 2003a). The concept and details of this experiment were presented to three internationally recognized limnologists for their review to determine the degree of risk to the lake (i.e., water quality) if the experiment were to proceed. A summary of their findings is found in Andrusak et al. (2004). In brief, they found there was low or virtually no risk in proceeding with the experiment. Stockner (in this OLAP report) argues that in 2003 and 2004 the depression of all algal forms including the blue-greens was most likely due to P being limited as well as N, therefore, algal growth was depressed due to co-limitation of N and P.

The issue of balance between nitrogen and phosphorus was originally the focus of considerable discussion at a Kelowna conference held March 3-4, 2001. Results of the workshop were reported by Andrusak and McGregor (2001). At that time the public reiterated its strong support for improving stream fish habitat, continuation of the mysid commercial fishery, and commencement of experimentation (only) with nitrogen and phosphorus in contained enclosures (Andrusak and McGregor 2001). These experiments were reported by Rae and Ashley (*in* Andrusak et al. 2004). Rae and Andrusak (2004) summarized the outcome of a workshop held April 7, 2004 in Kelowna, where public support for OLAP's work was again expressed but further consultation was expected prior to implementing the nutrient experiment. Even with the outside scientific reviewers supportive of the proposed experiment to modify nitrate levels in Okanagan Lake it could be controversial if the supporting science is not effectively communicated to the public. Nutrient addition remains controversial as it is clear that the public does not want to see Okanagan Lake being "fertilized" with results of undesirable consequences. Obviously, OLAP does not want to be seen to be an advocate of such a measure, therefore, a cautious approach in any nutrient manipulation is paramount. The most recent results from 2003 and 2004 suggest that during dry summer conditions P is also limiting. At no time has OLAP contemplated addition of P, therefore, nutrient manipulation (adding N) would only be effective in years when "normal" (2005) or "wetter" (2000-2002) conditions prevail.

Zooplankton

Sampling for zooplankton in Okanagan Lake has occurred since the early 1970s but only since the inception of OLAP has there been a consistent protocol. Some seasonal data collected over the last three decades indicates that densities have undergone only slight changes during the last decade but are only half those recorded in the late 1970s. Since the inception of OLAP, the lowest density recorded was $8 \cdot L^{-1}$ in 1998 and a high of $25 \cdot L^{-1}$ in 1999 while intermediate values of $16\text{-}17 \cdot L^{-1}$ were recorded from 2001-2004 but only $10.5 \cdot L^{-1}$ in 2005. Copepods continue to be the numerically dominate zooplankton group with *Diacyclops bicuspidatus* the most abundant copepod. While numerically dominant in Okanagan Lake, copepod biomass comprises only about one half of total zooplankton biomass due to the much larger size of the cladocerans.

In the last eight years, from May to October, Okanagan Lake cladoceran densities have averaged $0.7\text{-}1.3 \cdot L^{-1}$ with the low in 1998 ($0.3 \cdot L^{-1}$) and the high in 1999 ($2.1 \cdot L^{-1}$). During 2004 a density of $1.3 \cdot L^{-1}$ was the highest recorded since 1999 and was due to an increase in *Bosmina* and *Diaphanosoma* over previous years, whereas *Daphnia* have decreased slightly from 2003-2005. The cladocerans account for only 3-8% of the annual zooplankton population density. When considering biomass, however, they can account for up to 45% of total May to October biomass in the main lake and >50% during the mid-summer peak in Armstrong Arm. Cladoceran biomass is also variable among years with high biomass peaks in 1999, 2000, 2003, and at some stations in 2004 and 2005 but low biomass in 2001 and 2002.

Cladocerans are the most preferred food item for kokanee; so therefore it is important to understand their abundance and any changes that may occur. Even though cladocerans are the most important food source for kokanee they only accounted for < 8% of the total zooplankton density in Okanagan Lake in 2005. The < 8% contribution of cladocerans to total zooplankton density in Okanagan Lake is typical for oligotrophic lakes that contain *Mysis relicta* (Rae and Wilson in this OLAP report). Similar lakes that do not have *Mysis relicta* usually have > 10% of their zooplankton density represented by cladocerns. By way of comparison, Okanagan Lake *Daphnia spp.* densities have been less than half the densities recorded (1997-2001) in Kootenay Lake and Arrow Reservoir (Pieters et al. 2003). Although Okanagan Lake long term zooplankton trend data is sparse, data collected during August in most years indicate densities have decreased over time. Total zooplankton density was about $35 \cdot L^{-1}$ (1978-1980), declining to $21 \cdot L^{-1}$ in the 1990s and to $10\text{-}17 \cdot L^{-1}$ in the last five years (2001-2006). As the most important food items for kokanee/cladocerans have declined from about $4 \cdot L^{-1}$(1978-1980) to $1 < \cdot L^{-1}$ (1991-1993) to about $1 \cdot L^{-1}$ (1996-2005).

It has been suggested by Rae and Vidmanic (in this OLAP report) that annual variability in cladoceran zooplankton populations may be related to spring phosphorus concentrations. During the spring total phosphorus (TP) values increased during the 1970s, decreased during the 1980s and early 1990s, and then increased in 2001 but declined again through 2005 (Rae and Wilson, in this OLAP report). Cladoceran zooplankton abundance has followed a similar pattern to spring TP with an average of $5 \cdot L^{-1}$ in August of 1978-1979, a decrease through the early 1990s, small increases from 1996-2000 (except a particularly low density of $8 \cdot L^{-1}$ in 1998), and then three years of decline until 2004 when the density increased to it's highest level since 1999. Although the cladoceran spring TP relationship is present it is strengthened when data from Armstrong Arm are included.

Mysid Shrimp

The opossum shrimp *Mysis relicta* was introduced into Okanagan Lake as well as several other southern British Columbia lakes during the 1960s and 1970s (Lasenby et al. 1986; Northcote 1991). The original concept was to provide an additional food source for rainbow trout but this theory has proven to be largely incorrect and the introductions have caused serious competition between mysids and kokanee for the same macrozooplanktors (Northcote 1991). Mysids have been partially implicated by OLAP biologists for the significant decline in the Okanagan lake kokanee population (Andrusak et al. 2005). Mysids also prefer cladocerans, therefore their population status within Okanagan Lake is of particular interest. Mysid seasonal abundance in

Okanagan Lake has averaged $321 \cdot m^{-2}$ in the pelagic zone and $183 \cdot m^{-2}$ in the shallow (<40 m) zone. Total abundance in 2005 rose substantially to the second highest level in the last seven years. The shallow water densities have increased the most and are now about half the pelagic numbers. In the past, the deep water sample densities have been more than double the shallow water densities. As in previous years, the highest mysid densities in 2005 were again found in the pelagic samples at the north end of the lake located at Station OK 7. The numbers and biomass estimates at OK 3 were second only to those at OK 7 and OK 8 but still remain about 30% lower. Densities and abundance fluctuate seasonally (see Rae and Vidmanic in this OLAP report for details) and at Station OK 7 in 2005 abundance was as high as $5000 \cdot m^2$ compared to the usual range of $1000\text{-}2000 \cdot m^2$. In the last few years, average annual mysid densities in Okanagan Lake ($178\text{-}332 \cdot m^2$) have been higher than Kootenay Lake ($140\text{-}400 \cdot m^2$) and much higher than Arrow Reservoir ($66\text{-}125 \cdot m^2$).

A somewhat novel approach has been initiated by OLAP to restore kokanee numbers. Commencing in 1999, experiments were conducted to harvest mysids with the long term objective of removing enough mysids to provide kokanee with a competitive advantage. After a year of experimental fishing it was recognized that this approach not only worked but there was a commercial value associated with the catch (Andrusak *in* Andrusak et al. 2000). During the last six years, two commercial fishing interests have been harvesting mysids with annual harvests ranging from ~30-80 tons (wet weight). The mysid fishery has developed at a low key but progressive pace (see Andrusak et al. in this OLAP report). The demand by the market for mysid products has dictated the amount of harvest since commercial harvest began in 2000. The harvest rates experienced by the two permittees have gradually improved over time. These rate improvements are largely due to changes in fishing techniques as well as increased knowledge of where and when to fish. A conservative daily rate of > 300 kg•day can easily be achieved by both permittees. Canadian Plankton exceeded 600 kg•day in 2001 based on 86 days of fishing with a few days exceeding 1000 kg•day. Meanwhile Piscine has improved its catch rate each year and reached a high of 443 kg•day in 2005.

The question of how much of a harvest is required to impact the mysid population has been addressed by a researcher at UBC. Kay (2002) used a model to estimate the theoretical harvest rate required to impact the mysid population. The model indicated that a minimum 30% harvest rate was required before any downward measure of change in mysid biomass would occur. Kay (2002) applied a whole lake biomass estimate of 925 tonnes to the model and a number of simulations suggested that at least 250-350 tonnes (dry weight) needed to be harvested. A conversion factor of 6.3 is used to expand these statistics to wet weight used by the commercial fishing industry. In short, an annual harvest rate of about 1,500 tonnes (wet weight) is required before any impact to the population might be expected. In early 2006, a significant change in the market for mysids occurred. A multi-national food corporation became interested in omega fatty acids that mysids generate and as a result the demand for mysids has grown immensely. The projected demand has risen to over 2,000 tonnes so the mysid population warrants close scrutiny herein.

Data collected from the long term zooplankton sampling program have been used to determine the most productive sites and depths to fish for mysids. Clearly, the best sites are those located around stations OK7 and OK8, the areas where Rae and Vidmanic (in this OLAP report) reported the highest mysid densities. They estimated that the total lake mysid biomass in 2005 was 5,632 tonnes (wet wt.) compared to a low of 2,716 (1999) and the high of 5,739 tonnes (2001). In the last three years, the estimated range of tonnes of mysids in the area of station OK 7 has been 856-1953 tonnes or about 25% of lake total.

Kokanee by-catch was again closely monitored in 2005 and mid water trawling remains the best method of avoiding large kokanee by-catch. The 2005 by-catch levels were well within the permitted levels especially the surface trawl method that permits capture and live release of virtually all kokanee by-catch. Continued monitoring of by-catch will be required in view of the potential for significant increased demand for mysids in 2006.

Kokanee

Okanagan Lake kokanee are somewhat unique because there are two genetically distinct stocks: a stream spawning component and a shore spawning population. Okanagan Lake kokanee are the keystone species and their recovery and sustainability is the raison d'etre for the OLAP. Over the last 10 years there has been a great deal of effort and study directed at understanding Okanagan Lake kokanee. Some of the earliest work involved summarization of all available historical information and methodology used to collect this information (Shepherd *in* Ashley et al. 1998; Thompson *in* Ashley et al. 1998). Stream spawner escapement methods and results have been standardized (Matthews and Shepherd *in* Ashley et al. 1999; Andrusak *in* Ashley et al. 1999) to allow for comparisons over time. A reasonably good data set of stream escapements has been summarized and trend analysis has been conducted by Webster (in this OLAP report).

Shore spawner estimations have been problematic since counts of actual numbers of fish are virtually impossible due to variations in location, timing, water clarity and weather (Thompson *in* Ashley et al. 1998). Use of a video camera to monitor shore spawning by Thompson (*in* Ashley et al. 1998) confirmed the problems of relying on single shore spawner counts and concluded that multiple counts can, at best, provide an index of relative abundance. Andrusak et al. (in Andrusak et al. 2005) provided a more detailed assessment of the 2004 shore spawners, concluding that shore and boat based estimates can at least be used as an index of abundance. Based on the 2004 results they also discuss the possibility that the peak count may represent a true peak with only the left side of the spawner curve not accounted for due to unusual behavior of the spawners, such as they may only spawn at night early in the spawning event. Funding limitations in 2005 reduced the shore spawner estimates to a series of boat based counts.

The number of stream spawners increased again in 2005 to ~ 60,000. Escapement in 2004 totaled about 46,000, slightly higher than 2002 and 2003 estimates. As in previous years, over 50% of the 2005 spawners were observed in Mission Creek. The 2005 shore spawner estimate of ~162,000 was the highest estimate since 1989. The 2005 numbers far exceeded the parental numbers in 2001. By comparison, the relative abundance estimate of nearly 46,000 shore spawners in 2004 was similar to the 2003 estimate but far less than the parental year (s) of ~139,000 (2000) or ~91,000 (2001). Higher escapements in the last few years are encouraging, especially the 2005 estimates but the increases should not be interpreted that recovery of kokanee is underway on Okanagan Lake.

There is far more certainty today about the status of the kokanee populations in Okanagan Lake. Two stocks of kokanee (shore and stream) were originally identified in Okanagan Lake (Taylor and Pollard *in* Ashley et al. 1998) but at that time there was uncertainty about use of this technique to distinguish between the two from a mixed sample taken from the lake. In 1999, Pollard (*in* Andrusak et al. 2000) developed an improved method using genetic markers that could distinguish the two stocks. The original analytical tool developed by Pollard and other geneticists (Taylor and Pollard *in* Ashley et al. 1999) required further refinement and in early 2005 some new markers were used and clear distinctions were made between stream and shore spawners by Withler (in Andrusak et al. 2005). The 2004-2005 results also provided greater certainty that the shore and stream spawners are genetically different. With the genetic methodology reaffirmed and distinct markers identified for separating the two stocks this analytic technique should be applied to the annual trawl data to estimate proportions of shore versus stream spawning kokanee. By doing so, an estimate can be made of number of stream versus shore spawners.

The most reliable and consistent kokanee data from Okanagan Lake is obtained from annual hydroacoustics and trawl surveys. Sebastian and Scholten (*in* Ashley et al. 1998; 1999 and Sebastian et al. *in* Andrusak et al. 2005; also in this OLAP report) have established a continuous data set since 1988 that is extremely valuable in analyzing stock status, size-at-age and population trends. This information provides an in-lake abundance index that complements the shore and stream counts.

Total lake abundance estimate for 2005 was 9.7 million, a sizeable increase from the 2004 estimate of approximately 8 million (see Sebastian et al., in this OLAP report). The most significant part of the 2005 estimate was the age 1-3 component that increased to 3.84 million, the highest estimate in 11 years. The acoustics estimates in recent years suggest the lake may now have a slight increase in capacity to support more kokanee compared to the late 1990s. The continuing problem of uncertainty of ageing the mature kokanee through conventional analysis of scales or otoliths is eliminated through age determinations from the trawl catch. Length-frequency histograms of the trawl catch are plotted and fish from each distinct mode are aged by scale reading. Typically, four modes are discernable suggesting most mature fish are age 3+ or older. Since the trawl catch occurs after the stream spawners have spawned, there is certainty about the age of the shore spawners, (they are usually age 3+) but in some years including 2005 there is good evidence that a portion of them spawned at age 2+.

Communications with the public was on-going in 2005 with the focus on a possible short term kokanee fishery proposed for 2006. In 2004, an experimental sport test fishery was conducted to determine catch rates at the lower level of kokanee production. Catch rates were modestly high but lower than rates determined from the 1980s. Model analysis of the available population data indicates that a modest fishery can be allowed provided the annual catch does not exceed 10,000. A technical report separate from the OLAP series will be published at a later date. Fisheries managers are planning to have a seasonal fishery during the summer of 2006.

Okanagan Lake is comparable in size with nearby Arrow Reservoir and Kootenay Lake. All three water bodies have experienced major impacts from mysid introductions: decline in lake productivity and decreased numbers of kokanee (Pieters et al. 2003; Wright et al. 2002). A substantial amount of research and monitoring is currently underway on all three systems. Cooperation and coordination between these programs has resulted not only in program efficiencies but also in effective design of future monitoring and research work. Comparative analysis of data between the three projects is invaluable and there should be even more emphasis on such work. The comparisons of phytoplankton production between the three systems made by Stockner (in this OLAP report), zooplankton comparisons by Rae and Vidmanic (in this OLAP report) and kokanee population estimates by Sebastian et al. (in this OLAP report) provide much greater insight into how Okanagan Lake is functioning. Although there is some optimism about recent increased numbers of kokanee in Okanagan Lake, it is quite clear that this lake yields much lower numbers of kokanee compared with Arrow Lakes Reservoir or Kootenay Lake.

PRELIMINARY CONCLUSIONS

- Habitat protection of key spawning and rearing habitat must continue and public stewardship groups are critically important to the long term strategy of kokanee recovery in Okanagan Lake.

- Long term flow monitoring of key spawning streams is essential to obtain key data required to make the case for restoration of flows for fish. Trout Creek has considerable potential for improved fish flows, and therefore, kokanee production.

- Annual monitoring and negotiation over lake level regulation is required.

- Phosphorus (P) limitation alone is probably not the reason for poor kokanee survival in Okanagan Lake. Nitrogen limits phytoplankton growth in the summer months although in the last three years P was co-limiting in late summer.

- Cyanobacteria continues to dominate the phytoplankton community and it is believed these blue-greens are not particularly good food items for cladocerans that are the preferred food item of young kokanee.

- Preferred macrozooplankters (*Daphnia*) densities have decreased slightly over time and the Daphnid densities in Okanagan Lake are low compared to Arrow and Kootenay lakes.

- Kokanee spawner escapement levels appear to have improved slightly in recent years. The same applies to the shore spawners but the numbers remain < 20% of the 1970s estimates.

- Age determinations of kokanee using scales or otoliths continue to be problematic. Ageing of each cohort from the trawl samples is the most reliable means of ageing Okanagan Lake kokanee.

- The total numbers of kokanee in the lake determined by hydroacoustics appears to be increasing, especially the age1-3 component.

- Increasing kokanee numbers in the last few years appears to contradict the limnological and phytoplankton data that indicates less than optimal growing conditions for kokanee. The exact factors that limit kokanee are still not understood but certainly nutrient imbalance combined with competitive interaction between mysids and kokanee are major reasons why kokanee have declined over the last three decades.

RECOMMENDATIONS

1. Despite anticipated reduced budget for OLAP in 2006 the action plan work should be reported annually.

2. Mission Creek restoration plans should be implemented.

3. Continue discussions with Summerland public groups and municipality regarding fish flows for Trout Creek.

4. Continue investigating the question of effectiveness of blue-green algae as a food source for macrozooplankters preferred by kokanee.

5. Aggressively pursue increased mysid harvest.

6. Continue hydroacoustics and trawl work using recent DNA analysis techniques to differentiate the contribution of the two stocks.

7. Rely on aging from the trawl catch since there is certainty with each age group.

8. Continue comparative analysis of results of work conducted on Arrow, Kootenay, and Okanagan lakes in all future studies.

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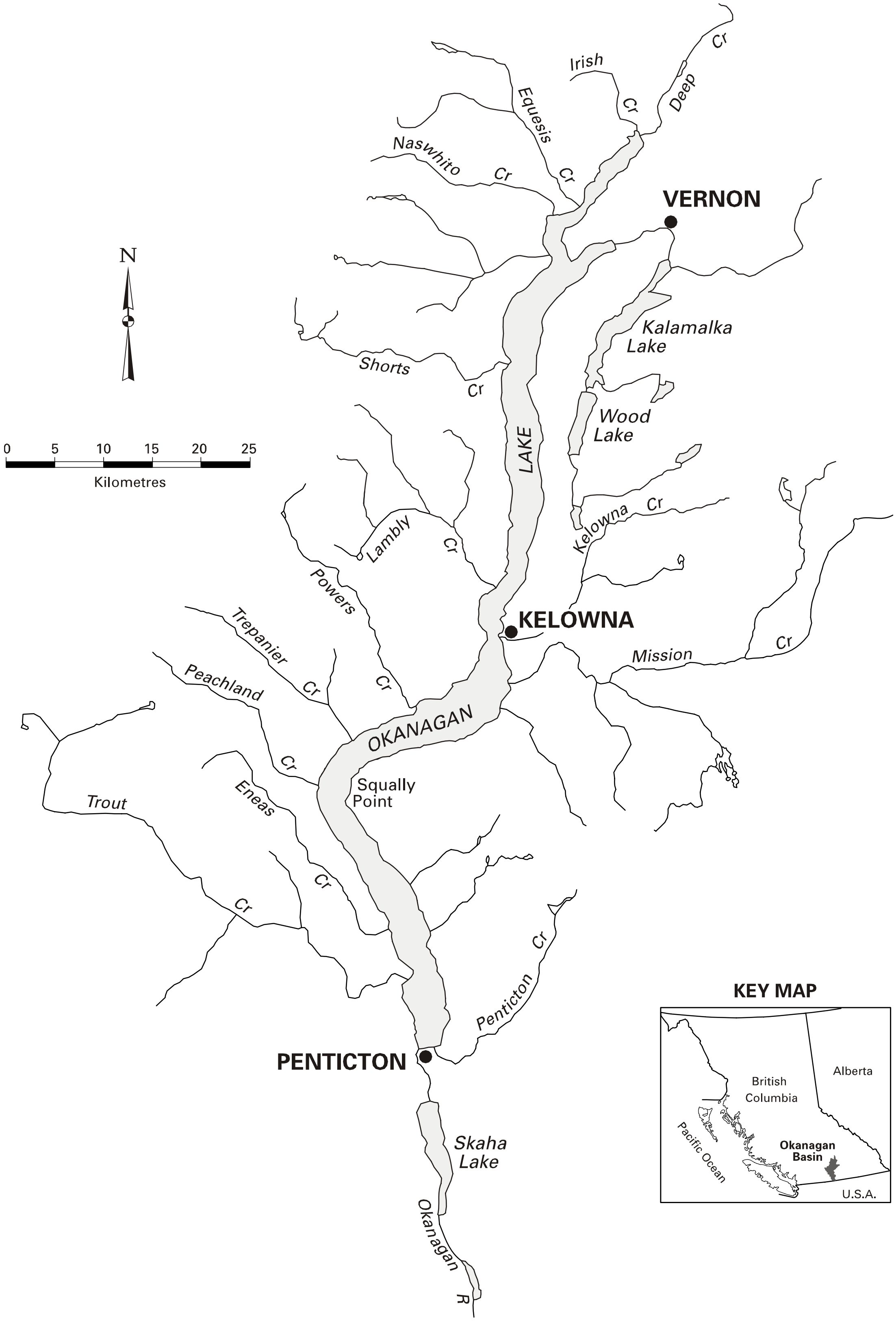
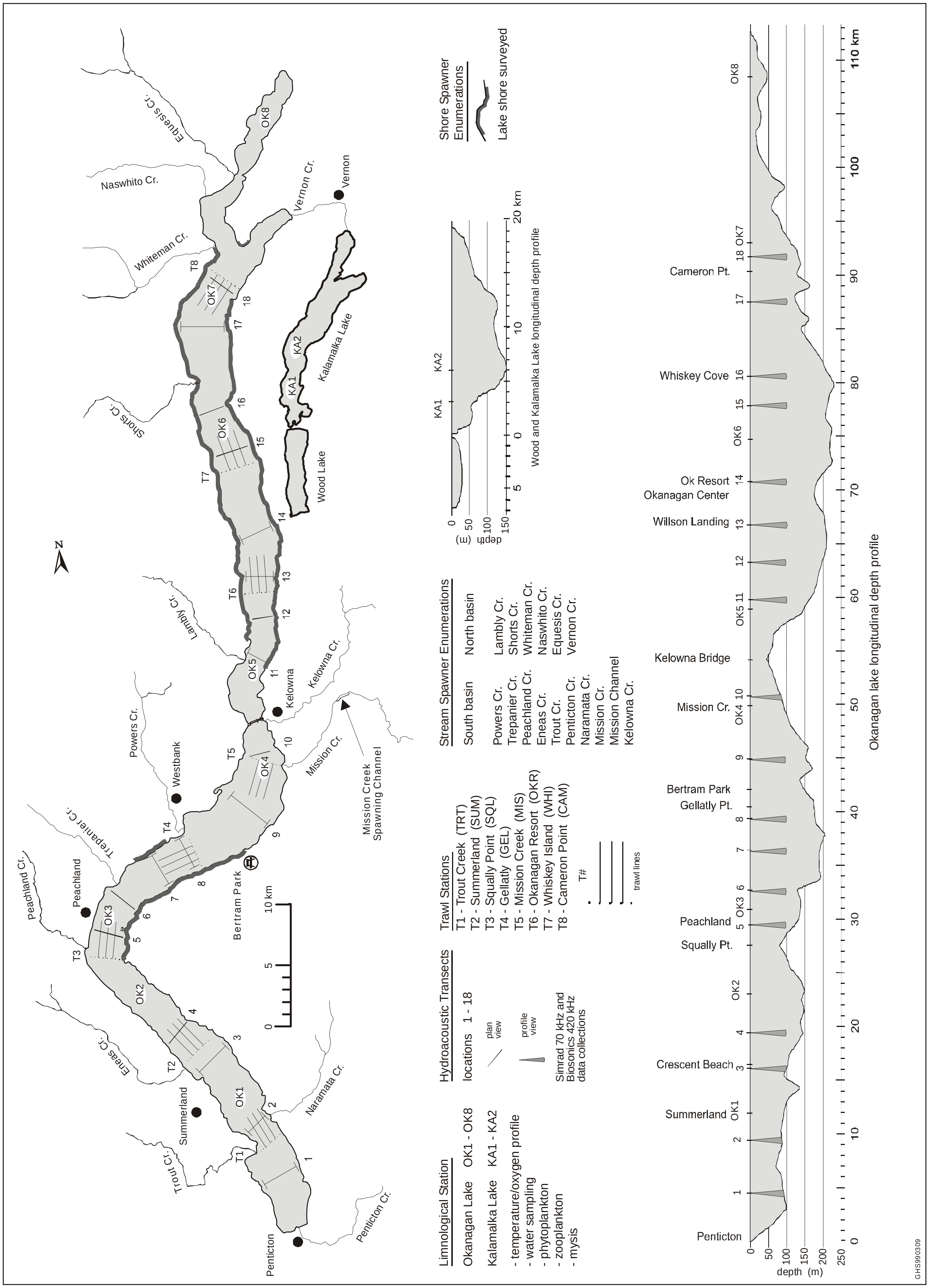


Map 1. Okanagan Lake and tributary streams.



Map 2. Okanagan Lake Action Plan sampling stations and key kokanee spawning locations.