TEN-YEAR SUMMARY OF THE OKANAGAN LAKE ACTION PLAN 1996-2005

MINISTRY OF ENVIRONMENT
JANUARY 2006

Primary funding for Okanagan Lake Action Plan is provided by Habitat Conservation Trust Fund

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1996-2005

INSIDE...

ACKNOWLEDGEMENTS

The Okanagan Lake Action Plan has been funded in large part by the **Habitat Conservation Trust Fund**. This Fund was created by an act of the legislature to preserve, restore, and enhance key areas of habitat for fish and wildlife throughout British Columbia.

Anglers, hunters, trappers, and guides contribute to the projects of the Trust Fund through licence surcharges. Tax deductible donations to assist in the work of the Trust Fund are also welcomed.

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HABITAT CONSERVATION TRUST FUND

BRITISH COLUMBIA
Ministry of Environment

Douglas County Public Utility District

The number of kokanee salmon in Okanagan Lake declined substantially during the 1980s. In 1995, the recreational fishery for kokanee was closed, and in 1996, the Okanagan Lake Action Plan (OLAP) began with the objective of rebuilding and maintaining the diversity of wild kokanee stocks in Okanagan Lake.

OLAP set out to collect information about the food web in Okanagan Lake in order to better understand the ecosystem. This work entailed measuring the characteristics of the water (limnology) and the algae, zooplankton, and kokanee populations.

With a better understanding of the lake ecosystem, OLAP then began several major initiatives to help recover the kokanee population. These initiatives included protection and restoration of stream and shore habitat, control of the introduced mysid shrimp through an experimental shrimp fishery, and investigation of a possible nutrient imbalance in the lake.

OLAP has achieved a remarkable amount in its first ten years of kokanee recovery on Okanagan Lake. Biologists now have a much better understanding of the factors involved in the kokanee decline, and they have made progress in many key areas.

Key results produced by OLAP include:

- ✓ Confirmed that Okanagan Lake is very unproductive due to nutrient deficiencies (phosphorus and nitrogen) resulting in low algae productivity.
- ✓ Detected that Okanagan Lake suffers from nitrogen deficiency during the algae growing season in wet years.
- ✓ Determined that blue-green algae dominate the algae population and that they are a poor-quality food source for cladoceran zooplankton.
- ✓ Identified that mysid shrimp and juvenile kokanee prefer cladoceran zooplankton, which appear to have low nutritional content due to the kind of algae the lake grows.
- ✓ Determined that juvenile kokanee are limited by poor growing conditions in the lake, resulting in low survival.
- ✓ Confirmed that the stream- and shore-spawning kokanee are genetically distinct.
- ✓ Determined that kokanee spawners declined for three decades from nearly 1 million to only 10,000 before recovering somewhat in the 2000s to more than 200,000.
- ✓ Improved stream flows on three important spawning streams.
- ✓ Developed and began implementing a restoration plan for Mission Creek.
- ✓ Improved lake level regulation to protect shore-spawning kokanee.
- ✓ Developed a limited commercial fishery for mysid shrimp.

◄ Orchards overlooking Okanagan Lake.
Vic Jensen

The number of kokanee in Okanagan Lake declined substantially during the 1980s. Both fisheries managers and the public were concerned about the decreasing kokanee numbers, and in 1995, the popular recreational fishery for kokanee closed. The provincial government then sponsored a technical workshop to better define the problems in Okanagan Lake.

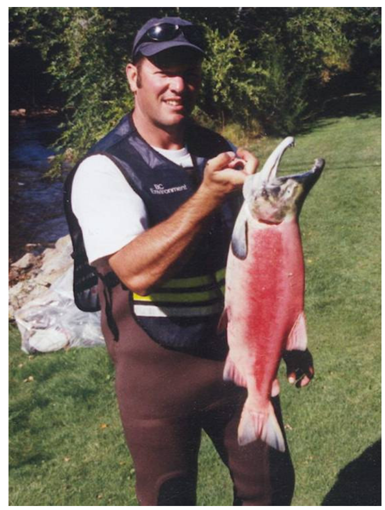
Research scientists, government biologists, and stakeholders from the Okanagan Valley participated in the 1995 workshop in Kelowna to review existing data and evaluate hypotheses about the kokanee decline. The limited information about biological, chemical, and physical characteristics of Okanagan Lake prevented workshop participants from identifying specific causes of the decline. Therefore, the workshop participants recommended forming a long-term program to improve our understanding of the lake and to identify and focus research efforts on kokanee recovery.

The resulting program, called the Okanagan Lake Action Plan (OLAP), was designed with a 20-year time horizon to address the complex issues thought to be affecting kokanee.

The stated objective of OLAP has been:

"To rebuild and maintain the diversity of 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."

A great deal of time and effort, supported by significant funding from the Habitat Conservation Trust Fund, has been spent over the last ten years in an effort to recover the kokanee population. The OLAP team collected baseline water quality data, obtained plankton and freshwater shrimp samples, assessed spawning habitat, and carried out numerous research studies. All this information has given us a much better understanding of Okanagan Lake and its fish populations.



Kokanee from Penticton Creek.
Ministry of Environment

How Okanagan Lake Compares

The issues affecting kokanee in Okanagan Lake are similar in some cases to those observed in several British Columbia lakes, and in other cases, quite different.

The introduced mysid shrimp, *Mysis relicta*, is found in Kootenay, Arrow, and Okanagan lakes, as well as in other lakes in the Okanagan Valley and elsewhere in BC. The shrimp was released into these lakes in the 1960s as a food source for rainbow trout and kokanee. Unfortunately, in deep lakes like

Okanagan Lake, the kokanee eat few of the shrimp, and instead, the shrimp competes with kokanee for the same food. The shrimp, therefore, have decreased the quantity of food available to kokanee. A lake's productivity dictates how much food is available, so the mysids have, in effect, limited the number of kokanee Okanagan Lake is capable of supporting.

Kootenay Lake and Arrow Lakes Reservoir both have problems with low nutrients due to upstream reservoirs and are currently having nutrients added to them to help restore their productivity. The program of nutrient additions, primarily of phosphorus and nitrogen, has stimulated the food web in these lakes and increased food availability for kokanee. Today, both lakes support about one million adult kokanee.

Okanagan Lake is in a different situation; this lake also has low productivity, but the two main nutrients in the water appear to be unbalanced in some years with too little nitrogen for the levels of phosphorus. A low nitrogen to phosphorus ratio promotes growth of blue-green algae that can use, or fix, nitrogen gas dissolved in the water rather than rely on the forms of nitrogen that other algae must use. These nitrogen-fixing blue-greens are a poor food source for the zooplankton that kokanee feed on. As a result, in some years, Okanagan Lake appears to have a food web bottleneck caused by low-quality food.

Unlike Kootenay Lake and Arrow Lakes Reservoir, Okanagan Lake is surrounded by highly developed land. Both urban and agricultural developments have threatened kokanee through alteration and destruction of their stream habitat. Most of the stream-spawning habitat for kokanee has been drastically altered or destroyed. The climate in the Okanagan is also very dry, which makes water precious, especially in drought years such as 2003 and 2004. Efficient and responsible water use is crucial but is not always taking place. The human population continues to grow in the Okanagan with one of the highest rates in the province. This growth is placing even greater pressure on the land and water resources in the basin, and the kokanee have suffered.

Communities dot the shores of Okanagan Lake, and the human population continues to grow.
Rowena Rae

Kokanee in Peachland Creek.
Steve Matthews, Ministry of Environment

OLAP Activities

Two five-year phases of OLAP were completed at the end of 2005. During Phase 1 (1996-2000), the main focus was on conserving native fish stocks, protecting habitat, and improving baseline information about the ecology of Okanagan Lake. To rebuild the kokanee population, a lot needed to be learned about kokanee survival in the lake and the survival of their eggs in the streams and on the lakeshore. The data OLAP collected has provided extensive information about kokanee and other organisms, including the mysid shrimp.

The knowledge gained from initial baseline monitoring in Phase 1 shifted the focus to carrying out restoration measures to benefit the kokanee population. Phase 2 (2001-2005) continued with kokanee monitoring, habitat protection and restoration, and water quality monitoring. The OLAP team developed plans for restoring water flow and habitat in key streams. They also initiated research to reduce the number of mysid shrimp and to examine nutrient balance in the lake.

Communication

A key component of OLAP has been timely communication with the stakeholders in Okanagan Valley. OLAP produces annual reports with details of all the information collected and work completed on Okanagan Lake (see list on page 36). In addition, public and stakeholder meetings have been held at regular intervals to provide progress updates and solicit input for shaping the future direction of the program. In 2001, at the end of Phase 1, a public conference and a strategic planning session were held in Kelowna. The strategic planning session was attended by representatives of local, provincial, and federal governments, First Nations, and non-government organizations. The outcomes of that strategic planning session formed the basis of the work that has taken place during Phase 2 of OLAP.

A second strategic planning session was held in April 2004, in Kelowna, to discuss progress in Phase 2 and activities over the next few years. Public information meetings were also held in late April 2004, in Penticton, Kelowna, and Vernon, to update the public and answer questions about OLAP's progress and future direction.

The Ten-Year Summary

Given its stated objective in 1995, the obvious questions that arise after ten years of OLAP work are:

- What has OLAP accomplished?
- Do we better understand the problems in Okanagan Lake?
- Has OLAP improved the kokanee population?

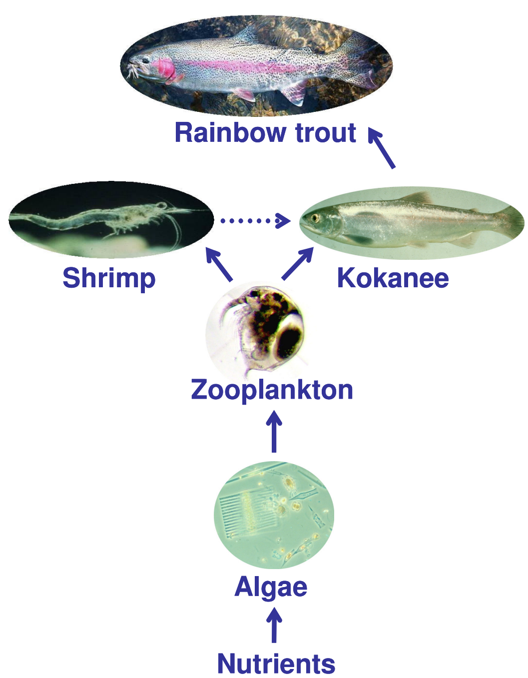
The purpose of this report is to present a summary of OLAP's progress over the ten-year period. We provide highlights of successes and failures to assist the public in understanding the status of OLAP at the end of 2005 and the need for continuing the program.

The first part of this report describes the results of food web monitoring, starting with the physical and chemical structure of Okanagan Lake and continuing with algae, zooplankton, and kokanee monitoring. The second part gives details about the recovery initiatives underway on Okanagan Lake, including habitat restoration, mysid shrimp control, and nutrient balance investigations. The third part explains OLAP's consultation and communication activities, and the report ends with a summary and a description of OLAP's future.

Okanagan Lake's Food Web

Any food web depends on the nutrition available for plants and animals to grow. In lakes, the major nutrients are phosphorus and nitrogen, although other nutrients are also necessary. The nutrients are used by microscopic plants, called phytoplankton or algae, which are grazed by small animals called zooplankton. The zooplankton are eaten by shrimp and fish.

Algae are one-cell plants at the base of the aquatic food web. Algae use sunlight, water, and nutrients to carry out photosynthesis and to grow. Zooplankton are next in line in the aquatic food web—they eat the algae. Larger organisms, including freshwater shrimp and some fish, including kokanee, then feed on zooplankton, as shown in the Okanagan Lake food web diagram below.



Photos, Top to bottom & left to right:
Ray Pillipow, David Lasenby, Ministry of Environment, Lidija Vidmanic, Rowena Rae

Okanagan Lake statistics

Elevation: 342 metres above sea level

Length: 110 kilometres

Average depth: 75 metres

Maximum depth: 242 metres

Surface area: 350 square kilometres

Water residence time: >60 years

In Okanagan Lake, both mysid shrimp and kokanee eat zooplankton, and both prefer the same type of zooplankton. This creates competition for food, which is described more in shrimp control on page 22.

Kokanee will also eat mysid shrimp, but because Okanagan Lake is very deep, the kokanee rarely encounter the shrimp. Shrimp spend the daytime deep in the lake and only swim to shallower water to feed at night. Kokanee, which stay in shallow water, are sight feeders, so they can't see the shrimp at night. In shallower lakes, such as Skaha Lake, there is a greater chance that kokanee and mysids will be in the same water layers during the day when kokanee are feeding.

At the top of Okanagan Lake's food web is another fish: rainbow trout. Rainbow trout primarily eat kokanee, so the health of the kokanee population is critical to the health of the trout population. OLAP has not studied rainbow trout directly, but we know that in the late 1970s, Mission Creek supported an average of 420 spawning rainbow trout each year. There are no in-lake population estimates. A recreational fishery continues for rainbow trout, and when Ministry of Environment biologists re-open the recreational kokanee fishery, they will monitor both kokanee and rainbow trout catches to ensure viable populations remain.

Limnology Monitoring

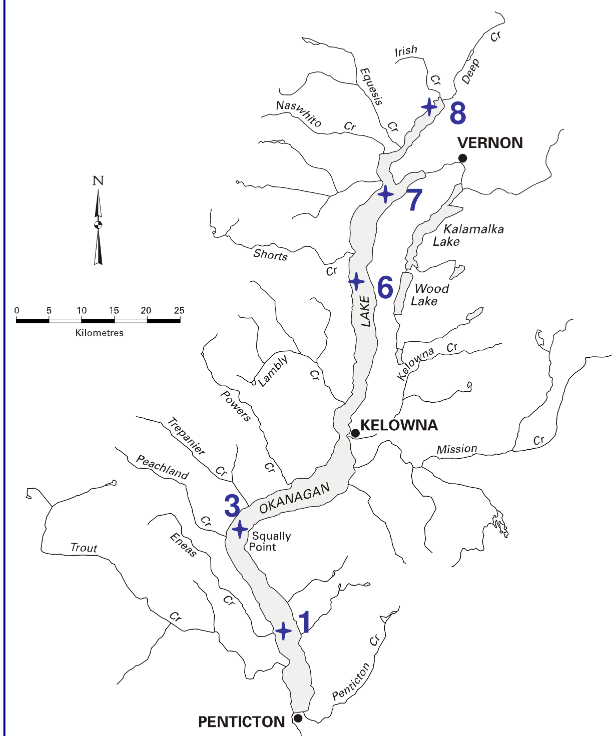
Limnology is the study of lakes; limnology monitoring means taking water samples and measurements to examine the chemical, physical, and biological characteristics of a lake. These characteristics reflect the health and productivity of the lake ecosystem. Productivity is a measure of how well a system, such as a lake, can grow organisms, including algae, zooplankton, and fish.

During the past ten years, OLAP has conducted monthly sampling from April or May through to November and, in several years, has also collected winter samples in February. For each sampling trip, OLAP biologists regularly visit five sites on Okanagan Lake. The sites are mid-way between the shores of the lake, as shown on the map, at these locations:

- Site 1 – South of Prairie Creek
- Site 3 – Opposite Rattlesnake Island
- Site 6 – North of Okanagan Centre
- Site 7 – Vernon Arm
- Site 8 – Armstrong Arm

At each site, biologists measure the physical characteristics of the water. These include depth profiles to record temperature and oxygen at various depths.

A water sampling bottle.
BC Lake Stewardship Society

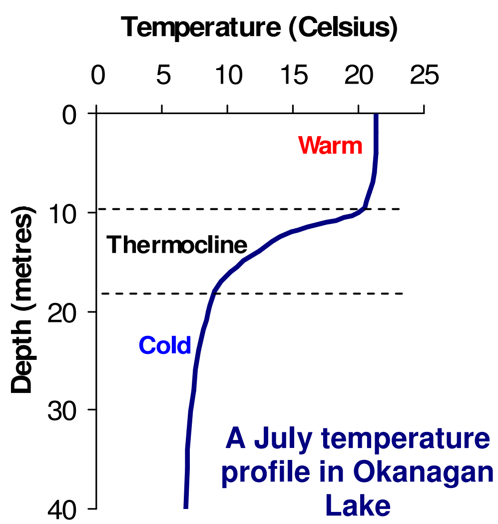


Okanagan Lake showing the five sites (1, 3, 6, 7, 8) sampled regularly by OLAP. Sites 2, 4, 5 (not shown) were sampled only occasionally.

The temperature varies with the seasons. In late fall, winter, and early spring, the water is a constant temperature of 4ºC from surface to bottom. In summer, the lake has a layer of warm water near the surface, a layer where the temperature drops quickly, and a layer of cold water at the bottom (see the diagram on the facing page).

At the height of summer, in July, the temperature layers are most stable (the wind can't mix them) with the warm layer at 18-25ºC from the surface to about 10 metres depth. Over the next 8 metres the temperature declines rapidly to about 9ºC; this layer is called the thermocline. Below the thermocline, the temperature continues to decline slowly until, at the bottom of the lake, the temperature is 4ºC.

When air temperature cools in the fall, the lake surface begins to lose heat, eventually the wind is able to mix the layers, and the thermocline disappears. Because Okanagan Lake does not freeze over in winter, the wind continues to mix the water and keeps the entire lake from top to bottom at about 4ºC until the following spring.



A July temperature profile in Okanagan Lake

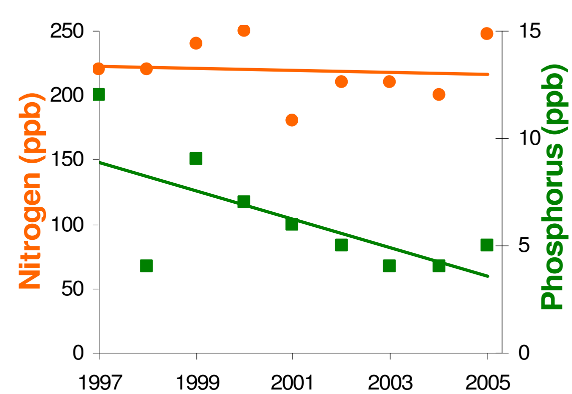
In winter, when Okanagan Lake is mixing, oxygen levels are constant from surface to bottom, and there is ample oxygen for fish and other organisms throughout the lake. During the stable summer temperature period, oxygen usually increases very slightly with depth in the lake—this is a typical situation for nutrient-poor or unproductive lakes (see discussion of nutrients below and on page 8).

Sometimes, oxygen peaks at a depth of about 16 metres. This is because algae (microscopic floating plants) grow at this depth and are busy producing oxygen as a by-product of their photosynthesis. Algae also cause the water to appear cloudy when they are abundant.

After collecting the physical information at each site, biologists take water samples from the lake and send them to a laboratory. Chemical analysis on the samples determines how much phosphorus and nitrogen is in the water. Phosphorus and nitrogen are the two key nutrients needed by algae to grow and reproduce.

A common way to determine a lake's nutrient status is to measure all the phosphorus and all the nitrogen in the lake each spring (April). Each of these measurements includes the phosphorus and nitrogen that are dissolved in the water; that are bound to sediments suspended in the water; and that are within the algae growing in the water.

In Okanagan Lake, spring phosphorus has been gradually declining since the mid 1970s. This decline continued over the last nine years. In 1997, spring phosphorus levels were an average of 12 parts per billion (ppb), and in 2005 they were 5 ppb (shown in the diagram below). The decline is related to upgrades at several sewage treatment facilities in the Okanagan, to alternative uses of treated sewage (for example, spray irrigation), and to the increasingly dry conditions in Okanagan Valley.



Spring nitrogen and phosphorus in Okanagan Lake

Spring phosphorus increases slightly from south to north in Okanagan Lake, and Armstrong Arm has the highest levels. The higher nutrient levels in Armstrong Arm are thought to be because of historic sewage inputs to this area of the lake and release of nutrients from the bottom sediments each time the deep waters get depleted of oxygen.

Spring nitrogen in Okanagan Lake has stayed relatively constant from 1997 to 2005. In 1997, average spring nitrogen was 220 ppb, and in 2005, it was 247 ppb (shown in the diagram on the previous page). Armstrong Arm again has higher levels.

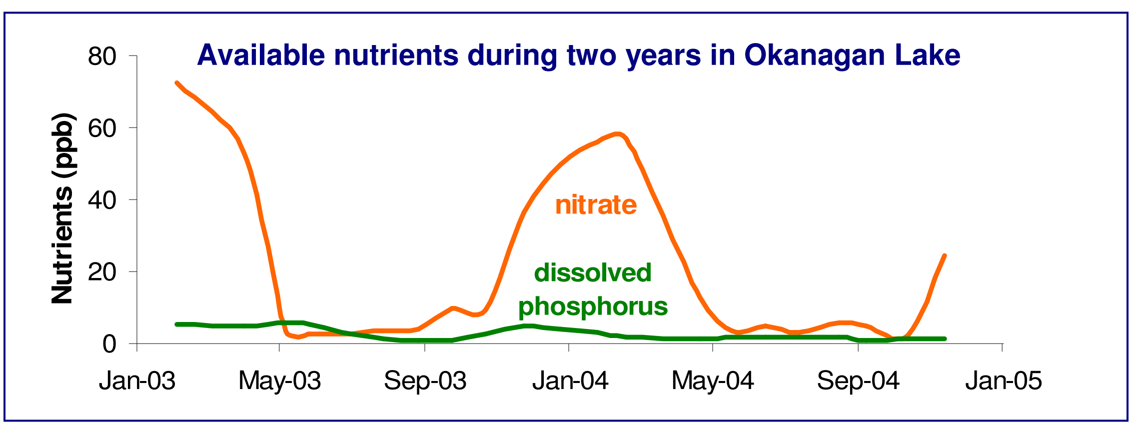
Nutrient levels vary from year to year in Okanagan Lake. This is particularly apparent in wet years versus dry years. In wet years, more snow and rainfall on the surrounding land equate to more water entering the lake. This water picks up nutrients as it runs over the land and down streams and delivers the nutrients to the lake. In dry years, there is less snow and rain, so less water and fewer nutrients enter the lake. The years 1995 to 1997 were wet years, while 2002 to 2005 were dry years. The nutrient levels in the lake match these periods.

The recent spring nutrient levels, both phosphorus and nitrogen, indicate that Okanagan Lake is nutrient poor—termed oligotrophic. If the trend in declining spring phosphorus observed over the past nine years continues, Okanagan Lake will begin to be termed ultra-oligotrophic, meaning very unproductive. Adequate nutrients are critical for algae and all other organisms in the lake to grow.

The total phosphorus and nitrogen measurements provide a good picture of the overall nutrient status of the lake. Algae, however, can only use specific forms of nutrients. The two main forms that most algae take up and use are called biologically available nutrients, and they are dissolved phosphorus and nitrate (a form of nitrogen).

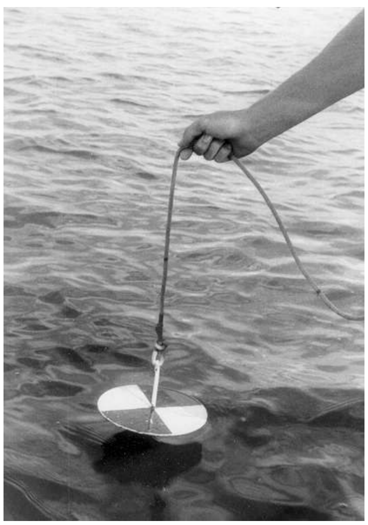
The water samples OLAP collects from Okanagan Lake are analyzed for dissolved phosphorus and nitrate, since these forms are the most important for growth. In the winter, both stay at constant levels: average dissolved phosphorus is 4 ppb, and average nitrate is 48 ppb. When the growing season begins in May or early June, however, dissolved phosphorus levels in the top 10 metres of the lake stay fairly constant, while nitrate levels plummet (shown in the diagram below).

Therefore, the ratio of available nitrogen to phosphorus, often referred to as available N:P, becomes unbalanced. The average dissolved phosphorus and nitrate levels mentioned in the previous paragraph



demonstrate an available N:P ratio in winter and early spring of 12:1 and in summer of 0.5:1. Possible consequences of this change in available nutrients are discussed on page 24.

At each sampling site, biologists also measure the transparency or clarity of the water. This is done with a simple tool, the Secchi disk, which is a white and black disk of 20-centimetre diameter. The disk is lowered into the lake on a rope until it can no longer be seen. The depth where the disk disappears is called the Secchi depth.



Lowering a Secchi disk.
BC Lake Stewardship Society

In Okanagan Lake, year-round Secchi depth measurements began in June 1996. They show that the lake is usually clearest in winter when few algae are growing and very cloudy in spring when a flush of nutrients to the lake encourages quick algae growth called a bloom. As the spring bloom fades, the water becomes clearer until a smaller bloom occurs in fall. So, the Secchi measurements give biologists an idea of how many algae are growing.

The last measurement the biologists take during limnology sampling is chlorophyll *a*. Chlorophyll *a* (Chl *a*) is the primary pigment used by algae when they carry out photosynthesis. Because all algae have Chl *a*, it is a good indicator of how many algae are in the lake. Chl *a* is measured by taking a water sample and pouring it through a filter paper to capture all the algae cells. A laboratory then extracts the Chl *a* pigment from the algae on the filter paper.

Chl *a* in the main part of Okanagan Lake is generally a little lower in the south compared with the north. Since 1997, the algae growing season (May to October) average has been 2.8 ppb in the south and 3.0 in the north. The Armstrong Arm again has higher levels, averaging 3.8 ppb over the same growing season.

In the past nine years, the highest growing season average for Chl *a* in the main lake was measured in 1999 at 5.7 ppb. In each of the past three years—2003 to 2005—average Chl *a* in the growing season has been 1.5 or 1.6 ppb. These three years have been extremely dry with little spring meltwater entering the lake. In the late 1990s, spring conditions were wetter. So, the recent decline in both phosphorus and Chl *a* has probably been the result of few nutrients being brought into the lake in spring, and consequently, poor algae growth.

As with phosphorus, Chl *a* can be used to determine a lake's level of productivity. Lakes with few nutrients have low productivity and low Chl *a* levels, usually less than 4 or 5 ppb. Okanagan Lake clearly fits into this category, particularly in recent years.

Algae Monitoring

There are five main groups of algae:

- **blue-greens** (Cyanophytes or cyanobacteria)
- **greens** (Chlorophytes)
- **golden-browns** (Chrysophytes and Cryptophytes)
- **diatoms** (Bacillariophytes)
- **dinoflagellates** (Dinophytes)

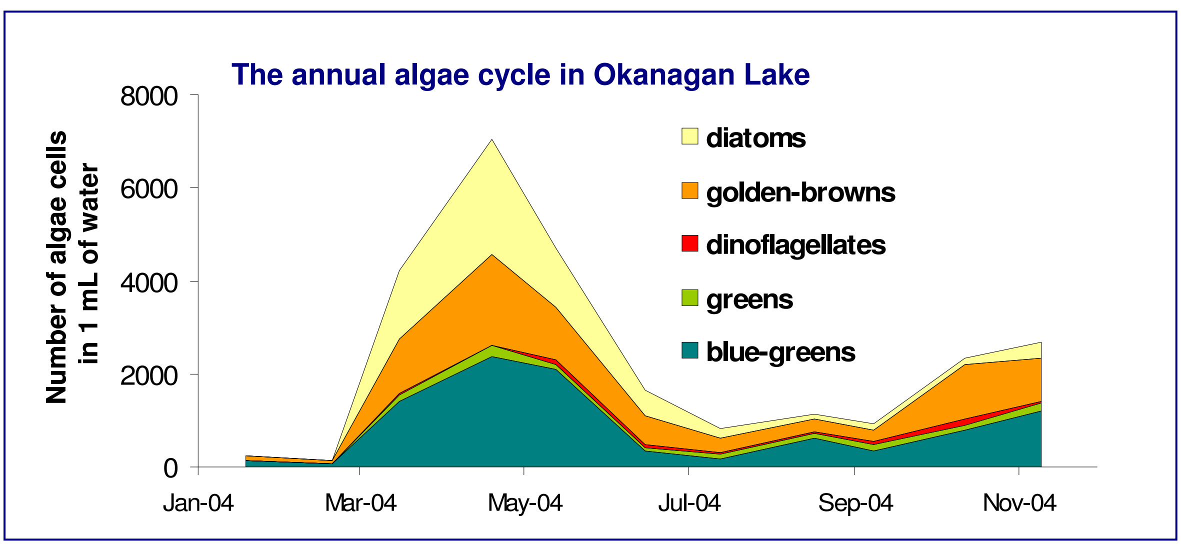
Each group has several characteristics that are important for the zooplankton that eat them and for the rest of the aquatic food web.

OLAP biologists collect water samples from the top 10 metres of the lake to identify and count algae. They sample the same five stations described earlier and have consistently taken monthly samples from April to November since 1997. Algae samples are preserved and then are analyzed with a microscope. The number of cells and the amount (total volume occupied by the cells) are recorded for each of the five algae groups.

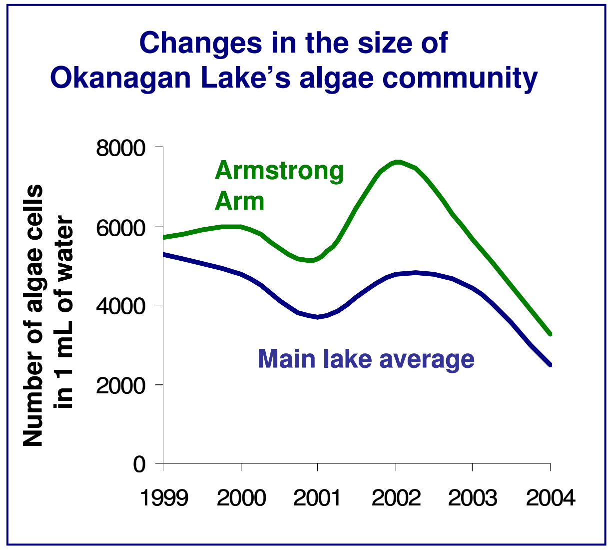
Okanagan Lake has an annual algae cycle that is fairly typical of Canadian lakes. Over the winter, there are few algae in the water, and little or no algae growth occurs. When spring meltwater enters the lake, the sudden burst of nutrients stimulates algae to grow rapidly. This is called the spring bloom and usually occurs in April and May, as illustrated in the diagram below. The spring bloom consists mainly of blue-greens, diatoms, and golden-browns. These algae use up most available nutrients, particularly nitrate.

As the nutrients are used up and stable temperature layers form in June and July, the size of the algae population decreases. Diatoms decrease in abundance, different blue-green species appear, and low levels of golden-browns grow. Most of the time, there tend to be few greens and dinoflagellates.

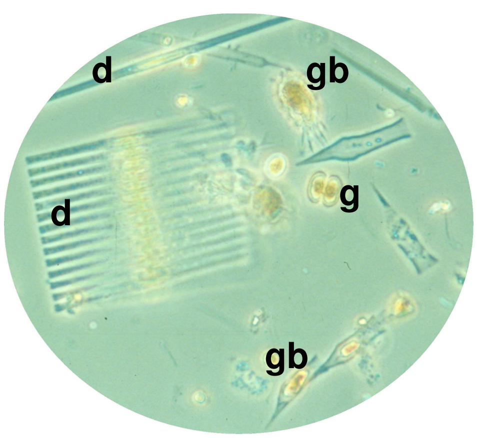
When the temperature layers degrade and wind mixes the lake in fall, more nutrients are stirred from deeper in the lake to the top 10 to 20 metres. This pulse of nutrients is smaller than in the spring but still stimulates algae growth. Blue-greens often dominate the fall bloom in Okanagan Lake. The fall bloom usually occurs in October or November, and the algae population then returns to its winter levels, and this cycle starts over again in the spring.



There have been changes in the abundance of algae since 1999, as shown in the diagram to the right. In 1999, the main lake averaged 5,260 cells in one milli-litre (mL) of water, while in 2004, the abundance of algae was recorded at an all-time low of 2,500 cells. The decline over this six-year period was also seen in Armstrong Arm.



The abundance of blue-greens at many times of the year is puzzling in Okanagan Lake. Blue-greens usually dominate in nutrient-rich waters. But, as mentioned earlier, Okanagan Lake falls into the category of oligotrophic, or nutrient-poor, lakes. The abundance of blue-greens could be one reason that the zooplankton and kokanee are growing poorly in the lake: blue-greens are often difficult for zooplankton to eat, and their nutritional value is comparatively low. In effect, zooplankton that feed on blue-greens are eating junk food. Early studies in 1935 and 1969 reported various species of blue-greens as common to abundant in Okanagan Lake, so they are not newcomers to the lake.



A microscope photo of diatoms (d), golden-brown algae (gb), and green algae (g).
Rowena Rae

Counting the number of cells and the amount of algae gives biologists a snapshot view of the lake at the time the water sample was taken. Biologists get additional information from finding out how productive algae are. In other words, how much new food, measured as carbon, do algae produce or grow in a day? The answer to this question gives biologists an idea of how well the algae support or feed the rest of the food web.

OLAP measured algae productivity and compared the information with two other southern BC interior lakes, Kootenay Lake and Arrow Lakes Reservoir. Both Kootenay and Arrow have nutrient addition programs to help restore their productivity. Biologists found that Okanagan Lake has extremely low productivity levels of about 70-150 carbon units. In Kootenay Lake, productivity was 430-700 carbon units, and in Arrow Lakes Reservoir, productivity was 450-560 carbon units. So, the algae in Okanagan Lake only make about 20% as much food as in the other two lakes.

Zooplankton Monitoring

There are two main groups of zooplankton: cladocerans and copepods. Cladocerans, also called water fleas, are the preferred food of kokanee. Copepods are often smaller than cladocerans and, therefore, can be harder for kokanee to catch. Unfortunately, mysid shrimp also prefer cladocerans and graze heavily on them. Competition between kokanee and mysid shrimp for cladocerans is believed to be a major factor limiting kokanee production; more discussion of this is on page 22.

As with the limnology and algae sampling, OLAP biologists collect zooplankton from five stations. They take samples monthly from April to October by lowering a fine-mesh net in the shape of a cone into the lake to a depth of 45 metres. They then pull the net at a constant speed back up to the surface, and all the zooplankton in that column of water are captured in a flask at the end of the net.

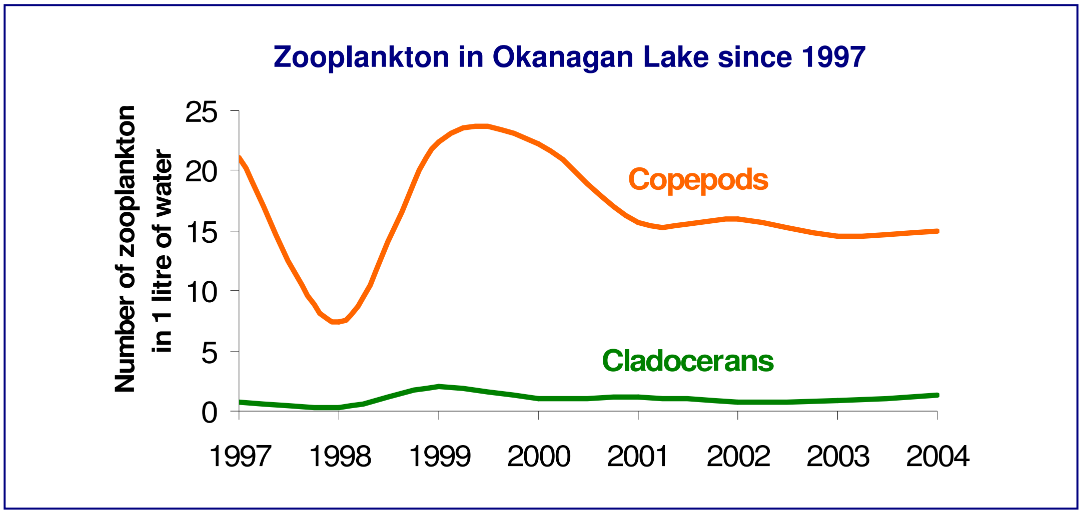
Copepods dominate the zooplankton numbers in Okanagan Lake. In April and May, copepods can be 99% of the zooplankton population, and in the summer and fall months, they generally make up at least 85%. Kokanee will eat copepods, but they prefer larger cladocerans.

Because cladocerans tend to be large compared with copepods, cladocerans can be a significant part of the total weight of zooplankton, even at very low abundance. For example, averaged over the growing season and the whole lake in 2004, cladocerans were 6% of the population by number but 31% of the population by weight.

Similar to nutrients and algae, zooplankton vary from south to north in Okanagan Lake. During the 2004 growing season, there were 15 zooplankton in one litre of water in the south, 18 in the north, and 31 in Armstrong Arm. The percentage of cladocerans increased very slightly as well: about 5% in the south, 6% in the north, and 8% in Armstrong Arm.

From 1997 to 2004, the zooplankton population has fluctuated in size with no real pattern, as shown in the diagram opposite. Its low has been 8 zooplankton per litre and its high 25. During this time, cladocerans have varied from about 3 to 9% of the population. In the past four years (2001-2004), the total zooplankton numbers have remained steady at about 16 per litre; of this, cladocerans have been 4 to 8%.

A cladoceran (left) and a copepod (right) from Okanagan Lake. Each is 1.5 mm long. The two smaller zooplankton at right are young copepods.
Lidija Vidmanic



As mentioned before, zooplankton eat algae. Okanagan Lake's zooplankton often have poor-quality algae (blue-greens) to graze, and so they may not be getting adequate nutrition. A University of Washington scientist who works with the OLAP team has done lab feeding experiments with cladocerans. He found that cladocerans fed blue-green algae were themselves of poor nutritional value. Cladocerans fed golden-brown algae were of high nutritional value, as the golden-browns are. In other words, zooplankton are a more nutritious meal for their predators when they don't eat blue-greens.

The importance of these findings cannot be emphasized enough. If they eat poor-quality algae, zooplankton are not as healthy as they should be. Then, the kokanee fry (young-of-the-year) eating poor quality zooplankton may not be getting adequate nutrition to grow and survive. This is discussed again in the nutrient balance section on page 24.

Mysid shrimp are the largest zooplankton of all, and they will eat plants or animals. Mysids eat other zooplankton, especially the cladocerans that kokanee prefer to eat. This competition between mysids and kokanee creates another problem: the kokanee can't find enough to eat. OLAP's zooplankton monitoring program includes monthly mysid collection at each of the five sampling stations. Mysids are discussed in more detail on page 22.

A microscope is used to identify zooplankton in Okanagan Lake.
Lidija Vidmanic

Kokanee Monitoring

The OLAP team has put a lot of effort into better understanding the biology of Okanagan Lake kokanee. Their work has included learning about when and where kokanee spawn, the total number and ages of kokanee in the lake, and how well kokanee fry survive to adulthood.

Most kokanee in British Columbia's lakes spawn in streams during the fall, the eggs incubate in the gravel during the winter, and the fry emerge in the spring and swim immediately to the lake. Young kokanee then spend two to four years growing in the lake before returning to spawn in their natal stream.

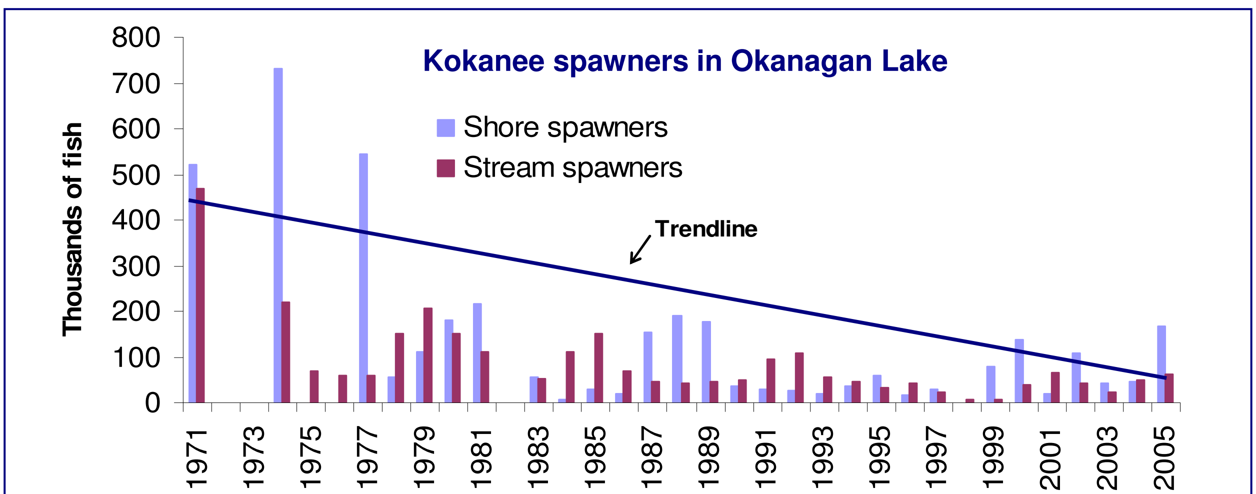
Okanagan Lake is unusual, because it has a shore-spawning population of kokanee as well as a stream-spawning population. Genetic research has shown that the stream and shore spawners are two distinct spawning populations. Stream spawning occurs about one month before shore spawning, stream spawners are often larger than shore spawners, and stream spawners are far more variable in age at spawning.

Fisheries biologists have been counting Okanagan Lake's shore- and stream-spawning kokanee for over thirty years. In

Stream-spawning kokanee.
Andrew Wilson, Ministry of Environment

this time, there has been a dramatic decline from hundreds of thousands in the 1970s to fewer than 10,000 in 1998. The number of kokanee spawners has shown a positive trend over the past seven years with the 2005 total exceeding 220,000 (see the graph below).

The decline in spawner numbers has occurred in both the stream- and shore-spawning populations. This tells biologists that loss of stream-spawning habitat due to development does not totally account for the decline, since much of the important shore-spawning habitat is largely intact. Nevertheless, protecting and restoring



spawning habitat is still vitally important and has been OLAP's highest priority since the program began.

Despite Okanagan Lake's large size, most stream spawners use fewer than ten streams, totalling about 15 km of stream length. Over 50% of all stream spawners are found in Mission Creek. Even the shore spawners choose to spawn along only about one third of the shoreline. Most shore spawning occurs along the eastern shore, within 20 km of Kelowna. Minimizing shoreline development at these spawning sites is an important role of government and stewardship groups.

Seining shore-spawning kokanee.
Ministry of Environment

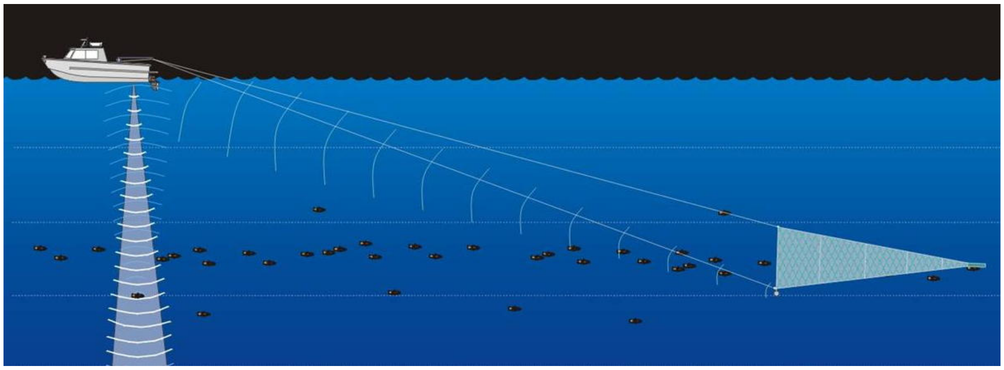
Prior to OLAP, little was known about the shore spawners, so several projects were launched to get more information about spawning behaviour and success. A comprehensive study of the shore spawners helped water managers regulate the lake's water level to minimize impact on incubating kokanee eggs (see shore habitat on page 21).

Since the number of adult spawners had declined so much, OLAP wanted to know if kokanee fry production was also a problem. During the last ten years, biologists have monitored fry production in the Mission Creek spawning channel. The spawning channel produces about half a million fry per year at survival rates five to six times higher than in the natural stream. Therefore, fry estimates indicate that production is fairly good, yet the number of adults returning to spawn remains low. This information tells us that there is a survival problem in the lake.

Regardless of age or spawning location, data from the last 20 years indicate that, in most years, spawners barely replace themselves. In other words, returning spawners are often not as numerous as their parents had been. Even Mission Creek kokanee, which are greatly assisted by the spawning channel, hardly replace themselves from one generation to the next.

All the data on the two spawning populations of kokanee led to the conclusion that spawning habitat alone cannot account for the dramatic decline in kokanee numbers. Biologists suspected that in-lake constraints to growth and survival must explain why kokanee numbers have not increased, despite promising stream protection and restoration work. Because of growth limitations in the lake, the OLAP team has not pursued a hatchery solution to low kokanee numbers.

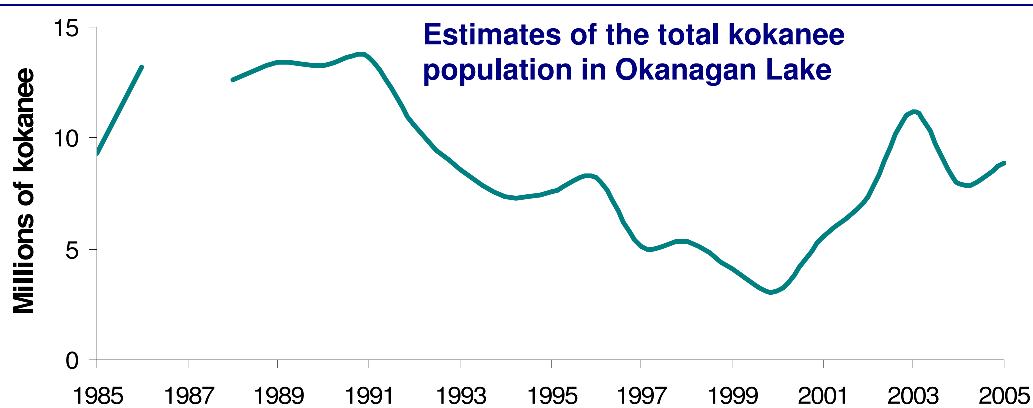
Fortunately, the provincial Ministry of Environment has been monitoring the size of the kokanee population in Okanagan Lake for nearly two decades. Echo sounding and trawl surveys conducted each fall provide good estimates of kokanee numbers in the lake. OLAP conducts this work at night when all ages of kokanee are concentrated near the lake's thermocline. Echo soundings estimate the number of fish in open water, and samples from the trawl catches confirm that 99% of these fish are kokanee. These samples are analyzed to determine size, age, and growth rates.

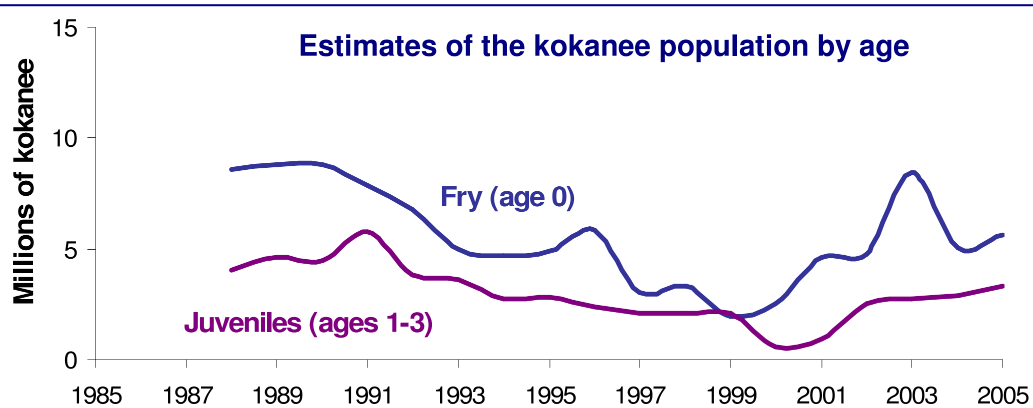


The echo sounder sends a signal into the water below the boat to gather information about the number of fish, while the trawl net is pulled behind to capture some of the fish for identification.
George Scholten, Ministry of Environment

In the late 1980s, when echo sounding work began, there were about 12-14 million kokanee in Okanagan Lake (see top diagram, below). These estimates include all age groups, although fry account for up to 80% of the total number in some years.

The total number of kokanee declined throughout the 1990s and reached a low of 3 million in 2000. Since then, kokanee have increased to a population of 9.7 million in 2005. From 1993 to 2005, the kokanee population has averaged 200 tonnes per year.





Kokanee numbers fluctuate naturally because of annual variations in fry production from the stream and shore spawners. The majority of fry die in their first year, so a more reliable indicator of the kokanee population's health is the estimate of ages 1-3 fish. In the 1980s, the total number of ages 1-3 was around 5 million. The numbers dropped to fewer than 1 million in 2000 and 2001, but they have shown a modest recovery to 3.8 million in 2005 (see bottom diagram, facing page).

The echo sounding information recorded over the last 17 years provides significant insights into how the kokanee respond to lake conditions. The fry seem to survive at about the same rate as in other lakes during their first summer, but the juveniles (ages 1 and 2) do not survive as well as elsewhere. Food supply appears to be a problem for the juveniles; this is discussed further in the recovery initiatives section on pages 18-27. Poor survival in the lake explains why the number of stream spawners is often much lower than the parental numbers, despite the high production of fry from the main spawning stream (Mission Creek).

Echo sounding and trawling boat.
Dale Sebastian, Ministry of Environment

Kokanee caught during a test fishery.
Jason Webster

In 2004, OLAP conducted a test fishery to determine if a limited sport fishery could be permitted. If the kokanee population is "stuck" at lower numbers but remains stable, it may be possible to have a safe harvest at this much lower population level. The test fishery suggested that this would be possible, especially with the higher fry production from Mission Creek spawning channel, improvements to stream flows, and habitat restoration. Biologists are currently determining the actual number of kokanee that can be safely caught in an annual summer fishery. They anticipate re-opening a limited kokanee fishery in 2006.

OLAP targets three main areas in its work to recover Okanagan Lake's kokanee. These are:
1. habitat protection and restoration
2. mysid shrimp control
3. nutrient balance and food web quality

Stream & Shore Habitat

The Ministry of Environment, independent of OLAP, and Fisheries and Oceans Canada have policies in place to help protect stream and shore habitat through both proactive and reactive measures. Proactive measures consist of developing standards and guidelines for developers, and reactive measures involve compliance and enforcement activities. To complement and build upon these policies, OLAP has been involved in habitat protection and restoration.

Stream Habitat

Protecting and restoring stream habitat is important for recovering the kokanee population in Okanagan Lake and also for maintaining populations of other fish such as rainbow trout. Both kokanee and trout spawn in streams, and their eggs incubate in the gravel. When they hatch, kokanee fry swim to the lake, and trout fry stay in the streams to rear and grow before they can survive in the lake.

Both land and water developments have damaged stream habitat in the Okanagan Valley. Destruction of fish habitat began in the late 1800s with the advent of flood irrigation. Many streams were diverted into the fertile valley bottoms to irrigate crops. This resulted in a reduction of available habitat for spawning and rearing fish.

Joe Rich Creek, tributary to Mission Creek.
Brent Magnan, Regional District of Central Okanagan

Streams were also channelized and dyked for flood protection, further reducing fish diversity and productivity. Since the 1970s, reduced productivity in the lake coupled with stream habitat degradation has resulted in a virtual collapse in the kokanee numbers. They have declined from the hundreds of thousands to only tens of thousands.

Stream habitat protection and restoration require continuous effort to retain what remains of key fish habitat after decades of human impacts. This work is the least noticeable part of OLAP, yet it is extremely important, since a fundamental principle of ecology is that high-quality habitat is a prerequisite for healthy fish populations.

OLAP's stream habitat work involves:
- working for fish-friendly water flows in streams
- prioritizing streams that require restoration
- developing and implementing restoration plans
- increasing the involvement of stewardship groups in stream work

Irrigation and residential demands on streams have led to very low stream flows. This has compounded the problem for kokanee stream spawners, which for years have experienced substantial losses due to stream alterations. OLAP began the daunting task of recovering water flows for fish and has achieved several successes.

In 1999, OLAP team members negotiated with water licence holders on Bellevue Creek, a trout and kokanee spawning stream, to relinquish their licences. The Irrigation District identified a groundwater source that met their needs and agreed to return the licensed water to Bellevue Creek. Previously, the stream dried during the late summer and fall due to irrigation practices, but it now has sufficient water flow to support year-round fish production.

Biologists also recently measured stream flows during low flow conditions to identify which streams had potential for flow improvement. Trout Creek was identified as the highest priority for flow recovery, while Mission Creek has the greatest potential for habitat restoration.

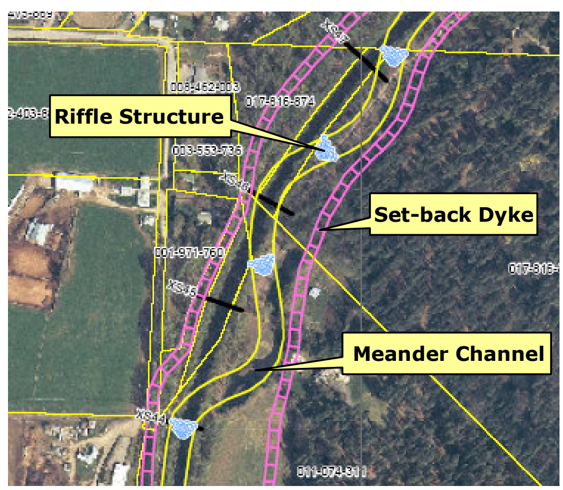
A Water Use Plan has been launched for Trout Creek, and OLAP has been successful in ensuring that the flow requirements of fish are adequately recognized in the water management plan. Similar planning processes are underway for Peachland and Trepanier creeks. Significant progress has been achieved on Trepanier Creek thanks to the cooperation of the Municipality of Peachland, some local water users, and Brenda Mines.

The highest priority for stream habitat restoration is Mission Creek. In the last three years, OLAP has developed an extensive watershed restoration plan for Mission Creek. This plan includes an ambitious set of strategies aimed at improving habitat for kokanee and rainbow trout.

The primary focus is on re-naturalizing the channel in areas where land can be secured and dykes set back from the channel. With a wider flood plain, the creek will develop many of the natural features that it had before it was channelized and dyked in the 1950s. A wider flood plain will also reduce the height of water during flooding, thus helping to protect the dykes.

OLAP and its partners are actively securing the property that will allow dykes to be set back and a meandering channel to be re-established. The Habitat Conservation Trust Fund (HCTF) purchased a key piece of stream-side land in 2004.

The Mission Creek restoration project is critical to the recovery of kokanee and rainbow trout stocks in Okanagan Lake since this stream has historically supported over 70% of the production of these species.



An aerial photograph of Mission Creek showing the location of some of the proposed restoration measures.
LGL Ltd.

A similar project is also underway on Penticton Creek. Local fish and game clubs will be restoring the channel over the next five years. Funding for this work comes from HCTF, City of Penticton, Penticton Lakeside Resort, and Ministry of Environment.

As a result of floods in Penticton in the 1940s, Penticton Creek was channelized and lined with concrete in its lower 800 metres. Over five years, the restoration work will slightly widen the channel where this option is available, remove the concrete liner, and re-naturalize the channel to include pools, riffles, and cover for fish.

Concrete channel of Penticton Creek.
Steve Matthews, Ministry of Environment

The restoration of Penticton Creek will also make an important contribution to long-term kokanee recovery. The stream has high potential to be more productive than it currently is. Local clubs are also strongly interested in doing restoration work on several other Okanagan Lake streams, including Trepanier Creek.

Since most land along the lower sections of Okanagan Lake streams is privately owned, fisheries biologists are enlisting the help of local stewardship groups to work with private owners to protect and restore valuable stream-side habitat. One measure of success in restoring stream habitat is the increased involvement of several stewardship groups. The work on Mill (Kelowna) Creek by the City of Kelowna is a case in point. Over a number of years, a total of about 1.5 km of this stream has been completely rehabilitated. The rehabilitation included stabilizing the stream bank, creating complex fish habitat, and re-introducing branches and other wood.

Another excellent example of community involvement has been the Mission Creek Greenway project. This is a partnership of Friends of Mission Creek, Ministry of Environment, City of Kelowna, Regional District of Central Okanagan, Westbank First Nation, and Central Okanagan Parks and Wildlife Trust. These stewardship groups have been very active in public education and protection of Mission Creek fish habitat, and they now use the restoration plan developed by OLAP as a guide.

Several other stream stewardship groups are actively involved in restoration planning and implementation on Okanagan Lake streams. In some cases, these groups are working with regulatory agencies as part of watershed planning and restoration roundtables. These stewardship groups include, but are not limited to:

Creek	Stewardship Group(s)
Bellevue	Kelowna & District Fish & Game Club
Equesis	Okanagan Nation Alliance
Kelowna	City of Kelowna
Naramata	Naramata Citizens' Association
Peachland & Powers	Peachland Sportsman's Association
Penticton	Penticton Flyfishers & Penticton Shooting Sports
Trepanier	Trepanier Creek Linear Park Society & Peachland Sportsman's Association
Trout	Trout Creek Watershed Roundtable

Shore Habitat

As development increased adjacent to Okanagan Lake's streams, flood control was the next measure imposed on these systems. A dam built in Penticton at the lake outlet regulates the level of water in Okanagan Lake. This can affect shore-spawning kokanee by exposing their eggs and alevins to air when the lake level is lowered too far between November and April.

Okanagan River dam at Penticton.
Ministry of Environment

OLAP biologists studied the shoreline where kokanee spawn and determined that kokanee lay their eggs in gravel at less than one-metre water depth. The kokanee begin shore spawning in mid-October. Based on this information, the biologists recommended drawing the water level down before the kokanee spawn and minimizing water level fluctuations during egg incubation. These recommendations mean that water levels should not drop until at least early February, when the eggs have hatched into alevins that are able to move in the gravel, and preferably not until April, when the kokanee emerge from the gravel.

The OLAP team had also reviewed past water level management of Okanagan Lake and historic flows into the lake. These reviews indicated that it would be possible to draw down the lake's water level before spawning (i.e., before October 15^{th}) without affecting other users. By working closely with water managers, a multi-agency working group successfully modified the lake drawdown pattern. Today, water managers draw down the lake in a way that minimizes the impact on shore-spawning kokanee.

Kokanee alevins.
Brian Jantz, Ministry of Environment

In addition to OLAP's efforts at habitat protection and restoration, there are other initiatives taking place in the Okanagan. For example, the Okanagan Nation Alliance, in partnership with Ministry of Environment and Fisheries and Oceans Canada, has begun a basin-wide program, called Okanagan Basin Fisheries Ecosystem Planning. This and various other initiatives are working toward the common goal of restoring aquatic habitats and ecosystems in the Okanagan.

Mysid Shrimp

Freshwater shrimp called mysids (*Mysis relicta*) were introduced into Okanagan Lake in 1966. They were intended to provide a good food source for rainbow trout and kokanee. Some individual kokanee appear to have benefited from these shrimp, but any such benefits have been outweighed by mysids competing with kokanee for food. Mysid competition has been found from research studies conducted throughout North America. In most lakes where mysids have been introduced, the kokanee population has declined. In Flathead Lake, Montana, the kokanee population has completely collapsed. OLAP biologists believe that the mysids in Okanagan Lake have also contributed to the kokanee decline.

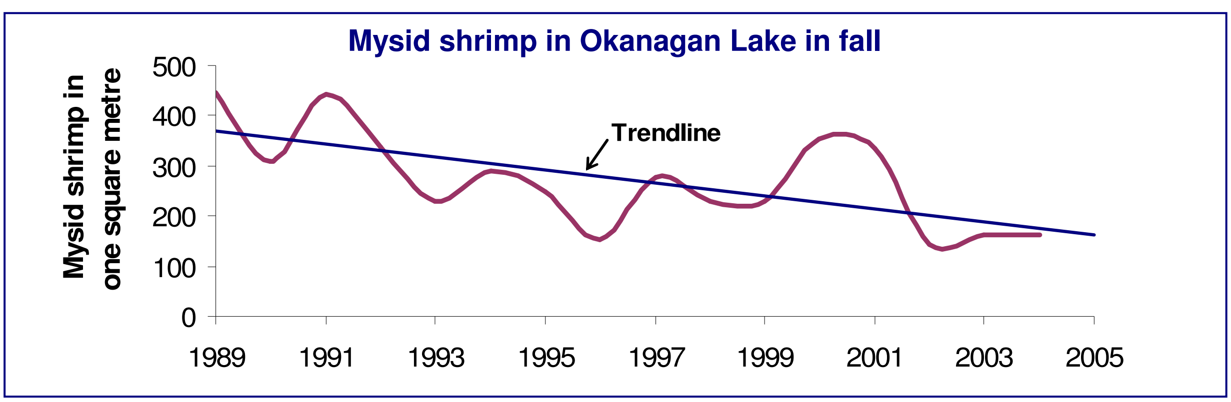
Mysid shrimp, about 1.5 cm long.
David Lasenby, University of Trent

To investigate this idea, biologists first had to learn more about mysids in Okanagan Lake. Mysids live near the bottom of the lake during the day, but they move upward after dark to surface waters to feed on zooplankton. Mostly, they feed on cladoceran zooplankton—the same ones that kokanee prefer. Mysids then migrate back to the lake bottom before dawn. This daily migration pattern means that mysids and kokanee occupy the same water layer for only a short time each day, so kokanee have little opportunity to eat mysids. In shallower lakes, like Skaha Lake, kokanee have more opportunities to eat mysids.

The average number of mysids in Okanagan Lake has declined since the late 1980s, but because the food habits of kokanee and mysids are so similar, OLAP wants to reduce the number of mysids in the lake so more food is available for kokanee.

For a time, biologists pursued the idea that an attractant could be used to concentrate and then capture mysids. This line of research proved not to be successful, however. In more recent years, OLAP has turned its attention to fishing for the shrimp. Fishing for mysids had never before been attempted on a commercial basis anywhere in the world.

In the late 1990s, OLAP experimented with different methods of fishing for mysids using a variety of commercial fishing gear. At the same time, a local resident was actively fishing for mysids and was successful at both harvesting and marketing the shrimp. A commercial fisherman from the Coast also became involved, and after months of experimentation, OLAP and the two fishing companies determined it was feasible to remove large numbers of shrimp



using trawl nets. There also seemed to be a growing market for shrimp—largely as aquarium fish food.

Mysid trawl boat towing nets.
Ministry of Environment

Before a commercial harvest could be developed, however, the fishing companies had two questions:

- Where are the mysids in Okanagan Lake?
- How many mysids are there?

Because the mysid population had been monitored for a number of years, OLAP had some answers. The data showed that the highest densities of mysids are found at the north end of the lake, near Cameron Point. Also, the mysids are at 100-120 metres water depth during the day and at less than 20 metres at night. Initially, biologists thought that about 1,000 tonnes of mysids were in the deep layers of the lake—more than enough to support a commercial fishery. By 2000, the two fishing companies applied for and received permits to fish for mysids.

While developing the mysid fishery, OLAP was acutely aware of the potential to capture juvenile kokanee. The amount of kokanee by-catch was therefore a major constraint imposed on the commercial mysid harvesters. The companies were very cooperative and ultimately designed techniques to minimize kokanee by-catch. Independent monitors confirmed that few kokanee were captured, and today their by-catch is not a major concern.

The efficiency of capturing mysids improved from 2000 to 2004, and harvest levels peaked at about 78 tonnes in 2001. They have since declined to about 33 tonnes. The main reason that harvest levels have not continued to climb is the market for mysids. At first, the aquarium and aquaculture industries were interested in mysids, but their demand is limited. Both mysid fishing companies can supply as many mysids as these markets require, but there has been only limited demand from other industries.

Emptying the mysid nets.
Ministry of Environment

A huge potential market exists with the pharmaceutical and nutriceutical industries since mysids have high levels of oils containing good fatty acids. These markets are actively being pursued. If a breakthrough occurs in either industry, all the mysids in Okanagan Lake would not be enough to supply the market. Because the potential for increased market demand appears high, government has assured the companies that they will have access to other lakes with mysids if the need arises. Kootenay Lake and Arrow Lakes Reservoir also have high densities of mysids, as does Kalamalka Lake. The OLAP team anxiously awaits further developments in the market.

How many mysids have been fished from Okanagan Lake? The monitoring data obtained from zooplankton sampling was used to crudely estimate total tonnage of mysids in the lake. Each year, the amount of mysids varies, but on average, there are an estimated 3,700 tonnes. About 25% of all mysids are found near Cameron Point where all the fishing occurs. The average annual harvest from 1999 to 2005 has been just under 39 tonnes, as shown in the table below. This is about 1% of the total in the lake or about 4% of the total estimated near Cameron Point. Clearly, many more mysids could be harvested if new markets become available.

Year	Total Mysid Catch (metric tonnes of wet weight)
1999	12.5
2000	15.1
2001	77.9
2002	49.8
2003	45.7
2004	37.3
2005	31.8
Average	**38.6**

Ultimately, increasing the number of kokanee in Okanagan Lake will most likely depend on the success of the shrimp fishery. How many mysids need to be fished from Okanagan Lake to start reducing the mysid population? A graduate student at the University of BC ran computer simulations with the mysid data to predict the necessary level of harvest to lower the mysid population. The computer model showed that the shrimp population would begin to decline at a harvest rate of 30% of total tonnage. With the current harvest at about 1%, OLAP realizes that a far higher harvest is required before any benefits can be expected for kokanee. However, considering the potential demand in new markets, there is optimism that the 30% removal target could be achieved over the next few years.

Nutrient Balance

Kokanee fry rely on obtaining and storing fats from the food they eat to survive their first winter. They prefer to eat cladoceran zooplankton. The nutritional value of cladocerans may depend on what types of algae they eat. The species of algae growing in Okanagan Lake depend on many factors, of which one is nutrient availability. In fact, all organisms grow only as well as the amount and quality of available nutrients, particularly nitrogen and phosphorus, so the status of these nutrients is of primary importance.

Sometimes, the ratio of nitrogen to phosphorus favours certain algae groups. Biologists noticed that the summertime ratio of available nitrogen (nitrate) to available phosphorus (dissolved phosphorus) is less than 3:1.

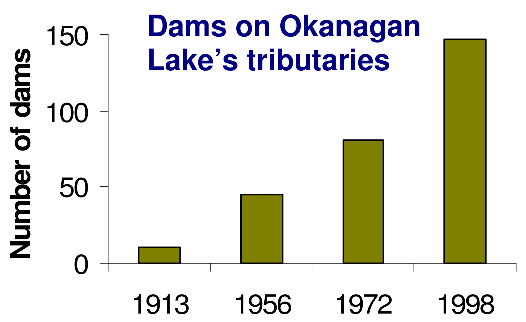
OLAP is testing the theory that nitrate and dissolved phosphorus are unbalanced in Okanagan Lake (ratio <15:1) and that this has promoted the growth of blue-green algae. Blue-greens are often too large or too difficult to eat and are of low nutritional value. Thus, blue-greens are a poor food source for zooplankton.

To gather more information about the possible nutrient imbalance, OLAP recently asked four questions. The projects done to find answers are described briefly after each question.

1. Are dams on inflowing streams preventing nitrate from reaching the lake?

Large dams can trap nutrients—algae grow in the reservoir created by a dam and use up the nutrients that would otherwise go downstream. This phenomenon has been observed on Arrow Lakes Reservoir and

Kootenay Lake. Small dams, such as those on Okanagan Lake's tributaries, might also trap nutrients.



Data from Hall and co-authors, 2001, Nutrient sources & ecological impacts on Okanagan Lake, Institute for Resources & the Environment, UBC.

Biologists sampled five streams: Whiteman, Trepanier, Lambly, Penticton, and Ellis creeks. The first two do not have dams on them; the last three do. Biologists measured nitrate and water flow at four sites along each stream. For those with dams, one site was above the dam and one immediately below it. The next site was at a mid-way point and the last where the stream flows into the lake. The biologists chose equivalent sites on the un-dammed streams.

The results varied. In some months, there was less nitrate below a dam than above, suggesting that the dam was trapping nutrients above it. In other months, the reverse was true. On the two un-dammed streams, the biologists expected nitrate to increase steadily down the length of each stream. For one, it did, and for the other, it didn't. Biologists can't say with certainty that dams and small reservoirs do or don't affect the amount of nitrate that reaches Okanagan Lake.

Interestingly, during the high waterflow period in May, both un-dammed streams delivered much more nitrate to the lake than the dammed streams. Taking into account the different volumes of water in each stream, Trepanier Creek contributed 3,000 grams of nitrate in one day, Whiteman 1,600, Lambly 260, Penticton 215, and Ellis 185. (Ellis Creek flows into Okanagan River downstream of Okanagan Lake.)

The results of the stream studies are inconclusive and simply underline that not all theories turn out to be correct.

Big Horn Reservoir on Terrace Creek.
Rowena Rae

2. How do Okanagan Lake's nutrient ratios, algae species, and algae nutritional value compare with other lakes?

OLAP took monthly samples (July-October) from lakes in the Okanagan Valley: Wood, Kalamalka, Skaha, and Osoyoos lakes and from lakes in southeastern BC: Kootenay Lake (north and south arms) and upper and lower Arrow Lakes Reservoir.

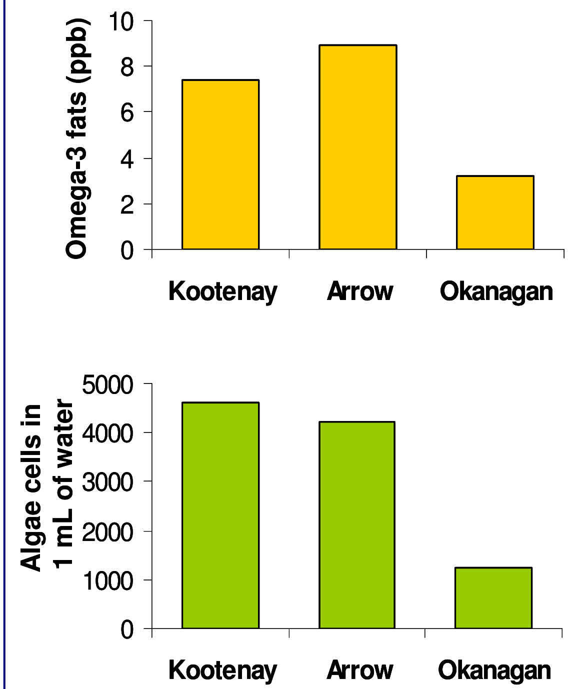
When the data from all these lakes were put together, the range of nutrient ratios (available N to available P) was large. In some lakes, the ratio was as low as 0.6:1 and in others, as high as 29:1.

Lakes with a ratio higher than 10:1 never had more than 20% blue-greens in their algae population. Lakes with a ratio lower than 10:1 generally had 30-60% blue-greens.

The nutritional value of algae hinges on the type of fats that they manufacture. The "good" fats—omega-3 fats—have the highest nutritional value for zooplankton and kokanee (and all other animals, including humans). Of all algae groups, the golden-browns manufacture a particularly large amount of omega-3 fats.

In OLAP's data, algae populations with a higher percentage of golden-browns also had a higher percentage of omega-3 fats. Okanagan Lake's algae population had about the same percentage of omega-3 fats (14-23%) as algae in the other Okanagan Valley lakes, including Wood, Skaha, and Osoyoos lakes. But, Okanagan Lake tended to have a smaller algae population compared with these other lakes.

Compared with Kootenay Lake and Arrow Lakes Reservoir, both of which receive scheduled nutrient additions, Okanagan Lake's algae differed in two ways. They had fewer omega-3 fats (14-23%) than the algae in Kootenay and Arrow, where there were 27-32% omega-3 fats. Okanagan Lake also had fewer algae compared with Kootenay and Arrow. On average, in 2004, both Kootenay and Arrow had four times more algae than Okanagan Lake. These results are shown in the diagrams to the right.



Average summer algae and omega-3 fats in three BC lakes

For Kootenay Lake and Arrow Lakes Reservoir, this translates into more growth, more productivity, and more food available for zooplankton. The higher nutritional value of algae in these two lakes adds to the health of their food webs.

3. Can the species of algae be changed by adding nitrogen to the water?

If too little available nitrogen is causing the abundance of blue-greens, then it should be possible to change the dominant algae group by adding nitrogen. OLAP tried this on a small scale by incubating lake water in clear 20-litre plastic containers. Different amounts of nitrate were added to the containers to see if, during one week, the algae would change to more nutritious species.

The experiments didn't show a strong response. At the end of one week, there were more algae in the containers with nitrogen added than in those without nitrogen added. The percentage of different algae groups didn't change, however.

Biologists did the experiments in late summer and fall 2003, and they think that this drought year affected the response. Less meltwater than usual entered Okanagan Lake in spring 2003. The summer was then extremely dry with no rain for many weeks. These two factors mean that the lake received very little phosphorus during the growing season. The algae were likely already limited by phosphorus, so the extra nitrogen provided little benefit.

4. Does nitrogen limit the growth of algae in summer?

After the weak response to nitrogen additions, OLAP decided to test phosphorus as well as nitrogen to find out if both were indeed limiting the algae. This time, biologists examined how algae productivity reacted to additions of phosphorus alone, nitrogen alone, and phosphorus and nitrogen together.

Phosphorus-only additions showed no increase in algae productivity, nitrogen-only additions showed some increase (27%), and nitrogen plus phosphorus additions resulted in a greater increase (54%). This information suggests that algae productivity is limited by nitrogen, but in particular, algae productivity is limited by the combination of phosphorus and nitrogen in Okanagan Lake. In other words, the algae need *both* nutrients at the same time to increase their productivity.

For the nutrient experiments, containers were filled with lake water and suspended in the lake.
Rowena Rae

There is sufficient evidence of nutrient imbalance, low nutrient status, and poor food quality in Okanagan Lake to continue the nutrient investigations. OLAP intends to conduct another summer of experiments to evaluate the degree of nitrogen limitation. After this, the next step may be to add small amounts of nitrogen to the lake itself in wet years, when N:P conditions indicate nitrogen limitation. This would be on an experimental basis and could be stopped if monitoring results are negative. Experimental nutrient additions are not planned for 2006.

Many people are concerned about water quality in Okanagan Lake. Adding nitrogen is perceived by some as “polluting” the lake. If nutrient additions are warranted in future years, OLAP will propose to add 0.04 parts per million (ppm) to a small area of the lake. The Canadian Drinking Water Guidelines published by Health Canada state that the maximum acceptable concentration of nitrate in drinking water is 45 ppm (more than 1,000 times higher than the levels OLAP would propose to add).

To help OLAP evaluate the benefits and risks of adding nitrogen, three well-known scientists, who have no links to the OLAP program, reviewed the data and the proposed lake experiment. All three scientists agreed that nitrogen additions would be the only practical solution to address the low nitrogen status in summer. They also agreed that there are no unacceptable risks. Their reviews and recommendations are described further on page 30.

OLAP evolved from a public workshop held in March 1995. The workshop was attended by members of the public and scientists who had expressed concern over the dramatic decline in Okanagan Lake kokanee. At that time, workshop participants recognized that kokanee recovery work for Okanagan Lake would happen over the long term since no "quick fix" solutions were obvious.

Scientific & Stakeholder Input

At the completion of its fifth year, OLAP held a conference in Kelowna (March 2001) to outline the results of the first five years of work. In general, conference participants, who included scientists, government representatives, and stewardship groups, strongly supported the work OLAP had undertaken. Some expressed concern about possible nutrient additions to the lake, and they emphasized the need for greater communication with the public if nutrients were to be added. Good input from the conference participants led to development of a blue print for OLAP's next five years (Phase 2).

The second phase of OLAP (2001-2005) became far more focused on stream restoration, mysid harvest, and the question of nutrient imbalance. Within the scientific community, there were varying opinions on the nutrient imbalance issue and the possibility of adding nutrients to Okanagan Lake. This led OLAP to organize a workshop in 2003 with leading scientists and fisheries biologists.

The workshop was held at UBC and provided an opportunity for participants to review all the data and debate the question of whether nitrogen and phosphorus were partly responsible for poor in-lake survival of kokanee. There was general agreement that surface layers of the lake are depleted of nitrogen in summer and that this can cause extensive blue-green algae blooms. These algae are known to be poor-quality food items for the zooplankton that kokanee prefer to eat.

The participants also agreed that nitrogen could be extracted from the existing sewage treatment plants in a cost-effective manner. However, they cautioned that adding nutrients to the lake would likely create the perception that OLAP was "polluting" the lake. Therefore, they recommended a precautionary approach and more communication with the public.

An OLAP workshop in Kelowna.
Rowena Rae

The scientists at the 2003 workshop generally agreed that nutrient additions should be pursued on a strictly experimental basis. Nevertheless, they expressed enough concern about this concept that OLAP decided to be cautious and undergo an outside review of its work. The review would be not only about nutrient addition but also about the general direction of OLAP.

Dr. David Bennett, Professor Emeritus at the University of Idaho, Moscow, was asked to provide a complete review and critique of OLAP's activities through 2004. His review was to include study design, sampling, analysis, and interpretation. (Bennett's review was published in the 2005 OLAP report, which is listed on page 36).

His summary findings were as follows:

1. An impressive team of researchers and managers are addressing kokanee recovery in Okanagan Lake alongside the competing *Mysis relicta*. Other than in Kootenay Lake and Arrow Lakes Reservoir, no other known kokanee population has been recovered when coexisting with *Mysis*.

2. Studies on Okanagan Lake were initially broad and, with the advent of more information, have become more focused towards identifying the limiting factors for kokanee.

3. Results to date are impressive relative to funding level. Additional monitoring and studies in certain areas and in other systems are recommended.

4. Although findings strongly implicate the imbalance of nutrients in structuring the algae community to those of lesser food quality for cladoceran zooplankton, further studies are recommended to identify contradicting results from other nearby systems.

5. Habitat restoration efforts must be expanded both in tributaries and lake levels to achieve the level of recruitment needed for recovery.

6. Funding at a commensurate or higher level is strongly recommended.

A poster display about OLAP for BC Rivers Day in September 2005.
Alex Bursac, City of Kelowna

In April 2004, another planning meeting was held in Kelowna with invited stakeholders and government representatives. OLAP biologists gave updates on results from 2001 to 2004 as well as an indication of OLAP's direction for 2004 and 2005.

Participants continued to express support for OLAP's direction with monitoring, mysid harvest, and habitat restoration, but they reiterated their caution about possible nutrient additions. They emphasized the controversial nature of this proposal and suggested that scientists outside OLAP should assess the risks of such an experiment (i.e., adding nitrogen to the lake).

Taking direction from the Kelowna planning session, OLAP asked three world-renowned scientists to conduct a peer review of the proposal to add nitrogen to the lake. The three scientists, independent of OLAP (and of each other), responded to a series of questions related to nitrogen addition. They critiqued the science and evaluated the risks posed by this proposal. All three scientists considered the risk level to be low. (Their responses are summarized in the Year 9 OLAP report, listed on page 36).

The peer review of the proposed Okanagan Lake nitrogen addition experiment provided valuable feedback to OLAP on both experimental design and associated risks to water quality and other values. All three peer reviewers stated that nitrate is absent from the surface waters of Okanagan Lake in the summer and early fall and that this probably plays a role in blue-greens being abundant in the algae population. Furthermore, the reviewers identified a nitrogen addition experiment as the only practical management alternative to try addressing the issue of high blue-green abundance.

The peer reviewers' unanimous agreement that there are no unacceptable risks and their general support for the concept have been forwarded to the BC government. The Ministry of Environment will ultimately make the decision about whether the proposed nutrient addition experiment should proceed. If the Ministry gives its approval and continuing studies indicate that a nutrient addition experiment would be valuable, OLAP will conduct an extensive consultation process to ensure people are fully informed and have an opportunity for input.

Future fish advocates at work on BC Rivers Day in Kelowna, September 2005.
Eve Wegscheidler, Regional District of Central Okanagan

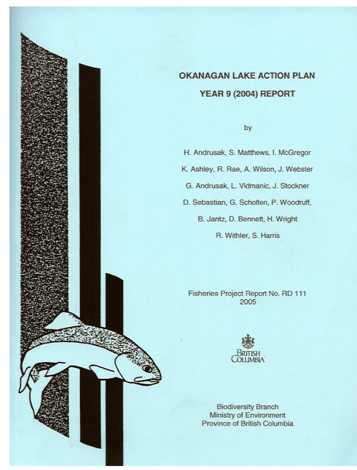
Annual Reporting & Communications

OLAP produces annual reports that detail all monitoring and recovery work undertaken. All OLAP reports are public documents and are available at Ministry of Environment in Penticton. A website is currently under construction and will house downloadable files for whole reports and individual chapters.

The OLAP team has made a concerted effort to keep the public informed of on-going activities and progress. In spring 2004, public information meetings were held in Penticton, Kelowna, and Vernon. At these meetings, OLAP team members summarized work to date and future directions, and they answered questions from the audience. They also sought opinions on OLAP's recovery initiatives from those in attendance through a questionnaire.

Throughout the year, Penticton-based OLAP team members give presentations to regional districts, municipalities, fish and game clubs, and environmental groups. They also set up display booths and answer questions at events such as BC Rivers Day in late September.

They give frequent media interviews with newspapers and radio and television stations. Interviews cover a range of topics, including low stream flows, kokanee spawner numbers and lake population estimates, the mysid test fishery, nutrient balance investigations, and habitat issues.



SUMMARY OF WORK IN OLAP'S FIRST TEN YEARS

OLAP has achieved a remarkable amount in its first ten years of kokanee recovery on Okanagan Lake. OLAP biologists now have a much better understanding of the factors involved in the kokanee decline, and they have made progress in many key areas. The following points summarize OLAP's findings and achievements.

LIMNOLOGY monitoring shows that:

- Okanagan Lake forms stable temperature layers in summer and mixes during winter.
- Armstrong Arm differs from the main lake in nutrient status, productivity, and oxygen levels.
- There is ample oxygen for aquatic life in the main part of the lake, but low oxygen occurs in the fall in Armstrong Arm.
- The lake tends to have a south to north increase in phosphorus and chlorophyll *a*.
- There is very little nitrogen available to algae during the growing season (unbalanced available nitrogen to phosphorus, or N:P, ratio).
- Okanagan Lake fits into the low productivity category for lakes, based on total phosphorus and total nitrogen levels in spring and on average chlorophyll *a* during the growing season.

Okanagan Lake kokanee, about 25 cm long.
Ministry of Environment

Several factors suggest that the ALGAE are unable to support the zooplankton and fish that depend on them. These factors are:

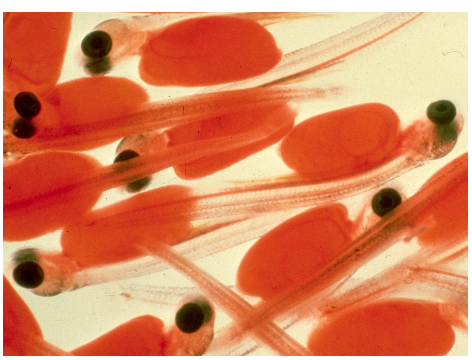
- Blue-greens are frequently abundant in the algae population, especially in summer and fall when zooplankton feed and grow.
- Many blue-greens grow in colonies or in chains that are difficult for zooplankton to eat. Blue-greens also have the lowest nutritional value of all algae.
- The algae population has decreased in size (both number of cells and amount of cells) between 1999 and 2004.
- The algae population has low levels of productivity, especially compared with other large lakes in southern BC.

The ZOOPLANKTON information suggests that:

- The desirable cladoceran zooplankton make up only a small portion—less than 9%—of the total zooplankton population.
- There may not be enough cladoceran zooplankton available for young-of-the-year kokanee to eat.
- The cladocerans that kokanee do eat may not have high enough nutritional value.
- Introduced mysid shrimp are large zooplankton that eat other zooplankton, especially cladocerans. Mysids compete with kokanee for cladocerans and are believed to be partly responsible for the decline in kokanee numbers.

Monitoring of KOKANEE spawners and of the total population shows that:

- The total number of spawning kokanee declined from over 800,000 in 1971 to fewer than 10,000 in 1998. Over the past seven years, the number of spawners has increased to about 220,000 in 2005.
- Both stream- and shore-spawning kokanee (which are genetically distinct) have undergone similar declines and subsequent increases.
- Loss of and damage to spawning habitat is not the only reason for the kokanee decline; conditions in the lake also contribute.
- Juvenile fish have particularly low survival and may be limited by food supply.
- The total kokanee population in the lake was 12-14 million fish in the late 1980s and dropped to its lowest at 3 million fish in 2000. Since 2000, the total population has increased, and in 2005, there were 9.7 million kokanee.
- At current levels, it may be possible to re-open a small kokanee fishery in 2006.



Kokanee alevins, about 2.5 cm long.
Ministry of Environment

Mission Creek spawning channel.
Rowena Rae

OLAP has made good progress on HABITAT PROTECTION AND RESTORATION work:

- OLAP is involved in water use planning on many streams to ensure that adequate water flow is available for fish.
- Some streams with heavy water use now have more water flow available for fish.
- Mission Creek is the highest priority for restoration and now has a restoration plan in place.
- With encouragement and help from OLAP, many stewardship groups have become involved in stream restoration and public education.
- Working with other agencies, OLAP has helped to establish a lake level drawdown pattern that benefits kokanee shore spawners.

The MYSID SHRIMP monitoring and experimental fishery show that:

- Kokanee have few opportunities to eat the mysid shrimp, because the shrimp spend the daytime deep in the lake, and when they swim to shallower water at night, the kokanee can't see the shrimp.
- Okanagan Lake has about 3,700 tonnes of mysids, a quarter of which are at the north end of the lake. This compares with about 200 tonnes of kokanee in the lake.
- It is possible to fish mysids from the lake with minimal kokanee by-catch.
- Current mysid markets are saturated, but huge potential markets exist.
- The two companies with mysid fishing permits catch about 1% of the total mysid tonnage each year.
- About 30% of the mysid tonnage must be removed to bring benefits to kokanee.
- There is potential to achieve the 30% removal target based on recent progress in developing new markets and the demonstrated ability to harvest shrimp.

Anglers have caught large kokanee in Okanagan Lake in the past.
Ministry of Environment

Shore-spawning kokanee.
Ministry of Environment

The information collected to date about NUTRIENT BALANCE suggests that:

- Dams on inflowing streams trap nitrate at times, but not always.
- During spring melt, dammed streams deliver less nitrate in their outflow than un-dammed streams.
- Compared with other Okanagan Valley lakes, Okanagan Lake has similar nutrient ratios, algae communities, and nutritional value of algae.
- Compared with Kootenay Lake and Arrow Lakes Reservoir, Okanagan Lake has fewer algae, and these algae appear to have lower nutritional value.
- In small-scale nutrient experiments, the type of algae did not change as expected during a drought year, when phosphorus and nitrogen may both have limited the algae population.
- In a second set of small-scale nutrient experiments, algae productivity was limited by *both* phosphorus and nitrogen in Okanagan Lake. The algae needed both nutrients at the same time to increase their productivity.

OLAP has engaged in CONSULTATION AND COMMUNICATION:

- OLAP began after a public workshop was held in March 1995.
- After its fifth year, OLAP held a conference to discuss progress and get input for its next five years.
- OLAP convened scientists and fisheries biologists in 2003 to discuss the possible nutrient imbalance in Okanagan Lake.
- An independent scientist, Dr. David Bennett, reviewed the entire OLAP program in 2004 and made favourable comments about progress, but he emphasized that more work is required.
- OLAP held another planning meeting in spring 2004 to get further input from local governments and stakeholders.
- Three independent scientists reviewed OLAP's proposal to add nutrients to the lake experimentally, and all three stated that there are no unacceptable risks.
- The OLAP team has held several public information meetings, has spoken at local club meetings, and has given numerous newspaper, radio, and TV interviews.

Looking at a kokanee spawner from Peachland Creek.
Ministry of Environment

THE FUTURE OF OLAP

OLAP has provided science-based evidence that nutrients and mysid shrimp are problematic for the kokanee in Okanagan Lake. Other scientists who are outside OLAP agree with these findings.

OLAP's work should continue with the following activities:

- Monitor water chemistry, mysids, and kokanee
- Re-open the recreational kokanee fishery under carefully monitored conditions
- Continue the commercial mysid fishery
- Assess rainbow trout growth and numbers
- Proceed with nutrient additions in years when nitrogen is limiting (wet years)

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