OKANAGAN LAKE ACTION PLAN

YEAR 4 (1999) REPORT

by

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RESULTS OF IMPLEMENTATION OF THE OKANAGAN LAKE OLAP

by

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ABSTRACT

This report is the third in a series of the activities undertaken by participants involved in the Okanagan Lake Action Plan (OLAP). Results from 1999 fieldwork are reported and discussion is provided on future direction(s). The OLAP is attempting to gain a much better understanding of whole lake biological relationships as well as defining limiting factors and remedial measures that will result in recovery of the lakes' kokanee populations. Decline of lake productivity, mysid competition with kokanee for macrozooplankters and loss of kokanee spawning habitat have all been implicated in the dramatic decline in kokanee over the last three decades.

In 1999, much of the study focus was aimed at habitat protection and restoration, estimates of primary and secondary production and feasibility of mysid harvest. Baseline limnological sampling and monitoring of kokanee spawner numbers continued while less emphasis was placed on large scale experiments and functional studies. Monitoring of stream flows has become a priority activity and several key spawning streams were selected for long-term flow measurements. A new technique has been developed to assist in predicting watershed snowpack that in turn may allow for setting of lake levels more conducive to shore spawning kokanee. Experimental harvesting of mysids was reasonably successful in 1999, and plans are discussed for expansion of this activity in 2000. Progress continues to be made toward a commercial fishery for mysids.

An updated summary was completed of key characteristics of Okanagan Lake kokanee. A technique has been developed using genetic markers to determine the relative contribution of the two kokanee stocks found in the lake. Hydroacoustics and kokanee trawl work was repeated in 1999, and this information continues to provide a good "picture" of kokanee population status in Okanagan Lake.

Stream spawning kokanee declined in 1999 to the lowest level recorded in the last three decades. On the other-hand, shore spawning numbers were the highest recorded in the last ten years thus giving some reason for cautious optimism.

Commencing in 2000, there will be more emphasis on comparative analysis of study results from Okanagan Lake with those from nearby Arrow Reservoir and Kootenay Lake. These latter systems are currently the subject of experimental fertilization (N and P) and a great deal of data is available that could provide better understanding of limitations to kokanee production in Okanagan Lake.

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1999

INTRODUCTION

This report reviews results of the fourth year (1999) of the twenty year plan directed at priority limnological and fisheries work on Okanagan Lake. It is the third report in a series of annual technical documents intended to summarize key findings of all research workers and the public who are committed to long-term improvement of Okanagan Lake and its fish fauna with particular emphasis on kokanee. This project is probably the largest undertaking in the province's history of freshwater fisheries management.

Concern for the future of Okanagan Lake kokanee heightened during the early 1990s and led to formation of a proactive plan in 1996 called the Okanagan Lake Action Plan (OLAP). This forward looking plan with a twenty-year time horizon attempts to address all of the physical and biological factors that influence Okanagan Lake and the kokanee populations that inhabit it. Results of on-going activities and studies under the OLAP are reported in an annual publication entitled: "Okanagan Lake Action Plan" (see Ashley et al. 1998; 1999). Most of the activities within the OLAP are directed at identifying fish habitat constraints, zooplankton and fish population characteristics and improving the limnological database of Okanagan Lake. There is an emphasis on understanding whole lake relationships with the intention of identifying limiting factors for fish production so that remedial measures can be implemented. In the short period of time since inception of the OLAP there has been some innovative work done in the field and laboratory. Progress has been made on problem identification and some potential solutions have been proposed.

The ecological relationships that govern Okanagan Lake are complex and not well understood. It is clear that key spawning and rearing habitat have been adversely impacted by human activities. Most of the day-to-day routine management is directed towards habitat protection and remedial activities. Since many species of fish in Okanagan Lake depend upon kokanee and because kokanee are at historic low levels there is considerable emphasis on them in the Action Plan. It has been known since the beginning of the OLAP that kokanee recovery is key to improvement to most of the fish assemblage in Okanagan Lake. It is also quite apparent that kokanee recovery is a long-term issue and not something that can be easily rectified. Results from activities in 1999 build upon the earlier work and provide some reasons for optimism in the long-term.

BACKGROUND

For at least the last fifty years there have been a number of problems associated with Okanagan Lake and its fish populations. In an area that has a very dry climate 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 have constantly been threatened. Anglers and fisheries biologists have observed a gradual decline of Okanagan Lake fish since the 1960s. Most of the observations have been made on kokanee since this species is not only an important sport fish but also a key food source for several other fish species.

As reported in Ashley et al. (1999) the impetus for development of the OLAP arose from a series of public meetings in 1995 that were held to identify what the problems were related to Okanagan Lake kokanee and what could be done to resolve them. Key issues identified included habitat deterioration, lake nutrient reduction and competition between kokanee and *mysis relicta* for food. Details of the work leading up to these conclusions can be found in Ashley et al. (1999) while the results of the 1995 meetings were used to develop the OLAP and were originally reported by Ashley and Shepherd (1996).

The scientific basis and direction of the OLAP was formulated by use of a simulation model under the direction of Walters (1995). The focus of the modeling work was to test the carrying capacity hypothesis, i.e., the lake had undergone a reduction in nutrients and or competition between mysis relicta and kokanee for food had led to a decrease in food for kokanee. The modeling work concluded that competition for food was the most likely reason for the decline in the kokanee population because nutrient loading had not declined below historic levels. A more detailed explanation of the modeling work and the assumptions used can be found in Walters (1995) and Ashley et al. (1999).

An important feature of the OLAP is adoption and use of the adaptive management philosophy since there is always an element of risk or failure in such a large undertaking. The adaptive management environmental assessment process was used in the 1995 meetings to develop management options, some of which are quite experimental (Ashley et al. 1999). Adaptive management recognizes that risk of failure is quite possible and that the management team must accept this as part of “doing business”. Flexibility in plan design and project experimentation is essential in order to achieve the overall objectives of the OLAP. Even within the short period of four years there already have been shifts in study emphasis because some studies have proven not to be leading to long-term solutions.

As previously mentioned a long-term approach to resolving Okanagan Lake kokanee problems is necessary, hence the proposed OLAP encompasses a twenty-year period in four blocks of five years duration. Under this scenario, the OLAP will initially be weighted in Phase 1 (1996 to 2001) towards conservation of native stocks and habitat protection (e.g., priority remedial measures and monitoring) and collection of priority information (e.g., comparative analysis studies, functional studies, applied research and large scale experiments).

In Phases 2 and 3 (2001 to 2006 and 2006 to 2011), the emphasis in the OLAP will shift towards collection of priority data, initial implementation of habitat restoration projects and development of innovative resource management techniques. Phase 4 (2011 to 2016) will involve long-term monitoring and the application of new information and techniques obtained from the comparative analysis studies, functional studies, applied research and large scale experiments. Tables in Appendix I outline each of the four phases of the OLAP, which has been reviewed and approved by the members of the Okanagan Lake Scientific Advisory Panel (see details *in:* Ashley and Shepherd 1996).

Results of the initial four years work on Okanagan Lake may allow for acceleration of certain components of the plan. As kokanee continue to dwindle in numbers there is growing pressure to implement potentially feasible solutions. The development of experimental techniques for harvesting mysids is a good example. *Mysis* harvest to reduce food competition with kokanee is now considered a possibility albeit still very experimental. Consequently, in 1999 a significant amount of effort and money was directed towards this novel concept. This in turn means that if mysid harvest is to become a reality then better baseline data of mysid distribution and densities is required. This is a good example of adaptive management (i.e., change in emphasis). It has to be kept in mind however, that commitment to the long-term vision of the OLAP must be adhered to due to possible risk of failure of any one experiment.

OBJECTIVE OF OLAP

Since the inception of the OLAP there has been a clear understanding of the long-term objective which 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.

Phase 1 (1996-2001) rationale: Conservation of native stocks and habitat protection to preserve remaining stocks and collection of priority information to improve present management and develop innovative future resource management techniques.

As Phase 1 draws to an end the considerable amount of information that has been generated requires an overview analysis and public discussion in preparation for Phase 2. Results of the 1999 fieldwork are presented in this report under the following chapter headings reflecting four of the six components of the OLAP. These are:

1) Priority Remedial Measures;
2) Monitoring Program;
3) Long-term Applied Research; and
4) Communications.

An impressive number of scientists, fisheries biologists and technicians as well as the interested public participated in the OLAP activities during 1999. A list of the participants and their primary focus is shown in Table 1.

Table 1. Okanagan Lake Action Plan Participants, activities and affiliation for Year 4.

PROJECT FOCUS	PERSONNEL	DESCRIPTION	AFFILIATION
Project coordination and scientific liaison	Ken Ashley		Fisheries Management Branch, BC Fisheries, UBC
	Ian McGregor		Regional Fisheries, MELP Kamloops
	Steve Matthews		Regional Fisheries , Penticton, MELP
	Dale Sebastian		Fisheries Management Br, BC Fisheries, Victoria
	Ted Down		Fisheries Management Br, BC Fisheries, Victoria
Regional support and logistics	Ian McGregor	Program direction	Regional Fisheries Kamloops, MELP
	Steve Matthews	Field coordination	Regional Fisheries Penticton, MELP
	Bruce Shepherd		Regional Fisheries Penticton, MELP
	Dave Smith		Regional Fisheries Penticton, MELP
	Brian Jantz		Regional Fisheries Penticton
	Graham Young		Penticton contractor- boat operator
	Nick Ipatowich		Penticton contractor- boat operator
Stream flow studies	Dr. Peter Ward	Hydrology- P.eng.	Engineering Consultant, Vancouver
	Dr. Hansen A. Yassien	Analysis – reporting	Engineering Consultant, Vancouver
	Ron Ptolemy	Field staff training	Fisheries Management Br, BC Fisheries, Victoria
	Robert Kirk	Field leader, reporting	Biological contractor, Penticton
	David Cassidy	Flow monitoring	Biological contractor, Penticton
	Melanie Betsill	Flow monitoring	OUC Deep River Science Academy, Penticton
Habitat restoration	Mike Zimmerman	Trout Cr. Screening	Watershed Restoration Program Contractor, Nelson
	Rhael Finnegan	Trout Cr. Screening	Watershed Restoration Prog Contractor, Coquitlam
	Reg. Dist. Centr Okanagan	O&M	Kelowna, BC
Mission Cr. spawning channel	Dr. Peter Ward	Analysis – reporting	Engineering Consultant, Vancouver
Okanagan Lake rule curve	Dr. Hansen A. Yassien	Analysis – reporting	Engineering Consultant, Vancouver
Limnology	Rob Kirk	Field	Biological contractor, Penticton
	Dr. Lidija Vidmanic	Lab analysis	Contract Scientist – UBC
	Greg Wilson	Reporting	Biological contractor – UBC
Water quality	Robert Kirk	Field	Biological contractor, Penticton
	Fraser Environment Lab	Lab analysis	North Vancouver
Phytoplankton	Dr. John Stockner	Anal.ysis, reporting	Eco-Logic Ltd.
Zooplankton analysis	Dr. Lidija Vidmanic	Lab analysis	Biological contractor – UBC
	Greg Wilson	Reporting	Biological contractor – UBC
	Taya Berkout	Data analysis	Biological contractor – UBC
Mysid biology	Dr. Dave Lasenby	Advisor	Biology Department, Trent University, Ontario
	J.D. Whall	Masters thesis	Grad Student, Trent University
	Steve Matthews	Coordinator	MELP, Penticton
Mysid harvest techniques	Dale Sebastian	Contract Management	Fisheries Management Br, BC Fisheries, Victoria
	Ken Ashley	Advisor	Fisheries Management Branch, BC Fisheries, UBC
	Bruce Shepherd	Field monitor	MELP, Penticton
	Dave Smith	Field monitor	MELP, Penticton
	Brian Jantz	Field monitor	MELP, Penticton
	Bob McIlwaine	Net design	Cantrawl, Richmond BC
	Bob Bowker	Commercial fisher	The Mystic Fishing Co. Ltd., Tofino
	Vince McGee	Commercial fisher	M&M Trading Ltd., Vancouver
	Lee Granberg	Commercial fisher	Piscine Energetics, Enderby
	Ron DaSilva	Video evaluation	Pacific Fisheries R&D. Ltd., Richmond
	Rob Kirk	Field monitor, recorder	Biological contractor, Penticton
	Brian Jantz	Field monitor	Biological contractor, Penticton
	Michelle Boshard	Data recorder	Biological contractor, Penticton
	Kevin Morris	Processing, recorder	Biological contractor, Penticton
	Graham Young	Deckhand	Contract boat operator, Penticton
	Nick Ipatowicz	Deckhand	Contract boat operator, Penticton
	Dave Smith	Market analysis	Commercial Fisheries Section, BC Fisheries
Fishery Development	Don Sollows	Market analysis	Albion Fisheries Ltd., Kelowna
	Harvey Andrusak	Anal.ysis, reporting	Redfish Consulting Ltd., Victoria
Kokanee enumerations	Steve Matthews	Coordinator	Regional Fisheries, Penticton
	Dave Smith	Contract monitor	Regional Fisheries, Penticton
	Jason Webster	Stream counts	Chara Consulting Ltd., Penticton
	Kevin Morris	Field	
	Kevin Ade	Field	

PROJECT FOCUS	PERSONNEL	DESCRIPTION	AFFILIATION
Kokanee biology	Harvey Andrusak Dale Sebastian Joel Sawada	Analysis, reporting Analysis, reporting Report editing	Redfish Consulting Ltd., Victoria BC Fisheries Management Br, BC Fisheries, Victoria BCCF sub-contractor
Kokanee life-history	Gary Carder Melinda Hirst Bob Land Dale Sebastian	Otolith analysis Scale analysis Otolith and scale anal. Coordination	Contractor, Salmon Arm, BC AMC Technical, Nanaimo, BC Fraser Valley Trout Hatchery, Abbotsford Fisheries Management Br, BC Fisheries, Victoria
Kokanee genetics Kokanee stock identification	Susan Pollard Seastar Biotek Inc.		Fisheries Management Br, BC Fisheries, Victoria Seastar Biotek Inc., Nanaimo, BC
Kokanee trawl and acoustics	Dale Sebastian George Scholten Don Miller Mike Lindsay	Hydroacoustics Hydroacoustics Trawling Trawling	Fisheries Management Br, BC Fisheries, Victoria Fisheries Management Br, BC Fisheries, Victoria Kootenay Wildlife Services Kootenay Wildlife Services
Communication	Mike Halleran	Interviews, video clips	Westland Television, Kalso
Annual technical report	Harvey Andrusak	Editor	Redfish Consulting Ltd., Victoria

Budget for Year 4 (1999 - 2000) OLAP

The annual expenditure for implementing the OLAP is provided in Tables 2 and 3. Approximately two-thirds of the money has been provided by the Habitat Conservation Trust Fund (HCTF) with other funding and in-kind support provided by lesser amounts secured from Fisheries Renewal BC, the Ministry of Environment, Lands and Parks, the Ministry of Agriculture, Food and Fisheries (BC Fisheries) and the Watershed Restoration Program.

M & M Trading Ltd. and the Piscine Energetics Companies provided equipment and considerable volunteer labour to assist with the mysid harvest feasibility work. The US National Marine Fisheries Service provided assistance and support for genetic analysis and the Deep River Science Academy of the Okanagan University College in Penticton provided students and a crew leader for stream flow studies.

Table 2. Estimated cost of Okanagan Lake OLAP by fiscal year.

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[2]

[1] Expenditures include $13K carryover from 1998-1999.

[2] Fisheries Renewal BC: $115K direct funding for *Mysis* Harvesting Feasibility, stream flow monitoring and screening of Trout Creek; WRP: $40K ; and DFO: $4K for habitat restoration work (screening) on Trout Creek; MELP Waste Management Branch: $10K for water sample analysis; MELP Fisheries and BC Fisheries: $60K for staff involvement on the Okanagan Lake Action Plan. In addition Public Utility Districts of Washington provided almost $100K to begin restoration activities toward sockeye extension on the Okanagan River (not included on the above table).

Table 3. Approximate expenditure in 1999/2000 by major components of Phase 1 of OLAP.

ACTIVITY	EXPENDITURE
Monitoring	$117,000
Comparative analyses	$ 5,000
Large scale experiments	$ 0
Priority remedial measures	$ 49,000
Applied research	$ 88,500
Functional studies	$ 0
Communication	$ 18,500
Reporting	$ 45,000
Total	**$323,000**

DISCUSSION OF 1999 RESULTS

The following is a brief synopsis of some of the key findings from work conducted under the 1999 OLAP. The reader is directed to the individual reports in the four chapters following this discussion for more detail.

Results of Year 4 (1999) of the OLAP show some interesting contrasts from previous years work and provide greater insight into Okanagan Lake trophic levels and the relationships that exist between them. Adding to and improvement of the baseline data set is fundamental to long-term success in rebuilding the Okanagan Lake kokanee populations. Analyzing the data and synthesizing it into this report requires a high level of communication and cooperation amongst the participants. This multi-disciplinary approach is essential since the problems facing kokanee as well as other fish species in Okanagan Lake are not readily apparent nor are they going to be simple to resolve. Examination of all aspects of Okanagan Lake limnology, biology and impacts of man on this ecosystem is anticipated to lead to some (eventual) practical solutions. In this regard there were some significant findings that arose from the work conducted in 1999.

Habitat Protection and Restoration

Since inception of the OLAP habitat protection activities have been strengthened within the Ministry of Environment, Lands and Parks as outlined by McGregor (in this OLAP report). Key strategies include encouraging DFO involvement in protection of riparian habitat and movement towards a basin-wide ecologically based planning process.

Habitat protection work is an on-going function requiring continuous effort to retain what remains of key fish habitat after decades of negative impacts by man. This work is the least noticeable part of the OLAP yet it is by far the most important. Small “victories” such as successfully negotiating a reduction in water licence demands on a spawning stream may take days if not months to accomplish, yet no one hardly notices it. Effort directed towards reviewing the operating rule curve for the lake involves hundreds of hours yet the change(s), if any, would not be something that the public would readily notice. Clearly though, such efforts are essential to the well being of Okanagan Lake spawning kokanee!

The final report on lake level regulation written by Ward and Yassien (in this OLAP report) provides an analytical technique that could be used for improving the predictive capability of inflow volumes to Okanagan Lake. Predicting in advance the probable inflow volume could result in designated lake levels being adjusted that would be more favorable to shore spawning kokanee without impacting other users.

Monitoring of key spawning streams for flow and water levels was initiated in 1999 to develop a better database for future negotiations for minimum flows. Most streams have been licenced for human use far in excess of minimum flow requirements for fish. To recover some water (in future) for fish requires good data that can then be used to estimate minimum flows. Streams described by Kirk (in this OLAP report) will be monitored annually for at least the next five years.

Limnology

A more streamlined routine sampling program of the lakes' physical and chemical parameters was implemented in 1999. In general, Okanagan Lake can be classified as a moderately unproductive or oligotrophic that has a productivity gradient from low to medium moving from south to north. A portion of the north end of the lake is actually moderately productive (mesotrophic). Documenting the present trophic status of Okanagan Lake is critical to gaining an understanding of how much change, if any, has occurred to the lakes' productive capacity. Fortunately, a good background limnological database exists due to the work done in the 1970s as part of the Canada-British Columbia Okanagan Basin Agreement.

Since the 1960s, it has always been thought that the lake was phosphorus rich hence the Province moved to reduce phosphorus loading with some very efficient sewage treatment facilities at Vernon and Kelowna. Phosphorus levels today are still slightly elevated but are much lower than would be the case if treatment had not occurred. Analysis of the 1998 and 1999 data suggests the possibility that periodically lake phytoplankton may actually be nitrogen limited in the summer months (Stockner in this OLAP report). This observation may be particularly important to understanding what limits lake productivity. Similar sized southern interior lakes (Arrow, Kootenay) that are phosphorus limited have been subjected to lake fertilization (Ashley et al. 1997; K. Ashley, Research Biologist, Fisheries Management Branch, UBC pers comm.). Such treatment of Okanagan Lake was originally rejected as an option (Ashley et al. 1998) but the question of nitrogen limitation was not contemplated. Closer examination of the N:P ratio is required in 2000 to better understand the dynamics of these two essential nutrients and how they control plankton growth (Kirk; Stockner in this OLAP report).

Algal growth appears to have remained fairly constant over the last three decades but blue-greens dominate during the summer months and their abundance is slowly increasing with time. It has been suggested by Stockner (in this OLAP report) that because blue-greens are a poor food source for macrozooplankton (e.g., *Daphnia*) this may be one explanation for why kokanee have declined, i.e., poor growth due to lack of preferred macrozooplanktors. Closer examination of this hypothesis is required in 2000.

Zooplankton

Total lake zooplankton densities were comparatively high in 1999. The lowest densities were found in the south end of the lake while the highest densities were found at the north end, especially in Armstrong Arm, (Wilson in this OLAP report). In 1999, *Daphnia* were found in very large numbers in Armstrong Arm at densities similar to those recorded in 1980. Since *Daphnia* are the preferred food item of *mysis* and kokanee this raises the question of whether or not food competition is the sole reason for decline in kokanee numbers? For example, at least in 1999, there appears to have been ample food for both *mysis* and kokanee. Additionally, the limited, comparative historical (recent) data indicates little change in the percent composition of *Daphnia* over the last twenty years (Wilson in this OLAP report). However, cladoceran densities are lower than those measured in Arrow and Kootenay lakes. Clearly, the zooplankton data is invaluable to the OLAP and the 1999 results raise some interesting questions about what controls kokanee numbers.

Mysid numbers continue to slowly trend downward and this further confounds the notion that *mysis* are limiting kokanee numbers. The highest mysid densities were again found at the north end of the lake. They were found at deep depths (>120 m) during the day but were observed vertically migrating to the surface waters at dusk only to return to deep water again by dawn. Results of examination of the energetic requirements of mysids and their impacts on zooplankton in Okanagan and Kalamalka lakes by Whall and Lasenby (in this OLAP report) did not fully support the hypothesis that mysid competition for zooplankton has singularly caused the decline in kokanee.

The unique limnological attributes of Armstrong Arm continue to be of interest to limnologists. This part of the lake has very low oxygen levels in the deeper water in late summer-fall. It is believed that these poor oxygen levels combined with warm surface temperature result in horizontal movement of *Mysis relicata* out of Armstrong Arm for several months in the fall. Zooplankton densities are also highest in this part of the lake, particularly the macrozooplankter-*Daphnia*- preferred by kokanee.

Mysid densities are highest at the north end of the lake and this area in 1999 was the focal point for a series of experimental fisheries for mysids. Data collected from the zooplankton sampling program was used to establish the best sites and depths to fish for mysids. Two commercial size boats were employed to test the effectiveness of fishing for mysids using both a bottom and mid water trawl net (Andrusak in this OLAP report). These test fisheries were not designed to maximize catch but rather they were intended to simply test whether or not mysids could be caught employing gear similar to that used in coastal shrimp fisheries. The results were sufficiently encouraging that additional commercial licences will be permitted in 2000. Considerable press coverage of this unique fishery was generated in 1999 and some examples are included in Chapter 4 of this OLAP report.

Fishing down mysids to reduce the population (hence competition for food with kokanee) is currently one of the strategies of the OLAP. It is fully understood that this is a high risk, experimental venture that may not be effective in significantly reducing mysids in Okanagan Lake. However, it is conceivable that a small-scale sustainable fishery may be an unexpected outcome of the OLAP even though kokanee may not ultimately benefit from it. The challenge is to develop fishing methods for mysids that do not result in kokanee by-catch.

Kokanee

Action Plan work in 1999 on kokanee provided some very interesting and somewhat encouraging information. Andrusak and Sebastian present a summary of all the relevant Okanagan Lake kokanee biology data (in this OLAP report). Data from this report and the hydroacoustics results will be used in 2000 to construct historic and current kokanee population estimates.

Hydroacoustic and trawl net survey work was again carried out in 1999 as reported by Sebastian and Scholten (in this OLAP report). Total abundance was estimated to be 4.1 M, the lowest recorded in the last twelve years. The estimates of 5.3 M (1998) and 5 M (1997) were previously the lowest on record while estimates in the late 1980s and early 1990s were >12 M. The downward trend in total abundance mirrors the decline of both stream and shore spawners.

Research work reported by Pollard (in this OLAP report) using genetic markers to distinguish kokanee stocks within Okanagan Lake has been highly successful. Commencing in 2000, this analytical tool developed by Pollard and other geneticists (Ashley et al. 1999) will be incorporated into the annual trawl, data collection program. Differentiating shore and stream spawning kokanee stocks from trawl caught samples will provide the means of estimating the relative size of the two stocks.

The annual stream kokanee enumeration results for 1999 reported by Webster (in this OLAP report) provides a stark reminder of the plight of kokanee in Okanagan Lake. The 1999 stream escapement was the lowest on record with less than an estimated total of 7,000 fish. Mission Creek escapement was only 1,600 fish although the average size was significantly higher than previous years.

Shore spawning kokanee numbers were considerably higher than any estimate made since 1989. Smith (in this OLAP report) estimated the shore spawning index at some 78,000 and this compares much more favorably than estimates of <1,000 in 1998 and <20,000 over the last two cycles. This index ranged between 200,000-730,000 in the 1970s. Nonetheless, the 1999 shore spawning estimate does provide some slight optimism for the future of Okanagan Lake kokanee.

Okanagan Lake is comparable in size with nearby Arrow Reservoir and Kootenay Lake. All three water bodies have experienced major impacts resulting in decline in lake productivity and fish numbers (Pieters et al. 1999; Ashley et al. 1997). 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 budget savings 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 most obvious example of why this should take place is that Arrow Reservoir and Kootenay Lake are being fertilized while Okanagan Lake is not. How Kootenay Lake and Arrow Reservoir fish populations react to such large-scale experiments should provide invaluable insight into understanding limitations to fish production in Okanagan Lake.

PRELIMINARY CONCLUSIONS

- Habitat protection of key spawning and rearing habitat must continue; public support and acceptance of resource ownership is critical to the long-term strategy of kokanee recovery in Okanagan Lake.

- Long-term flow monitoring of some spawning streams is essential to obtain key data required to make the case for restoration of flows for fish.

- The lake level rule curve could be modified to benefit shore-spawning kokanee by using the SOI index to predict normal and dry inflow years.

- Phosphorus limitation may not be the reason for poor kokanee survival in Okanagan Lake. Nitrogen limits phytoplankton growth in the summer months. More work needs to be directed at the N:P ratio dynamics in 2000.

- Limnological data collected in 1999 has raised the question of whether or not preferred kokanee food items are limited as suggested in previous years.

- Mysid densities were at record low numbers in 1999 but still higher than Arrow and Kootenay lakes.

- Preferred macrozooplankters (*Daphnia*) densities were relatively unchanged compared to those estimated over the last twenty years. *Daphnia* densities in Okanagan Lake are low compared to Arrow and Kootenay lakes.

- Mysid harvest appears feasible depending upon market demand.

- DNA analysis can be used to differentiate the origin of trawl caught fish, i.e., shore and stream spawning fish.

- Stream spawning fish in 1999 were at record low numbers.

- Shore spawning fish experienced resurgence with the highest index recorded in the last ten years.

- Study of Okanagan Lake should continue to be conducted in concert with the work on Arrow and Kootenay lakes.

RECOMMENDATIONS

1. Action Plan work should be reported annually.

2. With the completion of Phase 1 in 2000 a major public program should be held in early 2001 to review OLAP progress to-date and provide the opportunity for public input into the direction of Phase 2. A comprehensive workshop on Okanagan Lake limnology and fish biology should be part of this forum.

3. Discuss with BC Water Management Branch the use of the SOI index to assist in regulating future lake levels.

4. Continue to monitor stream flows in 2000.

5. Continue the limnological monitoring as in 1999.

6. Focus research in 2000 towards a better understanding of the N:P ratio and it's influence on lake productivity.

7. Investigate the question of effectiveness of blue-green algae as a food source for macrozooplankters preferred by kokanee.

8. Further develop the techniques used in the 1999 mysid fishery.

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

10. Confirm age of kokanee using otoliths.

11. Proceed with kokanee stock assessment to estimate population size in 2000.

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

REFERENCES

Ashley, K., and B. Shepherd. 1996, MS. Okanagan Lake workshop report and Action Plan. Fish. Proj. Rep. No. RD - 45, Univ. BC, Vancouver, BC.

Ashley, Ken, Lisa C. Thompson, David C. Lasenby, Laurie McEachern, Karen E. Smokorowski and Dale Sebastian. 1997. Restoration of an Interior Lake Ecosystem: the Kootenay Lake Fertilization Experiment. Water Qual. Res. J. Canada, 1997 Volume 32 No. 295-323.

Ashley, K., Bruce Shepherd, Dale Sebastian, Lisa Thompson, Lidija Vidmanic, Dr. Peter Ward, Hansen A. Yassien, Laurie McEachern, Rick Nordin, Dr. Dave Lasenby, Janice Quirt, J.D. Whall, Dr. Peter Dill, Dr. Eric Taylor, Susan Pollard, Cecilia Wong, Jan den Dulk, George Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Ashley, K.A., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, and G. Scholten. 1999. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. 78. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Pieters, R., L.C. Thompson, L. Vidmanic, S. Pond, J. Stockner, P. Hamblin, M. Young, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian, G. Scholten and D.L. Lombard. 1998. Arrow Reservoir Limnology and Trophic Status - Year 1 (1997/98) Report. Fisheries Project Report No. RD 67. Ministry of Environment, Lands and Parks, Province of British Columbia.

Walters, C. J. 1995, MS. Model for Kokanee Populations Responses to Changes in Lake Carrying Capacity. Contract report to the Fisheries Research and Development Section, Fisheries Branch, Province of BC. 5 pp.

CHAPTER 1

PRIORITY REMEDIAL MEASURES

This component of the Action Plan represents by far the most important set of activities that all workers are directly or indirectly involved in. Protection and maintenance of the remaining spawning and rearing habitat for Okanagan Lake fish is absolutely essential if there is to be any hope of eventual recovery of kokanee and other fish populations. In 1999, further efforts were directed towards rationalizing lake level regulation to improve shore spawning success. Low flow requirements for stream spawning kokanee were also investigated. It should also be emphasized that day-to-day habitat protection measures are negotiated with forest, agricultural, and land developers. Even though these activities are not summarized in this report it is acknowledged that this often unenviable task is effectively done by regular staff of the Thompson-Okanagan region of the Ministry of Environment, Lands and Parks.

AN OVERVIEW OF OKANAGAN LAKE FISHERIES HABITAT PROTECTION AND RESTORATION

MYTH OR REALITY?

by

I. McGregor[1]

INTRODUCTION

The Okanagan Lake workshop held in Kelowna, BC on June 28-30, 1995, identified several action items the provincial government should undertake in order to restore kokanee populations in Okanagan Lake (Ashley and Shepherd 1996). Representatives from government, universities and public stakeholders attended the meeting and decided a long-term 20 year Action Plan (OLAP) was required to protect and restore fish and fish habitat in Okanagan Lake. The OLAP, or road map, defined the 20-year strategy in five-year components. The strategic direction for the initial five-year component included, conserving native fish stocks, protecting habitat and collecting priority information to assist future decision making (Ashley et al. 1999). Two action items were identified under the fisheries habitat component of the plan that included:

1. developing protection and restoration plans for stream and shore spawning habitats; and
2. implementing effective stream and shoreline protection - preservation activities.

The one measure(s) that seems to have eluded mankind in general, and in the Okanagan Lake system in particular, are definitive legislation and action plans to protect, and adequately restore aquatic habitats. Galbraith and Taylor (1969); Wightman and Taylor (1978); and Shepherd (1990) all identified aquatic habitat protection as the number one priority for the Okanagan drainage. However, two missing elements, public support and proactive legislation, have impeded the implementation of progressive habitat protection. Unfortunately, we are not much further ahead today than we were when Galbraith and Taylor (1969) first made their recommendations over thirty years ago.

BACKGROUND

Destruction of fish habitat in the Okanagan Valley 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 reduced productive stream capacity to spawn and rear fish. As development increased adjacent to the Okanagan Lake tributaries, flood control was the next measure imposed on these systems. Streams were channelized and dyked further reducing the diversity and fish productive capability. Similar to Pacific salmon

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populations, Okanagan Lake kokanee seemed to survive for years despite the serious perturbations to the stream environment. Unfortunately, for our Pacific salmon and steelhead populations, ocean productivity appears to have diminished over the past 15 years. Reduced ocean productivity in combination with stream habitat degradation over the last 100 years has resulted in some coho and steelhead populations nearing extinction. A parallel situation is evident in Okanagan Lake where, for various reasons, the productive capability of Okanagan Lake has declined over the past 20 years. Reduced productivity coupled with stream habitat degradation has caused a virtual collapse in the Okanagan Lake kokanee populations. Kokanee numbers have declined from the hundreds of thousands to fewer than ten thousand.

In 1915 (see Ward in this OLAP report), a crude dam was constructed at the outlet of Okanagan Lake for lake level regulation and flood control. Downstream of the dam the Okanagan River was straightened and channelized from Penticton to the U.S. border in the 1950s for flood control. Essentially, the entire Okanagan system is now regulated for flood control, a situation not conducive to natural fish production.

METHODS

In order to achieve current Ministry of Environment, Lands and Parks (MELP) fish and fish habitat objectives several actions and methodologies have recently been implemented that include:

- continuing fish habitat protection and stewardship activities through the MELP’s Habitat Protection Section based in Penticton;

- encouraging Department of Fisheries and Oceans (DFO) Habitat Protection Section to become involved in the Okanagan drainage;

- seeking additional resources to complement fisheries and habitat protection staff in the Okanagan Valley;

- developing a document describing optimum low flow scenarios for fish in all the Okanagan tributaries using current technologies;

- reviewing historical dam management activities and improving seasonal inflow forecasting so lake levels typify historical hydrographs and remain stable for shore spawning kokanee populations and sockeye populations downstream;

- initiating a program to determine beneficial water use on selected fish bearing streams; and

- initiating and participating in an international committee (Okanagan Basin Technical Working Group) with First Nations, DFO, and U.S. interests to better manage water releases and restore habitat downstream of Okanagan Lake.

RESULTS AND DISCUSSION

Since inception of the OLAP in 1996 there has been considerably more emphasis placed on fish habitat protection within the Okanagan Lake basin. The MELP has recently reorganized the Okanagan regional habitat section and now have dedicated additional staff time to protecting the urban environment. While staff continue their work in forested watersheds they are also are implementing protection activities in the valley bottoms. To complement MELP's Habitat Protection staff, DFO has now placed Habitat Auxiliaries in the First Nations Office in Westbank and the MELP Office in Penticton. These staff members will assist with habitat protection activities and encourage resource stewardship in the Okanagan Valley.

MELP and DFO have also allocated additional financial resources to locate habitat protection and resource stewardship staff in Okanagan municipalities and regional district offices. The goals of this program are to heighten public awareness of aquatic environmental issues and provide advice through resource stewardship to these rapidly developing communities. The City of Kelowna has already become very proactive by developing a plan, applying and receiving resources to restore Mill Creek.

In many Okanagan Lake tributaries water is diverted for domestic and agricultural purposes. In some cases, streams are totally de-watered in the fall period obviously reducing the capacity to produce fish. In order to identify and improve flows for fish, in these Okanagan Lake tributaries, the MELP is developing a document to identify optimal base flows for fish and develop a critical path to restore these flows. This "Flows For Fish" document will be completed by March 2001. Also, MELP has initiated a monitoring program to identify selected streams where water is not beneficially used. This report will also be available in March 2001.

Some positive measures have already been achieved. In 1999, MELP staff negotiated the relinquishment of water licenses on Bellevue Creek, a trout and kokanee spawning stream. The Irrigation District that operated the ditch irrigation system identified a ground water system that met their needs and agreed to return the licenced water to Bellevue Creek. Historically, the stream dried during the late summer and fall due to these irrigation practices.

Due to the dam construction at the outlet of Okanagan Lake the natural hydrograph on Okanagan Lake has been altered effecting the production of shore spawning kokanee. In order to compensate and mitigate for shore spawning kokanee losses the OLAP commissioned a study to review Okanagan Lake water level management and to recommend operational changes to protect kokanee. Ward (in this OLAP report) has provided some recommendations regarding lake level regulation that would be beneficial to shore spawning kokanee. A one-day workshop will be held in May 2000 with contractors, agencies and First Nations to develop and identify alternative operating regimes for Okanagan Lake. A goal of the workshop is to explore alternatives to improving seasonal inflow forecasting so lake levels may be better managed to protect fish resources.

In 1998, the Okanagan Basin Technical Working Group (OBTWG) was formed. The goals and objectives of the OBTWG include protecting and restoring fish habitat in the Okanagan River and communicating with the U.S. over mutual flow and fish issues. MELP, DFO and First Nation make up the working group, which forms an integral link to management of the entire Okanagan Basin.

In order to better protect and restore Okanagan Lake's aquatic habitat and subsequently its fish populations, municipalities, regional districts, both provincial and federal governments, First Nations and the general public must become actively involved. Elsewhere in British Columbia for salmon bearing streams, DFO, MELP, First Nations and stakeholder are considering a watershed based planning process. To be successful, endorsement of this process is required from all the stakeholders and a similar template needs to be implemented for the Okanagan basin.

It is clear that forest industry activities can have a major impact on effect fish habitat. The majority of forested land in BC is on crown land and is protected by the Forest Practices Code (FPC). While the FPC is still in its infancy stages it appears BC has turned the corner relative to forest land management. There are still issues surrounding riparian leave strips on small streams but what is important is the basis for sound management is now in place to protect the aquatic environment on crown land.

One of the major habitat challenges facing OLAP fishery managers is maintaining and restoring aquatic environments in the productive valley bottoms where land is privately owned. Water use, channelization, dredging, and riparian management are paramount issues in the valley bottoms. Unlike the forested lands there is no proactive legislation to actively maintain and plan restoration activities around the aquatic environment.

In order to complete watershed based protection and restoration activities both the forested and valley bottoms must be incorporated into a basin plan. The "River Continuation Concept" is a useful ecological template for such a holistic approach. This concept recognizes that fluvial geomorphic processes occurring within the drainage from its headwater gullies to the stream mouth largely regulate biological processes. These processes involve energy input, nutrient spiraling, organic matter transport, storage and use by aquatic biota including invertebrates and fishes. Slaney and Zaldokas (1997) emphasize the functioning of downstream communities is contingent on upstream contributions of materials.

In summary, it appears all the Okanagan Valley constituents are finally moving towards improving fish habitat protection and restoration. Patience and perseverance are the operative words since as noted by Slaney and Zaldokas (1997), it takes 20-50 years to restore an ecosystem!

REFERENCES

Ashley, K., and B. Shepherd. 1996, MS. Okanagan Lake Workshop Report and Action Plan. Fish. Proj. Rep. No. RD - 45, Univ. BC, Vancouver, BC.

Ashley, K.A., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, and G. Scholten. 1999. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. 78. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Galbraith, D.M. and G.D. Taylor. 1969. Fish Habitat Survey: Okanagan Tributary Streams 1969. Unpub. MS. BC Fish and Wildlife Branch, Victoria. 190 pp.

Shepherd, B.G. 1990, MS. Okanagan Lake Management Plan, 1990 - 1995. BC Min. Env., Recreational Fish. Progr., Penticton, BC.

Slaney P. A. and D. Zaldokas. 1997. Fish Habitat Rehabilitation Procedures Watershed Restoration Technical Circular No. 9. Watershed Restoration Program. Ministry of Environment, Lands and Parks and Ministry of Forests, BC Government.

Wightman, J.C. and G.D. Taylor. 1978. Overview and Rating of Production Capabilities and Enhancement Opportunities for Rainbow Trout and Kokanee in Tributaries to Upper Okanagan Basin Lakes. Unpub. MS. BC Fish and Wildlife Branch, Victoria. 183 pp.

OKANAGAN LAKE WATER LEVEL MANAGEMENT REVIEW OF PAST TRENDS WITH RECOMMENDATIONS

by

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INTRODUCTION

Water supplies in the Okanagan Basin are controlled mainly by inflows and outflows from Okanagan Lake. This is a large lake with relatively small average throughflow. Hydrologically the area is arid, with low annual runoff amounts and large inter-annual fluctuations. In addition, the evaporation from Okanagan Lake is high, so the outflow in wet years vastly exceeds the outflow in dry years. A map of the area is shown (Fig. 1), with the downstream river (Okanagan River), leading via Skaha, Vaseau and Osoyoos lakes to the US border, and from there to the confluence with the Similkameen River. The Okanogan River (as it is called in Washington State) joins the Columbia River about 100 km south of the international border.

Capacity of the channelized Okanagan River downstream of Okanagan Lake is not large. The peak flow that it can pass depends on factors such as the backwater exerted by Skaha Lake, and inflow from tributary steams. The design flow of the channelized river is 60 m^3 s. Under optimal conditions higher flows can be released (for example, during the early part of August 1997, a flow estimated at about 77 m^3 s was passed). Prolonged release of high flows sometimes causes damage to drop structures in the river downstream of Skaha Lake. The maximum daily volume (about 7.5 million m^3) that may be released from Okanagan Lake at this flow rate is a small fraction (1.8%) of the live storage volume of the lake. Thus, many days and weeks of outflows are needed to significantly change the water surface level of the lake.

Water supply management, water quality and related issues for Okanagan Lake were comprehensively investigated in 1972 to 1973, and in 1974 a series of reports which included the *Comprehensive Framework Plan*. A summary of selected recommendations from this report is included in the section on the Okanagan Basin Framework Plan and Okanagan Basin Implementation Agreement in this report. The Plan emphasized aspects such as flood reduction, water supply for irrigation and municipal use, phosphate reduction from treated sewage waters, and flow needs for Okanagan River sockeye salmon. A clause was inserted relative to shore spawning kokanee and regulation of lake levels.

Engineering and other work set out in the Plan were executed, and a report was published at the end of the implementation period (September 1982). The report was titled *Report on the Okanagan Basin Implementation Agreement* included details of the management of lake surface levels. Recommendations were made specifically directed at mitigating the effects of man made water surface changes in lake levels on shore spawning kokanee populations.

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For the last 15 years the lake has been operated by Water Management Branch staff, following guidelines set out in the Plan of the Implementation Report. The Plan permits late winter drawdown of the lake, if needed, to create storage for larger than average anticipated runoff events the next spring and summer.

This procedure has the following attributes:

1. ***Benefit*** in creating space in the reservoir so that high runoff flows appearing weeks or months later can be stored and slowly released. This reduces maximum water surface levels the following summer, and reduces summer flow peaks in the Okanagan River. Lakeside residents, particularly those with low basements, benefit from reduced flood levels, because inundation of basements is minimized.

2. ***Detriment*** for lake and riverine spawning fish, because a) the lake may be drawn down sufficiently that lake spawning kokanee eggs may be left high and dry prior to completion of incubation and hatching, and because b) high flows in the Okanagan River during the winter months may mobilize gravels and cause wash out of sockeye salmon spawning sites. In this context, both the sockeye salmon run on the Okanagan River and the Okanagan Lake kokanee populations are particularly valuable. The sockeye salmon run is one of only two substantial runs left on the Columbia River system, and the Okanagan Lake shore spawning kokanee are unique, with very different spawning behaviour and habitat preference compared to other kokanee. They therefore have a high intrinsic value from the point of view of genetic diversity.

Difficulties in managing the system from the point of view of spawning fish and egg survival stem from the large lead-time involved. The fish (both lake and riverine salmonids) spawn during the month of October, and select sites based on water levels (in the river and the lake) that they experience at the time. These water levels need to be kept at a fairly constant level at spawning time (sometime in mid or late October) to ensure optimum survival. Water levels must be maintained until early or mid April for the kokanee alevins to mature successfully. However, if these levels are held and an unusually high snow pack year occurs (as in the 1996 to 1997 winter) there is insufficient time during the April to early May period to create storage space in the lake prior to the onset of flooding. The result is very high lake levels and flooding of homes and other facilities. Although the flood construction level has been set at a relatively high elevation (343.66 m) for many years, there are a lot of non-conforming residences and other properties. If the level in Okanagan Lake is lowered starting in late January (as was done in 1997), then it is possible to create sufficient storage to reduce flooding in the summer months. However this is done at the expense of shore spawning kokanee.

In the natural system, with uncontrolled flow over a gravel or cobble bar at the outlet of Okanagan Lake (Fig. 2), the changes in outflow were gradual and determined by slowly changing lake levels as the winter months progressed. No provision was possible to reduce peak water elevations during the summer, by pre-releasing water following large snowfall winters. With the installation of a sill and gates at the outlet (starting in 1915), the possibility has existed for the last eighty years of significant lowering ("pulling the plug") of the lake, below previously occurring natural lows. This is done during high snow pack winters, to create room for storage

River system. A listing of a selection of the most important types of data for water level

Rights Information System computer files, at Water Management Branch, MELP. Meteorological and hydrological information was obtained from Environmental Ser
Information Division, Environment Canada.

Okanagan Basin Framework Plan and Okanagan Basin Implementation Agreement

Two important sets of documents were produced, detailing what engineering, construction and administrative work had to be done,
These were the report on the Canada-
the report on the Okanagan Basin Implementation Agreement, 1982. The first of these sets of documents included a
Recommendations from these documents were incorporated into the Water Management Branch's operating schedule, which specifies target lake levels and river flows at different times

prehensive analysis of water supply, flood potential and eutrophication possibilities for Okanagan Lake was carried out in the early seventies. Under a joint Federal Provincial effort, a Canada British Columbia Consultative Board was set up to oversee the work that had been

report, published in 1974 in three parts:

1.
   Okanagan Basin Agreement, March 1974, 42pp.
2.
3. Twelve Technical Supplement Reports, including Volume 1: Water Quantity Report: Canada British Columbia Okanagan Basin Agreement, March 1974, 610 pp.

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growth projection (2.6% per annum) of the three, the report concluded that there was sufficient water in the basin to supply all projected withdrawals and to meet pro
recreation requirements. This scenario assumed withdrawal of larger volumes of water from Okanagan Lake during prolonged drought periods than had occurred in the past. Also forecast
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Forecast ranges of Okanagan Lake water surface levels were as follows:

- *Not normally to exceed four feet in any one year, but a total variation of nine feet may occur between an extreme flood level in one year, and an extreme low lake level following a succession of drought years.*

Table 1. Summary of available data on Okanagan Lake.

TYPE OF DATA	SAMPLING PERIOD	YEARS AVAILABLE
Evaporation:		
Kelowna Airport	Monthly	1971 to present
Penticton Airport	Monthly	1951 to 1980
Summerland	Monthly	1962 to 1992
Precipitation:		
Kelowna Airport	Monthly	1971 to present
Penticton Airport	Monthly	1951 to present
Water Surface levels:		
Okanagan Lake at Kelowna	Daily	1943 to present
Okanagan Lake at Penticton	Daily	1920 to 1974
Stream flow on Okanagan River:		
Okanagan River near Oliver	Daily	1944 to present
Okanagan River at Penticton	Daily	1921 to present
Okanagan River at Okanagan Falls	Daily	1915 to present
Okanagan River at Oroville	Daily	1942 to present
Stream Flow in main tributaries which supply 60% of the inflow to Okanagan Lake:		
Mission Creek near East Kelowna	Daily	1949 to present
Vernon Creek at outlet of Kalamalka Lake	Daily	1927 to present
Trout Creek at the mouth	Daily	1969 to 1982
Penticton Creek above Dennis Creek	Daily	1970 to present
Equesis Creek near the mouth	Daily	1969 to 1982
Kelowna Creek near Kelowna	Daily	1922 to present
Powers Creek at the mouth	Daily	1969 to 1982
Peachland Creek at the mouth	Daily	1969 to 1982
Water Licences:		
Nine hundred and nineteen licences leading to a total licenced diversion of 110 mm^3 annually.		

The projected maximum elevation of Okanagan Lake during a 200-year flood event was 1,125.5 feet (343.05 m). This maximum elevation was based on statistical projections, and is hard to interpret and use, because the maximum levels attained in Okanagan Lake depend on inflows and how the outflow gates are regulated during the weeks and months leading up to the major flood event.

In the section concerning "Detailed Recommendations", "Part A Water Quantity", of the Basin report water levels in Okanagan Lake are recommended to be regulated to target values

(Table 2). Target water surface elevations for Okanagan Lake and sill elevations at the lake outlet are summarized on a scale drawing (Fig. 3). Values shown in Figure 3 were taken from the Plan, and as mentioned in the Report on the Implementation Agreement.

Table 2. Target Water Surface Elevations for Okanagan Lake Recommended in the Plan (1974).

Normal Operating Conditions:	Regulated within its normal four foot range (1,119.8 to 1,123.8 feet, 341.32 to 342.54 m) in all years except extreme flood years (inflows projected to exceed 500,000 acre feet · yr., 617 million $m^3 \cdot$ yr) and successive drought years (inflows less than 200,000 acre feet · yr., 247 million $m^3 \cdot$ yr).
Flood Conditions Predicted:	Lake to be drawn down below its normal low water elevation of 1,119.8* feet (341.32 m) prior to freshet by up to one foot (0.305 m). (Drawdown to as low as 341.01 m is thus recommended, if necessary).
Drought Conditions Predicted:	Maintain the lake level as high as possible. Under prolonged drought conditions, the lake level may reach as low as 1,116.8 feet (340.4 m). The bottom 0.92-m of water storage is known as ‘emergency storage”.

* Normal low water elevation specified in Plan of 341.32 m. Note that operational experience has shown that in most years meeting this target would result in excessive and unnecessary drawdown. In practice, a minimum level in an average year of 341.5 to 341.6m is usually sufficient.

The Plan also had the following recommendations:

- Flood plain zoning be implemented and enforced by a regional water management authority up to 1,127.5 feet (343.66 m) elevation around Okanagan Lake. Further development on this floodplain should be limited to recreation, parks and agriculture.

- Irrigation and domestic intakes around Okanagan Lake be adjusted as required to be operable at a minimum lake elevation of 1,116.8 feet (340.4 m).

- As of March 1974, future intakes, wharves, boat ramps and other structures around Okanagan Lake are built to operate with a lake elevation range of 1,116.8 to 1,125.5 feet (340.4 to 343.05 m).

- Water requirements for sockeye salmon in Okanagan River should be met in all years, except consecutive drought years, using the following guidelines:

DATES	**FLOWS, OLIVER GAUGING STATION**	
August 1 to September 15	8.5 to 11.3 $m^3 \cdot$ s	(300 to 450 $ft^3 \cdot$ s)
September 16 to October 31	9.9 to 15.6 $m^3 \cdot$ s	(350 to 550 $ft^3 \cdot$ s)
November 01 to April 30	5.0 to 28.3 $m^3 \cdot$ s	(175 to 1,000 $ft^3 \cdot$ s)

‘In two or more consecutive drought years, these flows may have to be reduced”.

- Clause 40: That due consideration be given to shore spawning kokanee when regulating Okanagan Lake water levels over the winter months. To minimize damage to shore spawning kokanee during the fall and winter months, the drawdown of Okanagan Lake between October 01 and February 28 should not normally exceed six inches. In anticipated high runoff years however, greater drawdown may be necessary to accommodate the spring runoff.

Without long-term forecasting, the recommendations of the Plan for drought conditions cannot in practice be met. During times of very low inflows, it is not possible to maintain high water levels, because of demands on the system. For example, during the winter months the Okanagan River flows must be maintained relatively high to avoid exposing sockeye salmon eggs. The Plan's recommendations for flood conditions to draw the lake down prior to freshet is impossible to do in practice without causing damage to the lake kokanee.

There is clearly a conflict when the requirements of the Plan for fish habitat and fish spawning are combined with requirements for flood and drought management. In our opinion, this conflict could be mitigated with long-term trend forecasting, i.e., determining by July or August what the following spring's snowmelt runoff conditions are likely to be.

Implementation Agreement Report

Nearly all of the engineering work outlined in the Plan was undertaken during the period 1976 to 1982, and this document describes what was achieved. Of importance to lake levels and outflows are the following:

Okanagan Lake Intakes

In order for the intakes to be operable at an extreme low lake elevation of 340.4 m (1,116.8 feet), the Plan advised that *all irrigation and domestic intakes be adjusted (lowered) as required.* The Implementation Report quotes the Board as advising that *any intake modifications should not be undertaken until such a time as an actual drought event may occur.* This directive was given because of a) anticipated zero benefit from any change during the life expectancy of the intakes, and, b) the ability to make the required modifications quickly if required. All new intakes after 1977 were built to operate at a lake surface elevation of 340.5 m.

Sockeye salmon flows

The allowed flow for the period August 1 to September 15 was changed, to allow more flexibility in releasing flows from Okanagan Lake. The revised schedule was:

DATES	FLOWS, OLIVER GAUGING STATION	
August 1 to September 15	8.5 to 28.3 m^3 s	(300 to 1,000 ft^3 s)
September 16 to October 31	9.9 to 15.6 m^3 s	(350 to 550 ft^3 s)
November 01 to April 30	5.0 to 28.3 m^3 s	(175 to 1,000 ft^3 s)

> "After February 1, flood control requirements are given priority over fishery flows and it may on occasion be necessary to exceed the 28.3 m^3 s upper limit".

Kokanee Spawning

During the Okanagan Basin Study a multi-agency water analysis was conducted for salmon flows and conditions for kokanee (determining how to minimize the drawdown of Okanagan Lake during the winter months). One of the outcomes of this study were key lake level objectives that the operator should aim for in most years. These were:

- February 1st flood control target elevation of 1,121.3 feet, preceded by
- October 15th secondary target elevation of 1,121.8 feet

> “If this secondary target level of 1,121.8 ft on October 15 is met, then the drop in lake level between October 15 and February 01 should not exceed six inches in most years”.

The Implementation Agreement Report modifies Recommendation 40 of the Plan, to read:

> “To enhance shore spawning kokanee conditions over the fall and winter months, Okanagan Lake will be operated such that, when possible, the lake level is not greater than 1,121.8 feet on October 15, subject to flow restrictions for sockeye salmon”.

For reasons that are not known, the need to preserve water levels within a close range from the spawning period until February 28th (as envisaged in the Plan) were changed, and the February 01 date adopted. This modified date is too early to protect kokanee spawn, because emergence occurs after this date, even in warmer than average winters. Approximately six additional weeks are required after emergence, for successful development of the alevins in the shore side gravel.

Other Selected Reports

Four reports are reviewed as follows:

Summit Environmental Consultants Ltd., 1999. “Improved Seasonal Inflow Forecasting Models for Okanagan and Kalamalka Lakes: Final Report and Users Manual”. For Ministry of Environment, Lands and Parks, Southern Interior Region. 80pp plus Appendices.

This report focuses on forecasting of expected inflows into Okanagan Lake from the period beginning of February to early May. To assist in the operation of Okanagan and Kalamalka lakes, forecasts of freshet period inflow to each lake are presently made four times a year; on February 1st, March 1st, April 1st and May 1st. A prediction for the total lake inflow volumes from these dates, until July 31st, is made each year.

Statistical models for inflow prediction were originally developed by the provincial government in 1984. It became apparent that there was a need to improve the performance of these models, particularly for results of the February 1st and March 1st predictions.

The Summit report tested previously used as well as new variables in the regression equations, including:

- Snow Water Equivalent at Key AES Stations in the Basin;
- Surface Inflow Volumes for the Previous Three Months;
- Forecast Period Precipitation from Canadian Institute of Climate Studies;
- Groundwater levels;
- Plateau reservoir storage; and
- Basin-wide Index of Snow Water Equivalent.

A statistical procedure (principal components (Garen) analysis) was used to undertake the comparisons of modeled and actual flows. The result of the analysis includes suggested new procedures that substantially improve the early season forecasts for both lakes.

For reasons that are not explained, several of the suggested new variables were not included in the final recommended equations. This may be because the effects of some variables are implicitly included in others. For example, groundwater levels are expected to be correlated with the December to February lake inflow values in most years.

Obedkoff, W., 1994. "Okanagan Basin Water Supply". File No. 42500-60/S, Study No. 384, Province of British Columbia, Ministry of Lands, Environment and Parks.

A review, including modeling of monthly inflows and outflows to Okanagan Lake and the downstream river, was carried out. The purpose of the review was to establish what additional future withdrawal of water from the system would be possible, under the operating conditions of the Plan, and assuming a worst case hydrological period, equal to three drought years in succession (as occurred in 1929 to 1931).

The conclusion of the report was that an additional 63 million m^3 per year of water could be abstracted from the system, if the maximum lake draws down (i.e., all the emergency storage) was used. Following this drought period, it would take three years of at least average inflow conditions for the lake water surface to return to its normal range. Management of flood events was not discussed. Winter fluctuations of Okanagan lake surface levels during drought periods were not discussed in the report.

McNeil, R. 1991. MS. "Report on Frequency Analyses of Flood Flows and Levels for Okanagan Valley, Mainstem System", File No. S5111, S5211. Water Management Division, Hydrology Section, Ministry of Environment, Lands and Parks.

An analysis of peak flow events and maximum water levels for Okanagan, Skaha and Osoyoos lakes and for the Okanagan River were computed. The 200-year and 20 year return period events were listed. The author is careful to point out that because the system is dominated by releases from Okanagan Lake, and because this is not natural but is human controlled, the normal statistical projections do not apply. However, in the absence of a better way to proceed, the statistical analyses were done, with the data set being tested with all the data (1921 to 1990) and modern data (1951 to 1990). A change in operating procedure for the system occurred after 1951, hence the split in the data set.

The values computed provide guidance for flood construction levels around the lakes, and for peak channel capacity. The report states that with 0.61 m freeboard above the 200-year peak water surface level for Okanagan Lake, the flood construction level should be 343.66 m, the same level that has been in effect since 1974.

Operational aspects, such as the need to lower Okanagan Lake ahead of a predicted high snow pack season, are not discussed.

Shepherd, B.G. 1997. MS. "Impacts of Regulating Okanagan Lake Water Levels on Shore Spawning Kokanee Stocks". Okanagan Sub-region Fisheries Section, Ministry of Environment, Lands and Parks. Draft report, 17 February 1997.

The history of water level regulation activities is summarized in the first section of the report. Reference is made to Volume 1 of "Report of Joint Board of Engineers on Okanagan Flood Control" 1946. The outlet of Okanagan Lake prior to 1909 was controlled by a natural bar, whose elevation was surveyed at 341.3 m. Control dams, with sills at elevations of 340.8 m were constructed in 1914 to 1915, and 1920. The present control structure was built in 1953, with the sill set at 339.75 m. Clearly, with the gates of the control structure open, there is the capability of discharging much more water at low lake levels than could be discharged in the original (uncontrolled) situation, because the sill elevation has been lowered.

The report includes a section concerning an overview of water level patterns, and a section concerning kokanee shore spawning. The Okanagan Lake shore spawning kokanee stock utilize water depths of less than 3 m for spawning with depths of less than 0.5 m preferred. In a recent report by Dill (1997 MS), the majority of embryos were found at substrate depths of 15 to 20 cm, with a prediction for optimal incubation conditions at about 15 to 30 cm. The likelihood of increased mortality of kokanee embryos from man-induced water level drops during the winter months is discussed. Declines in the kokanee population due to other causes, such as the introduction of *Mysis relicta* in the lake, are mentioned.

Licenced Withdrawals of Water from Okanagan Lake

A considerable volume of water is taken from Okanagan Lake for industrial, agricultural and domestic purposes. Licenced and actual withdrawal of water may be significantly different. This is particularly true of large waterworks licences that are intended to provide for future growth in demand.

Currently, there are about 919 water licences allowing diversion of water from the lake. The water licences grant a total diversion volume of 110 Mm^3 of water annually, and this diversion volume is about 23% of the mean annual outflow of Okanagan River at Penticton. Out of the 996 water licences, 17 licences grant about 83% of the total diversion volume, with each licence allowing more than 1 Mm^3 diversion annually. The City of Kelowna has the highest licenced abstraction volume of 47 Mm$^{3\cdot}$ year, mainly for municipal water supply purposes. Table 3 shows the sum of diversions from Lake Okanagan, the total number of licences, and details of the major licences.

Note that:

1. A considerable return flow exists for water pumped from the lake and utilized for various purposes. A factor of 65% return flow is recommended in the Plan, for municipal/domestic water withdrawals, and

2. Several water users abstract water in volumes that are significantly below their annual licenced amounts.

Since the inception of the Plan in 1974, all intakes have been designed to function at an extreme low lake level of 340.4 m. We do not know how many old or non-complying intakes exist.

Table 3. Licensed maximum water withdrawals from Okanagan Lake.

Licence No.	Licensed Purpose	Quantity At POD	Units	Annual Diversion Volume (1000m^3)	Priority Date	Licensee	Licensee Address
C032633	Cooling	12,000,000	GD	19,910	19670203	Riverside Forest Products Ltd.	820 Guy St Kelowna BC V1Y 7R5
C032829	Waterworks Local Auth	3,285,000,000	GY	14,929	19670726	Kelowna City Of	1435 Water St Kelowna BC V1Y 1J4
C022362	Waterworks Local Auth	2,190,000,000	GY	9,953	19541108	Kelowna City Of	1435 Water St Kelowna BC V1Y 1J4
C108281	Waterworks Local Auth	1,934,500,000	GY	8,791	19690623	Winfield & Okanagan Centre Irrig Dist	10591 Okanagan Cntre Rd E Winfield BC
C032828	Waterworks Local Auth	1,825,000,000	GY	8,294	19670726	Kelowna City Of	1435 Water St Kelowna BC V1Y 1J4
C027158	Waterworks Local Auth	1,095,000,000	GY	4,976	19611214	Kelowna City Of	1435 Water St Kelowna BC V1Y 1J4
C019680	WATERWORKS LOCAL AUTH	912,500,000	GY	4,147	19500803	Penticton City Of	171 Main St Penticton BC V2A 5A9
C025236	Waterworks Local Auth	730,000,000	GY	3,318	19590212	Penticton City Of	171 Main St Penticton BC V2A 5A9
C040839	Waterworks Local Auth	730,000,000	GY	3,318	19720724	KELOWNA CITY OF	1435 Water St Kelowna BC V1Y 1J4
C032615	Waterworks Local Auth	584,000,000	GY	2,654	19670606	Summerland Corp Of The District Of	Box 159 Summerland BC V0H 1Z0
C014633	Waterworks Local Auth	547,500,000	GY	2,488	19380802	Kelowna City Of	1435 Water St Kelowna BC V1Y 1J4
C015910	Irrigation Local Auth	1,800	AF	2,221	19310320	Glenmore-Ellison Improvement Dist	C/O D Mcfadden 445 Glenmore Rd Kelowna BC
C066159	Waterworks (Other)	1,077,000	GD	1,787	19861120	Transportation & Highways Ministry Of	523 Columbia St Kamloops BC V2C 2T9
C019098	Waterworks Local Auth	365,000,000	GY	1,659	19490510	Kelowna City Of	1435 Water St Kelowna BC V1Y1J4
C034312	Irrigation Local Auth	1,000	AF	1,234	19680925	Okanagan-Similkameen Regional Dist Of	101 Martin St Penticton BC V2A 5J9
C018611	Irrigation	900	AF	1,110	19480316	Okanagan Indian Band	RR 7 Comp 20 Site 8 Vernon BC V1T 7Z3
C020914	Irrigation Local Auth	900	AF	1,110	19520605	West Bench Irrigation District	PO Box 537 Penticton BC V2A 6K9

91,897	Sum Of The Above 17 Licences Contributing To Over 83% Of The Total Diversion From The Lake.
18,424	Other 902 Licensees
110,321	Total Licenced Diversion From Okanagan Lake

Annual Water Outflows and Approximate Inflows for Okanagan Lake

The intent of this section is to provide some approximate inflow and outflow values to understand the nature of the water management problem associated with Okanagan Lake. Because the regional climate is very dry, the runoff from year to year fluctuates a great deal. During dry years and wet years net inflows of about 100 Mm^3 and 1,000 Mm^3 respectively are noted. The year 1997 provided a record inflow volume of about 1,400 Mm^3.

Few of the tributary streams are gauged, so that annual inflow volumes can only be approximated based on the hydrological balance for Okanagan Lake. This method is subject to error because evaporation from the lake is unknown and difficult to determine yet is a very important part of the water balance.

Ministry of Environment, Lands and Parks Flood Forecasting Branch annually compute data on net annual inflow volumes into Okanagan Lake, for the periods 01 October to 30 September the following year. These inflows were computed from outflows, with a correction for changes in storage in Okanagan Lake. Outflows were taken from data from Water Survey of Canada gauging station No. 08NM050, *Okanagan River at Penticton* (see Figure A1, Appendix A). Evaporation is not included in the calculation, so actual inflows are considerably higher than the computed net inflows. The data concerning net annual inflows from 1922 to present are shown in the Appendix A, as Figure A2.1.

Data for climate are available in the Plan, see for example Table 3.2, page 64, Technical Supplement No. 1. The long-term annual precipitation averaged for the whole basin is about 560 mm. For the lake itself the precipitation is much lower, and high summer temperatures lead to relatively high lake evaporation. Evaporation from the lake basin is estimated at 420 mm per year. The long-term average precipitation on the lake is estimated to be 315 mm per year, which is about 56% of the average precipitation for the whole basin.

Evaporation from the lake is hard to assess. Temperature differences from one year to the next have a significant effect on annual total evaporation. The value listed in the Plan is 965 mm per year, and we believe that an error of ±15% should be attached to this value, because of uncertainties in the actual value, and because of year to year fluctuations. This approximate value is confirmed by other published data (Calculated Lake Evaporation data) based on meteorological measurements at Summerland and Kelowna, (see Canadian Climate Normals, 1951 to 1980, Volume 9).

Mean evaporation from the lake is approximately three times that of the precipitation on the lake. Evaporation is a major factor in the water budget for the lake (see Table 4). A summary of mean annual water budget value is given in Table 4. Errors of measurement are estimated as follows:

- up to 15% is estimated for assessment of precipitation and up to 15% for evaporation directly from the lake,
- up to 5% error on the net runoff from the basin and flow measurements at Penticton, and
- an error of up to 15% on abstraction, to account for abstracted flows less than licenced amounts.

Table 4. Approximate Annual Water Budget for Okanagan Lake.

Description	Annual Volume (Mm^3)	Estimated Error* (Mm^3)	Record Period	Reference
Net runoff on the Lake basin (without Lake)	780	±39	1921-1970	Canada-BC Okanagan Basin Agreement, 1974
Contribution from Precipitation on the Lake	100	±15	1931-1960	Assuming annual precipitation on the lake of 315 mm ± 48 mm
Evaporation from the Lake	330	±50	1921-1970	Canada-BC Okanagan Basin Agreement, 1974
Abstraction	96	±14	1997 Record	BC Government Water Rights Information System
Return flow from abstraction	62	±9		Return flow assumed as 65% of the total diversion
Outflow at Penticton	470	±24	1921 to present	HYDAT CD ROM

** Estimate of measuring/calculation error.*

Historic Water Level Fluctuations

Review of water surface levels during the past 40 years

An analysis of water surface elevations on February 1st for the last 40 years was carried out (Fig. 4). In addition, an analysis was made to determine the amount of surface level lowering of the lake during the period October 15th to February 1st the following year (over winter drawdown).

Since the inception of the Plan in 1974:

- the water surface on February 1st has been within the range +0.15 m to -0.28 m of the target level of 341.77 m. The lowest level (February 1, 1993) in recent years was associated with drought runoff conditions the previous summer;

- the water surface on October 15th has been within the range +0.33 m to -0.36 m of the target level of 341.92 m. The two highest levels were prior to preparation of the Okanagan Basin Implementation Report (1982), and the lowest level was associated with the 1992 drought; and

- the over-winter drawdown has exceeded 6 inches (15 cm) eight years out of 23 years. Since the Implementation Report of 1982, the over winter drawdown has exceeded 6 inches (15 cm) three years in 15 years (Fig. 4).

Figure A3.1 to A3.4 (Appendix A) illustrates water surface elevations for the whole year, for all years from 1960 to present. The graphs show changes in water surface elevations during the weeks following the 01 February date.

Drawdowns in recent years during the spawning period

As previously mentioned the weeks after February 1st are important to kokanee spawning success because fry emergence does not occur until approximately March 1st with an additional six weeks required after this date for successful alevin growth Dill (*in* Ashley et al. 1998). Therefore, a stable water surface level up to the end of March is considered vital for overall development of kokanee fry. To assess possible impacts on kokanee fry survival, an analysis of water surface drawdown for the period between October 15th and April 1st of the next year was carried out. Results are illustrated on Figure 5. The water surface elevations for the last 40 years are presented in Figure A3.1 to A3.4 with the October15th and April 1st levels highlighted.

Since the inception of the Okanagan Basin Plan in 1974, the lake surface drawdown has exceeded 15 cm (6 inches) in 17 years out of 23 years, and has exceeded 30 cm (12 inches) 9 years in the past 23 years (Fig. 5).

Outflow History

Okanagan Lake outflows, measured at Water Survey of Canada gauging station (*Okanagan River at Penticton*, Station No. 08NM050) for the years 1960 to present have been plotted (Fig. A4, Appendix A). These are illustrated as 7 day moving average flows, for clarity of plotting. Also shown on the same figures are Okanagan Lake water surface levels, as 7-day moving averages. The range of outflows varies from an average annual minimum flow of about 5.7 m^3· s to an average annual maximum flow of about 46 m^3· s.

During the last 40 years the largest daily outflow was 85.6 m^3· s, recorded on August 7th and 8th, 1997. This wide range of flows reflects the arid nature of the Okanagan basin with large differences in runoff from one year to the next quite common.. Note the very low peak outflows in years such as 1992, associated with very poor snow pack conditions the previous winter.

Linkage between Southern Oscillation Index and Snow Pack/Runoff

Introduction

The Southern Oscillation Index (SOI) is a measure of sea level barometric pressure differences between Tahiti and Darwin, Australia in the Southern Hemisphere tropics. During El Niño events, unusually high atmospheric sea level pressures develop in the western tropical Pacific Ocean with abnormally low sea level pressures developing in the eastern tropical Pacific Ocean.

An accompanying phenomenon is significant heat build up in the surface water of the eastern Pacific Ocean, changing the ocean surface temperature by as much as 1 to 2 degrees centigrade over an extremely large area. This heat build up takes many months but once it has occurred, several months are required before the heat anomaly is dissipated. During this period, tracking patterns of the jet stream over the northern Pacific Ocean are affected, with consequences for the rain and snow bearing winds that bring frontal storms to the Pacific Northwest coast.

The SOI index measurements are updated monthly and published on the Internet so access to the data is quick and inexpensive. These SOI measurements are also available for a very long period (year 1882 to present). Ministry of Environment, Lands and Parks' Flood Forecast Center has recently provided a WEB site information bulletin concerning the effect of El Niño global climate fluctuations on runoff in British Columbia. The most noticeable effect of the El Niño is along the south coast and in the southern interior. For the Okanagan Basin, the April 1, 1997 snowpack was below normal a large (74%) proportion of the time following the 1997 El Niño event, having on average 16% less snow than normal.

An excellent unpublished report (G.A. McBean 1994, MS) summarizes the possibilities for long-term climate and runoff predictions for Canada. McBean found that streamflow in most BC regions was positively correlated with SOI for lagged correlations.

There is good preliminary evidence that climate and streamflow in the US northwest is influenced by world scale climate fluctuations. For example, Redmond and Koch (1991) have shown that the ENSO (El Niño Southern Oscillation) measured by the SOI has an effect on temperature, precipitation and runoff in mountainous parts of the US northwest. Snow accumulation is likely impacted by combined changes in temperature and precipitation. During El Niño years, the winter climate tends to be both slightly drier, and slightly warmer than normal. Additionally, there is a suggestion of cause-effect relationships, with the SOI change preceding the climate change by as much as 4 to 6 months.

Snow pack correlation

We selected a number of snow survey measurement stations in the Okanagan Basin. Three of the snow courses selected were near the Okanagan Basin, but outside the catchment area. At each snow course station, the maximum snow pack was analyzed for possible correlations with the Southern Oscillation Index values. In the analysis, the Southern Oscillation Index was averaged over the six months period of April to September for each year and correlated to the maximum snow pack of the following year.

Results of the analysis show that there is a reasonable correlation between the six month average SOI and maximum snow pack for some of the high altitude stations. For eight of the twelve stations the correlation is good (Table 5), and for four of the twelve stations the correlation is very good. For one station (Mount Kobau) there is no significant correlation.

Table 5. Correlation between April to September Mean SOI and the Following Year Maximum Snow Pack.

Station Name and Course Number	Elevation at Station (m)	Record Length (years)	Record Period	Correlation Coefficient
Trout Creek, Course No. 2F01	1430	61	1935-97	0.390
Summerland Reservoir, Course No. 2F02	1280	56	1942-97	0.449
Graysoke Lake, Course No. 2F04	1810	27	1935-97	0.470
Mission Creek, Course No. 2F05	1780	58	1939-97	0.523
Whiterocks Mountain, Course No. 2F09	1830	41	1953-97	0.210
Silver Star Mountain, Course No. 2F10	1840	39	1959-97	0.338
Isintok Lake, Course No. 2F11	1680	33	1965-97	0.453
Mount Kobau, Course No. 2F12	1810	32	1966-97	0.092
Esperon Creek (upper), Course No. 2F13	1650	28	1966-97	0.337
Morrissey Ridge No 1, Course No. 2C09[a]	1860	28	1961-88	0.576
Mission Ridge, Course No. 1C18[b]	1850	29	1967-95	0.548
Blackwall Peak, Station No. 2G03P[c]	1940	30	1968-97	0.518[d]

[a] *The station is located in East Kootenay Sub Basin.*
[b] *The station is located in Middle Fraser Sub Basin.*
[c] *The station is located in Similkameen Sub Basin.*
[d] *Water equivalent data used in stead of snow pack.*

Runoff correlation vs SOI values for high altitude basins

We selected a number of medium and high altitude basins in the Okanagan region with Water Survey of Canada gauges (Fig. 6). Some of these basins were close to the Okanagan Valley but in different river systems. The flow during the snow melt period at these stations was totaled, and possible correlations with the Southern Oscillation Index values were investigated. In almost all basins analyzed, over two thirds of the annual flow occurs in the two months of the spring freshet. Volume of flow over the two months was checked for any significant correlation with the mean SOI of the previous summer. In the analysis, the SOI was averaged over three to six months for the periods: April to September, May to September, June to September, July to September, and June to August. In all cases, the best correlation was found between the mean SOI over the six month period of April to September to the total volume of flow in May and June of the following year.

In summary, results of correlation analysis indicate that there is a significant correlation between the six month average SOI and stream flows in the following spring. The coefficients are provided in Table 6. Most of the correlation coefficients are significantly different from zero (the null hypothesis) at the 0.1% level. Scatter plots of the average stream flow for the months of May and June versus the average April to September SOI are illustrated in Figure 7 for selected basins. The examples in Figure 7 cover basins with areas ranging from 5 km^2 to 185 km^2.

Table 6: Medium and High Altitude Basins: Correlation between April to September Mean SOI and Following Year May to June Stream Flows.

Station Name and Number	Record Length	Elevation at Station (m)	Basin Area (km^2)	Correlation Coefficient
Whipsaw Creek below Lamont Creek, Station No. 08NL036	30	785	185	0.545
Camp Creek at mouth near Thirsk, Station No. 08NM134	29	1,005	33.9	0.556
Vaseux Creek above Terrace Creek, Station No. 08NM171	24	1,100	117	0.320
Two Forty Creek near Penticton, Station No. 08NM240	11	1,630	5	0.607
Two Forty One Creek near Penticton, Station No. 08NM241	11	1,610	4.5	0.565
Dennis Creek near 1780 Metre Contour, Station No. 08NM242	10	1,780	3.73	0.517
Trapping Creek near Mouth, Station No. 08NN019	28	1,040	144	0.605

Correlation of stream flows allowing for interannual water storage

The larger basins in the Okanagan Basin are characterized by ephemeral stream flows often having small dams that overflow only during high runoff years. Streams that have flows generated from groundwater storage/release are also important. In these basins, storage from previous years affects the volume of stream flows in the spring freshet, because of inter-annual storage and release. This storage may be associated with small dams that top up and overflow only during high runoff years supplemented with groundwater flows. During a wet year, when the annual total flow volume is clearly higher than the long term average flow, the storage increases, adding to the flows of the following year. In years following wet years, the stream flows are the result of the current year runoff and groundwater contribution from the past.

In order to analyze the relationship between the SOI and the spring freshet flow in these basins, a crude technique was used to account for the groundwater contribution to streamflow in the year following wet years. For the data set analyzed it was assumed that about 25% of the previous years were wet, 25% of the previous years were dry, and the other 50% of the previous years were neither wet nor dry. For the wettest 25% years only, an adjustment for groundwater contribution was made.

The following rough procedure was used to account for the groundwater contribution, based on previous year (V_{i-1}) water volumes:

- compute, long-term mean annual flow volume, V_{mean}
- compute standard deviation of annual flow volume over the record period, V_{std};
- set upper flow volume bound = $V_{mean} + 0.7 * V_{std}$;
- set lower flow volume bound = $V_{mean} - 0.7 * V_{std}$;
- compare annual flow volume of previous year (V_{i-1}) with upper and lower annual flow volume bounds;
- if V_{i-1} is greater than the upper flow volume bound, then it is assumed that the groundwater volume increases and augments the following years freshet. Thus, the adjusted freshet flow volume of the following year will be the measured freshet flow volume minus contribution from previous year;
- if V_{i-1} is less than the lower flow volume bound, then the groundwater decreases and will be replenished from the following years freshet. Thus, the adjusted freshet flow volume of the following year will be the measured freshet flow volume plus some additional flow, which was used to augment the groundwater storage; and
- if V_{i-1} lies between the upper and the lower flow volume bounds, then groundwater storage does not affect the following year freshet, and no adjustment is necessary to the following year measured freshet flow volume.

The formula that was used for adjustment of flows to allow for groundwater storage was simple and was done for trial purposes only. No attempt was made to optimize the formula, or to relate it to surface and groundwater physical conditions in the various watersheds. The purpose of the formula was to demonstrate a trial allowance for the groundwater contribution from the previous year when base flow conditions were much larger or much smaller than average.

The formula used:

Two month (May and June) adjusted flow rate, $Q_{2miadj} = Q_{2mi} - C^* \Delta Q_{2mi-1}$

in which:

Q_{2mi} is the two month average flow rate happening in the present year,

ΔQ_{2mi-1} is the difference between the average two month flow rate and the two month flow that occurred in the previous year,

C* is an inter-year groundwater flow contribution coefficient (C* = 0.21 was used for most basins and C* = 0.42 was used for the Okanagan Basin).

After these adjustments for groundwater contribution, the SOI averaged over the six month period (April to September) for each year was correlated to the spring freshet flow volume of the following year. Correlation coefficient values for four large basins with large valley floors, characterized by high storage associated with small dams that top up in wet years are shown in Table 7. The results of this analysis indicates that there is up to a 13% improvement in correlation between SOI and following year freshet flow, when inter-annual storage associated with groundwater flow is taken into consideration.

It should be noted that the final column of Table 7 shows that all correlations are medium to very good. In particular there is a medium correlation for the Okanagan Basin itself. In view of the contribution of spring and early summer rain events to the Okanagan River flows, the correlation is surprisingly high.

Scatter plots of the average stream flow for the months of May and June versus the average April to September Southern Oscillation Index are illustrated for the Okanagan Basin (Fig. 8A) and the Mission Creek Basin Fig. 8B). Plots are provided for: 1) the original data, and for 2) the data corrected for interseasonal storage. The trend shows that the smaller the value of the 6 month (April to September) SOI, the smaller is the May to June inflow the following year.

Figure 8A shows that in 13 out of 66 years when the 6 month SOI is less than –0.6, the following year May to June inflow volume to Okanagan Lake was no greater than 33% above the long-term average inflow. In most of these low value SOI years, the following year May to June runoff was low. There were no significant, above normal events during these years. Three of these 13 years were the most serious drought years of record.

Table 7. Correlation between April to September Mean SOI and Following Year May to June Stream Flows with Interannual Groundwater Storage Consideration.

Station Name and Number	Record Length	Elevation at Station (m)	Basin Area (km^2)	Correlation Coefficient without storage	Correlation Coefficient with inter-annual storage effect
Camp Creek at mouth near Thirsk, Station No. 08NM134	30	1,005	33.9	0.556	*Insignificant storage**
Vaseux Creek above Terrace Creek, Station No. 08NM171	24	1,100	117	0.320	*Insignificant storage**
Two Forty Creek near Penticton, Station No. 08NM240	11	1,630	5	0.607	*Insignificant storage**
Two Forty One Creek near Penticton, Station No. 08NM241	11	1,610	4.5	0.565	*Insignificant storage**
Dennis Creek near 1780 Metre Contour, Station No. 08NM242	10	1,780	3.73	0.517	*Insignificant storage**
Trapping Creek near Mouth, Station No. 08NN019	28	1,040	144	0.626	*Insignificant storage**
Whipsaw Creek below Lamont Creek, Station No. 08NL036	30	785	185	0.545	0.566
Mission Creek near East Kelowna, Station No. 08NM116	28	427	811	0.556	0.561
Tulameen River Near Penticton, Station No. 08NL024	44	640	1,760	0.437	0.464
Okanagan Lake, Net Inflow	66		6,090	0.359	0.406

**Small watersheds at medium and high altitude; small inter-annual storage.*

Use of southern oscillation index to assist in seasonal trend analysis

A relationship between the snowmelt component of stream flows and the Southern Oscillation Index was evident from the analysis. Using the correlation coefficient for the six month average (April to September) SOI, and the volume of flows in the two spring months of the following year provides a method for forecasting the probable volume of the spring freshet. Although this approach is probably most useful for predicting the snow melt component of the flow (recognizing that this component is less than 50% of the spring runoff in some years) it is also believed the procedure will enable seasonal trends to be predicted well in advance.

Advance knowledge of a normal or below average snow pack year would enable Water Management Branch staff (who are responsible for controlling the lake levels) to feel confident about going into a Fall season with relatively high water lake levels.

This report demonstrates a loose correlation between runoff conditions and global climate indicators measured the previous summer. Figure 8A shows that in 13 out of 66 years when the 6 month SOI is less than –0.6, the May to June inflow volume to Okanagan Lake was no larger than 33% above normal.

Several months of advance notice about approximate snow pack will allow adjustments to be made to lake levels starting as early as the first day of September, or perhaps earlier. The possibility of using water level adjustments to Okanagan Lake with one target level for the majority of years, and another target level for low SOI (predicted drought/normal) years is discussed in the following section.

CONCLUSIONS AND RECOMMENDATIONS

Management of water levels in the Okanagan basin and particularly Okanagan Lake is of considerable strategic importance to the entire Okanagan Valley. Agricultural irrigation, municipal demands, flood control, fish and recreational users all depend on how wisely the flow of water is managed. Control over the timing of opening and closure of the gates at the outlet dam on Okanagan Lake at Penticton is crucial to determining lake levels and downstream flows.

Regulation of lake levels for Okanagan Lake was set by the Province of British Columbia in 1982 when the *Okanagan Basin Implementation Agreement* Report was finalized. Of particular importance are target water levels at key dates, such as October 15th and February 1st. Because of very large water storage in Okanagan Lake relative to discharge capability at Penticton, adjustment of lake levels (up or down) takes several weeks. Any new procedure(s) that provide operators more time and flexibility in regulating the lake level should be beneficial.

Presently, the lake level is regulated at elevations that are higher than may be necessary particularly in the late summer (September) period. This creates problems for fish during high runoff years. Kokanee spawn in October along the shoreline at the high lake levels but the eggs are then stranded and dewatered during the winter as the lake is drawn down. Results of data analysis from this study suggests regulating Okanagan Lake levels could be considered under two different scenarios using the SOI index as a guide.

A loose correlation between spring runoff conditions and global climate indicators measured the previous summer has been demonstrated. Figure 8A illustrates that in 13 out of 66 years when the 6 month SOI coefficient is less than –0.6, the May to June inflow volume to Okanagan Lake was no greater than 33% above normal. Except in 1983, there were no events during these years that resulted in significant floods. In fact, three of these 13 years were the most serious drought years of record. Therefore, using the SOI index to determine when a climate scenario causes normal or drought conditions means that lake levels could be held higher than in the majority of years commencing on September 1st. Adjustments to the outflow at Penticton could be started at this time, and the decision about the final target lake elevation confirmed on September 30th. Spawning kokanee would benefit from this method of lake level regulation.

With long range weather trend predictions improving it may be possible to operate the lake during the winter at lower elevations than previously used for the majority of years, without increasing the risk to irrigation water supplies. The two operating scenarios that could be used are:

1. A revised water surface target for February 1st, such as 341.6 m, 0.15 m less than presently used, with a similar revision to the water surface target for October 15th. These water surface elevation values would be used for the majority of years.

2. The currently used target elevation of 341.75 m for February 1st for low SOI years only.

Prior to implementation of this revised method of lake level regulation, some important considerations must be taken into account. Water flow and water balance studies using the historic data set should be carried out to substantiate the following questions:

A. Proposed lower water surface elevations during the majority of years:

- Would the additional amount of water that would be released during late summer-fall period imply flows at Oliver gauging station in excess of 28.3 $m^3 \cdot s$.

- Would there be sufficient water in storage to supply the normal winter-spring minimum release flows (3 $m^3 \cdot s$) from Okanagan Lake?

- Would the lake be able to fill during spring-summer the majority of years, following winters when the revised target is used?

B. Allowed flows at Oliver gauging station: Are the presently allowed flows during the period August 1st to October 31st unnecessarily conservative? Would it be possible to release up to 45 $m^3 \cdot s$ (for example) during this period?

C. Lower lake levels: Would the proposed revised range of lake levels cause problems with dock owners (fixed elevation docks)?

If this suggested method of predicting the spring flows is to be used as part of future lake level regulation the River Forecast Center, Ministry of Environment, Lands and Parks would need to annually conduct an assessment of the previous 4-6 months SOI value prior to August 31st. Other global indicators of heat and weather in the Pacific Ocean may be available and may be preferable predictors (better than SOI value) of seasonal runoff. These indicators should be tested for correlation with Okanagan basin runoff. Annual recommendations should be made for the Okanagan system, if runoff conditions for the following spring are likely to be significantly larger than, or significantly smaller than average. Adjustments to lake outflows should be initiated by Water Management staff on September 1st of each year, to allow the water level to meet target levels on October 15th and February 1st. Confirmation of the decision on the target water level should be made on September 30th.

ACKNOWLEDGMENTS

This project was funded by the British Columbia Habitat Conservation Fund and administered by BC Fisheries. The support is highly appreciated. Documentation and other reports were provided to us by Water Management Branch, and by the River Forecasting Centre, Ministry of Environment, Lands and Parks. A review of the Conclusions section of the report was kindly provided by the Water Management Branch, Southern Interior Region.

REFERENCES

British Columbia Ministry of Environment. 1982. ‘Report on the Okanagan Basin Implementation Agreement”, by Okanagan Basin Implementation Board. ISBN 0-7719-9054-5. 126 pp.

Dill, P.A. 1997. A study of shore-spawning kokanee salmon (*Oncorhynshus nerka*) at Bertram Creek Park, Okanagan Lake, B.C., Fall 1996. Report prepared for MEL&P, Penticton, B.C.

McBean, G.A. 1994. Xirculation Patterns for Streamflow and Temperature Predictions in Canadian Surface Climate. University of British Columbia, Department of Oceanography Report, for Canadian Electrical Association, Report No. 9206G931

McNeil, R. 1991. Peport on Frequency Analyses of Flood Flows and Levels for Okanagan Valley, Mainstem System, File No. S5111, S5211. Water Management Division, Hydrology Section, Ministry of Environment, Lands and Parks.

Obedkoff, W., 1994. Okanagan Basin Water Supply. File No. 42500-60/S, Study No. 384, Province of British Columbia, Ministry of Lands, Environment and Parks.

Okanagan Basin Agreement, Canada-British Columbia Consultative Board, 1974. ‘Summary Report including Comprehensive Framework Plan”. 41 pp.

Okanagan Basin Agreement, Canada-British Columbia Consultative Board, 1974. ‘Main Report including the Comprehensive Framework Plan”. 536 pp.

Okanagan Basin Agreement, Canada-British Columbia Consultative Board, 1974. ‘Technical Supplement 1 to the Final Report: Water Quality in the Okanagan Basin”. 610 pp.

Redmond, K.T. and R. W. Koch. 1991. Surface Climate and Streamflow Variability in the Western United States and Their Relationship to Large-Scale Circulation Indices. Water Resources Research Vol. 27 No. 9, pp 2381-2399.

Shepherd, B.G. 1997. Impacts of Regulating Okanagan Lake Water Levels on Shore Spawning Kokanee Stocks. Okanagan Sub-region Fisheries Section, Ministry of Environment, Lands and Parks. Draft report, 17 February 1997.

Summit Environmental Consultants Ltd., 1999. "Final Report & Users Manual: Improved Seasonal Forecasting Models for Okanagan and Kalamalka Lakes". Ministry of Environment, Lands and Parks, Southern Interior Region. March 1999. 80 pp + Appendices.

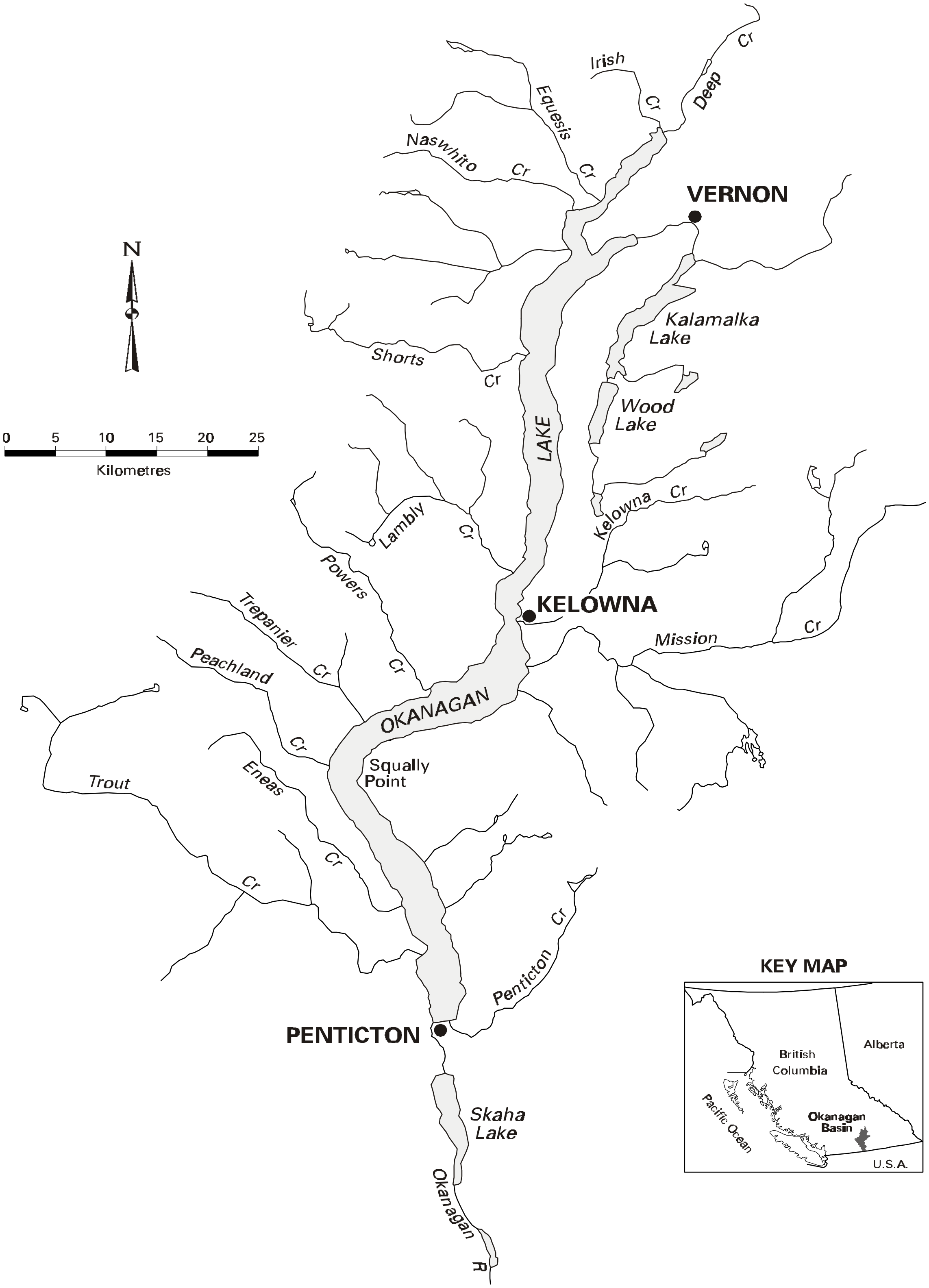
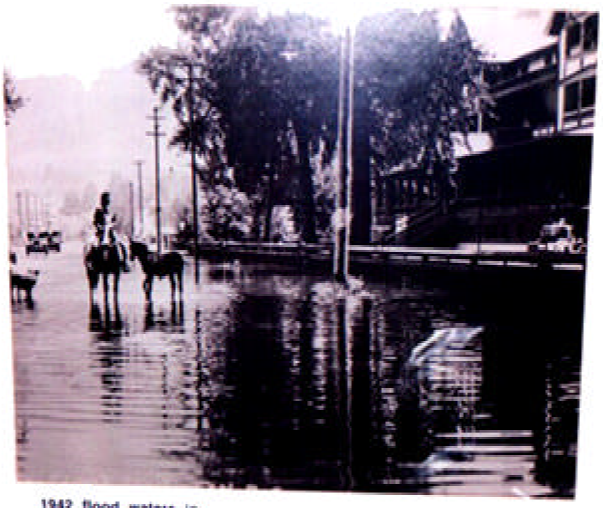


Figure 1. The Okanagan Basin.

A long wooden bridge
crossed the slough
west of Penticton,1914-28.



1942 flood waters in
front of the Incola Hotel
[illegible] photo

FIGURE 2: HISTORICAL WATER LEVELS AT PENTICTON

Figure 2. Historical water levels at Penticton.

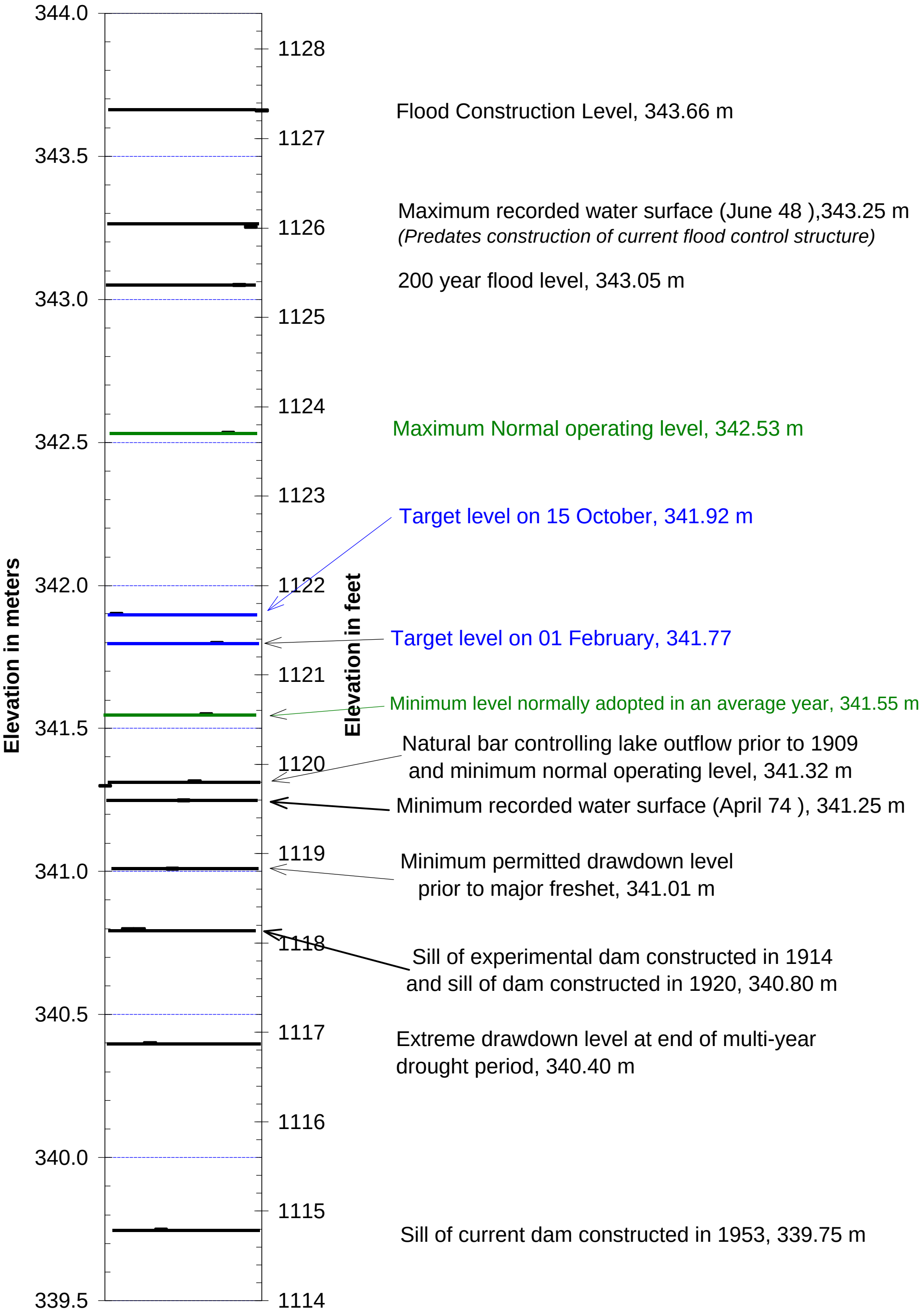


Figure 3. Okanagan Lake target water surface levels and sill elevations.

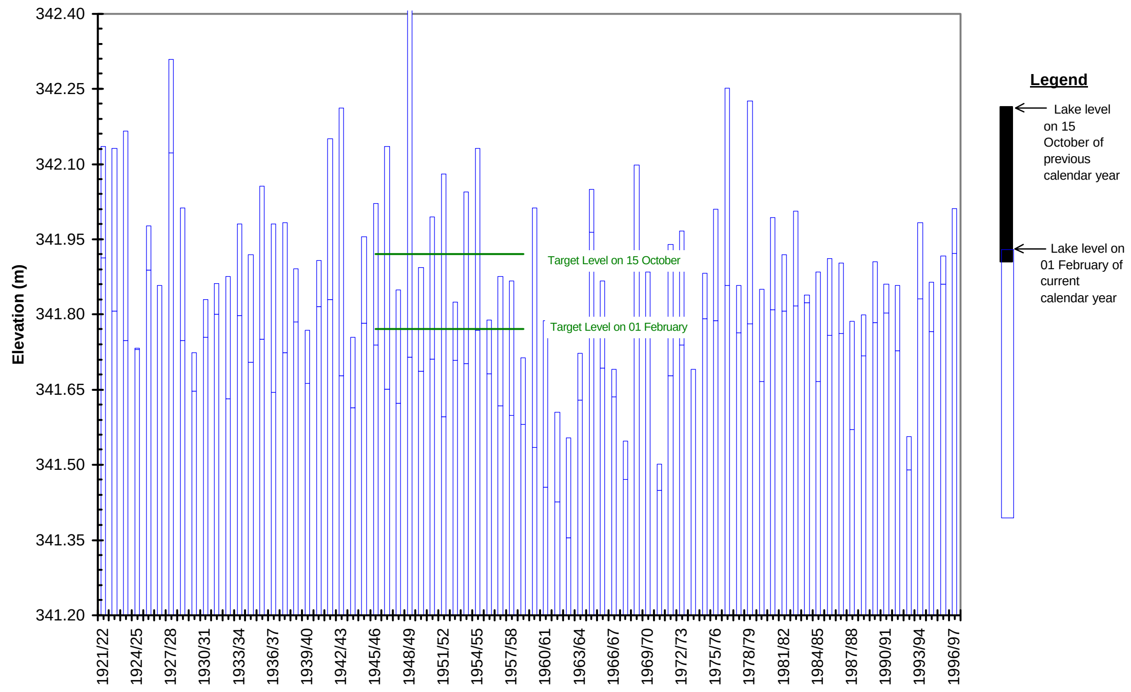


Figure 4. Water surface elevation on 15 October and 01 February (the following year) for all years of record.

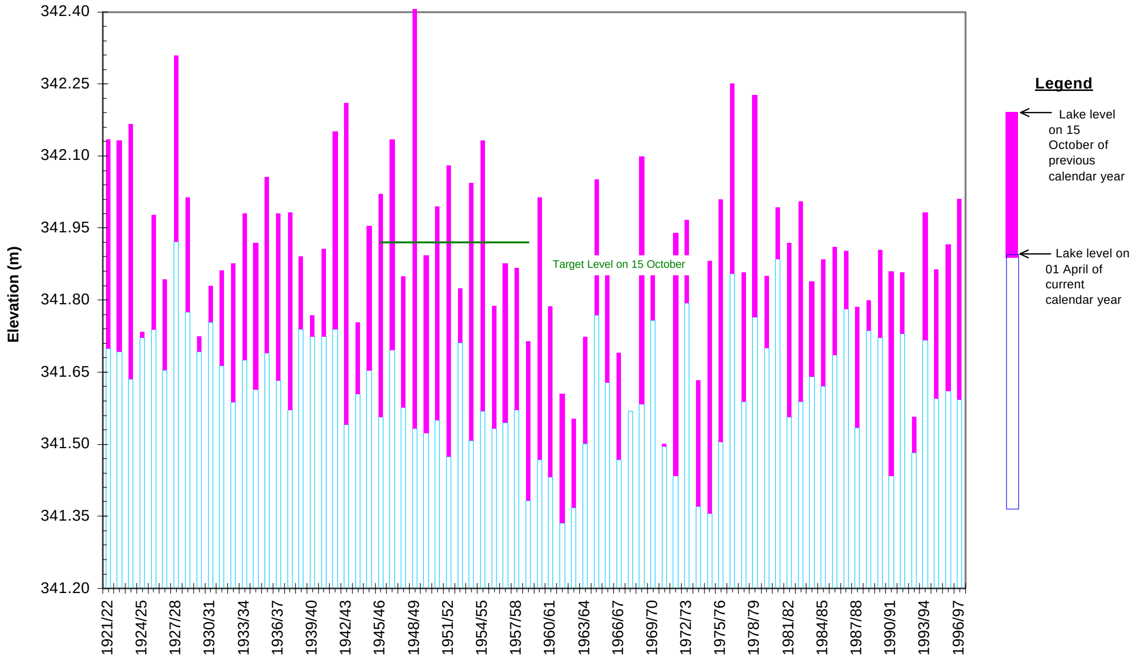


Figure 5. Okanagan Lake water surface elevation on 15 October and the following year 01 April for the years 1960-1997.

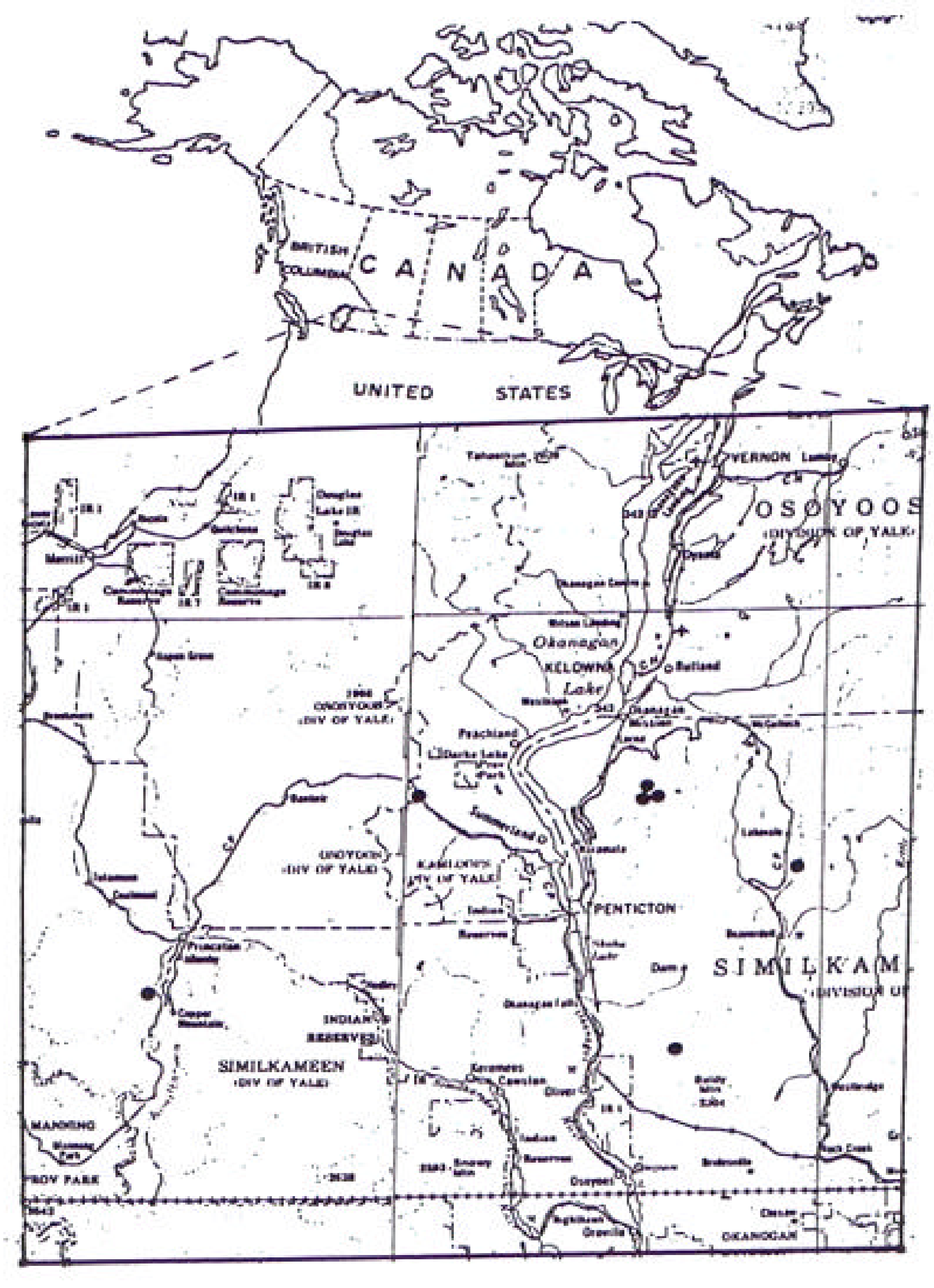


FIGURE 6. LOCATION MAP OF GAUGING STATIONS USED IN CORRELATION ANALYSIS BETWEEN SOI AND STREAM FLOW.

Figure 6. Location map of gauging stations used in correlation analysis between SOI and stream flow.

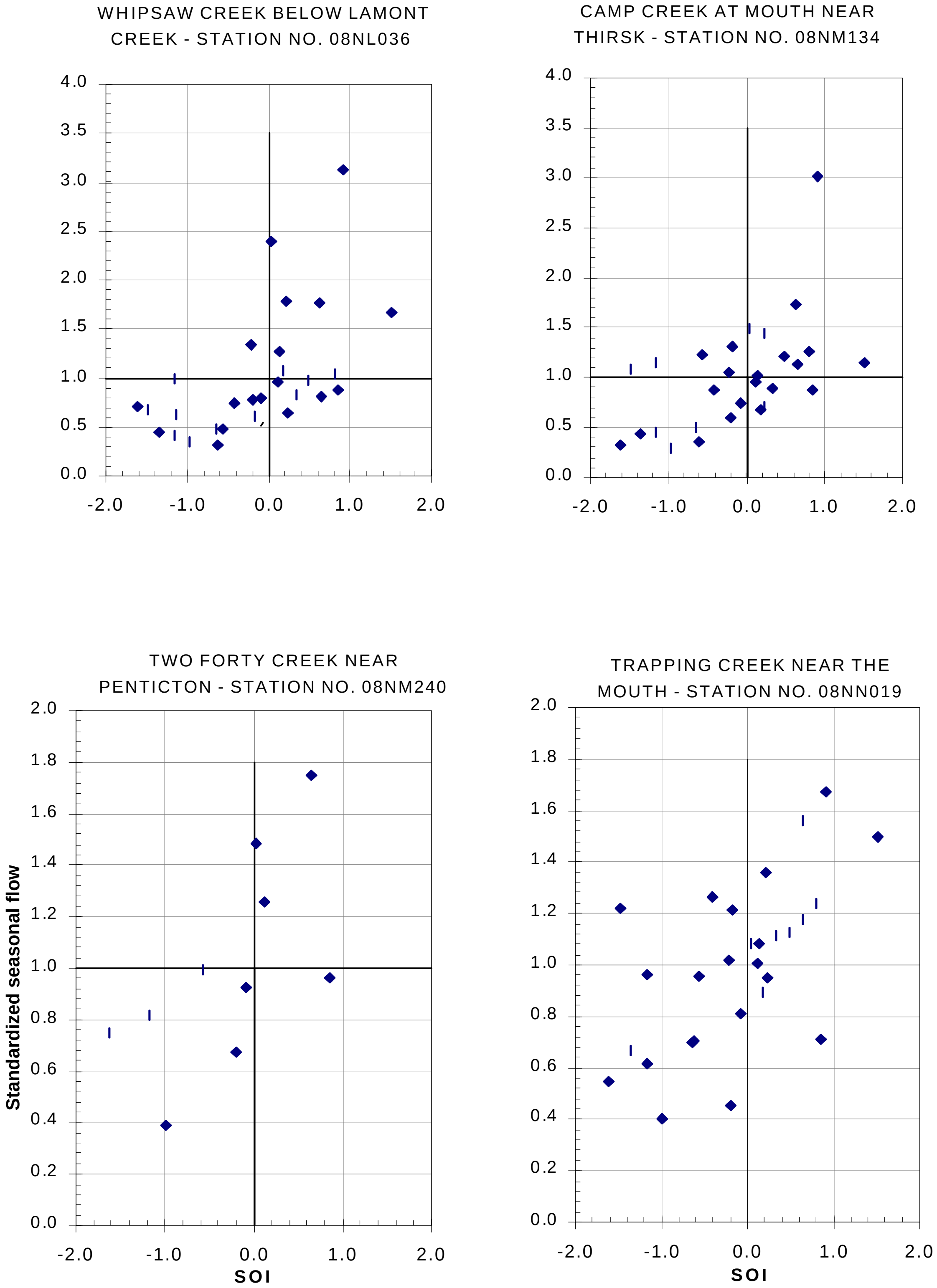
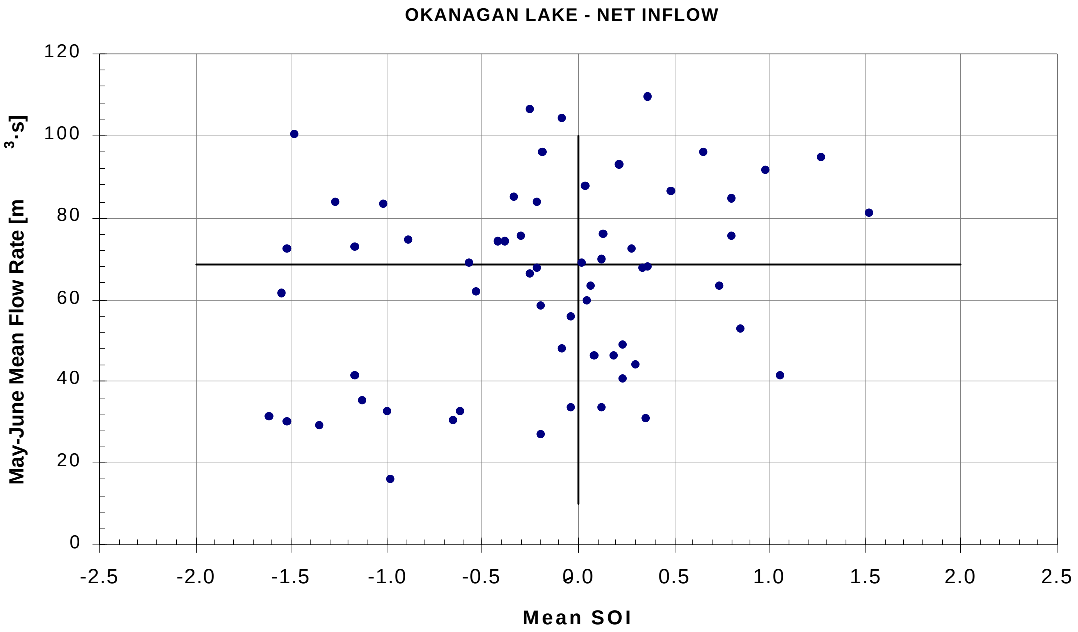


Figure 7. Snow melt runoff correlation, selected basins (April to September southern oscillation index and following year values for May and June flows).



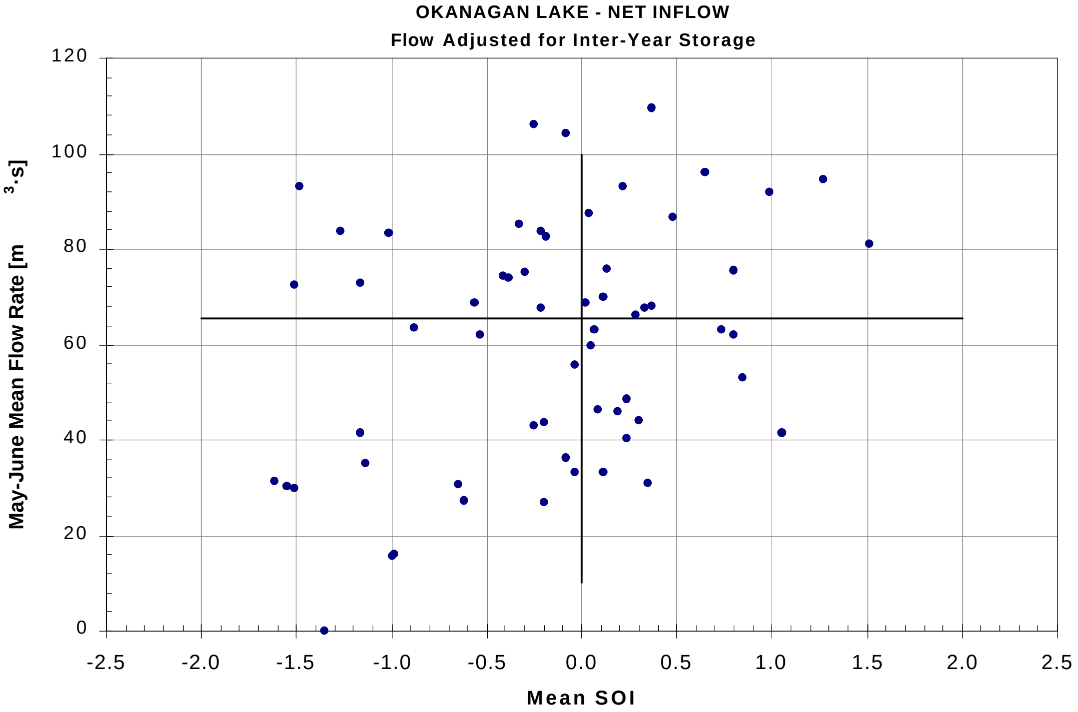
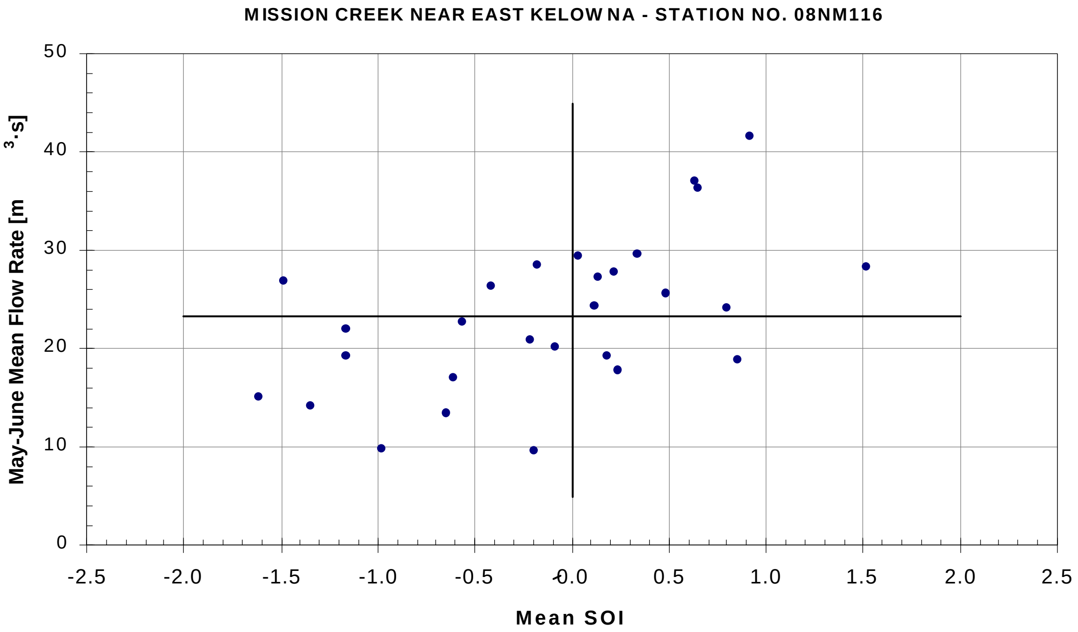


Figure 8A. Snow melt runoff and SOI correlation, Okanagan Basin (April to September SOI and following year values for May and June flows).



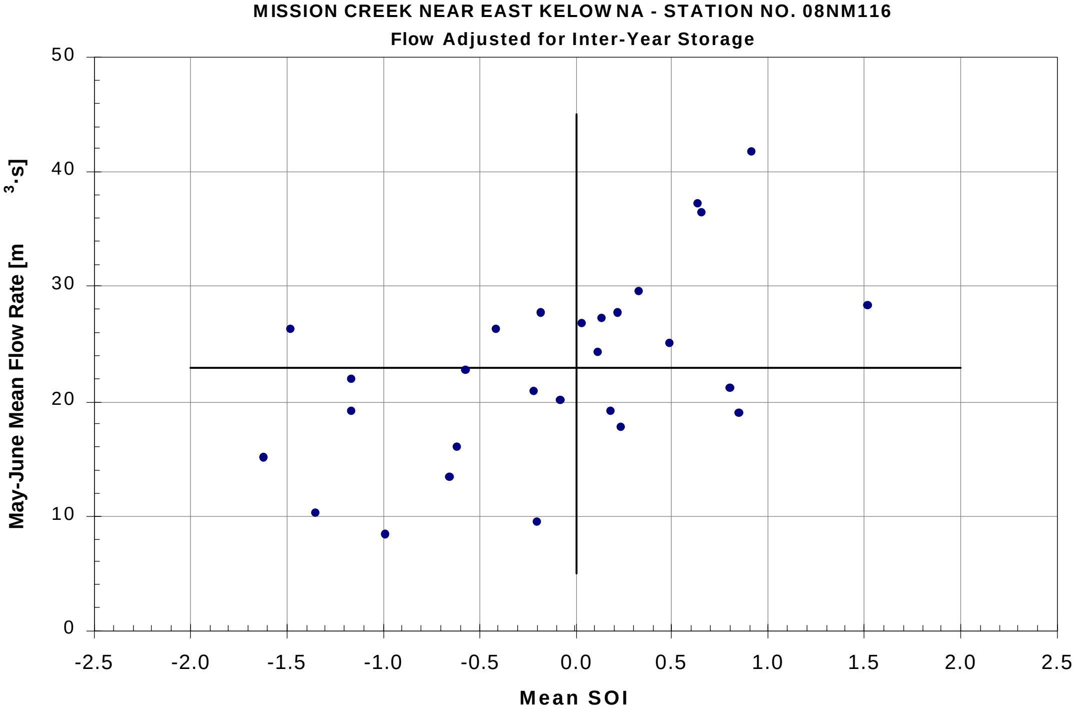


Figure 8B. Snow melt runoff and SOI correlation, Mission Creek Basin (April to September SOI and following year values for May and June flows).

APPENDIX A. Hydrological Data Okanagan Lake

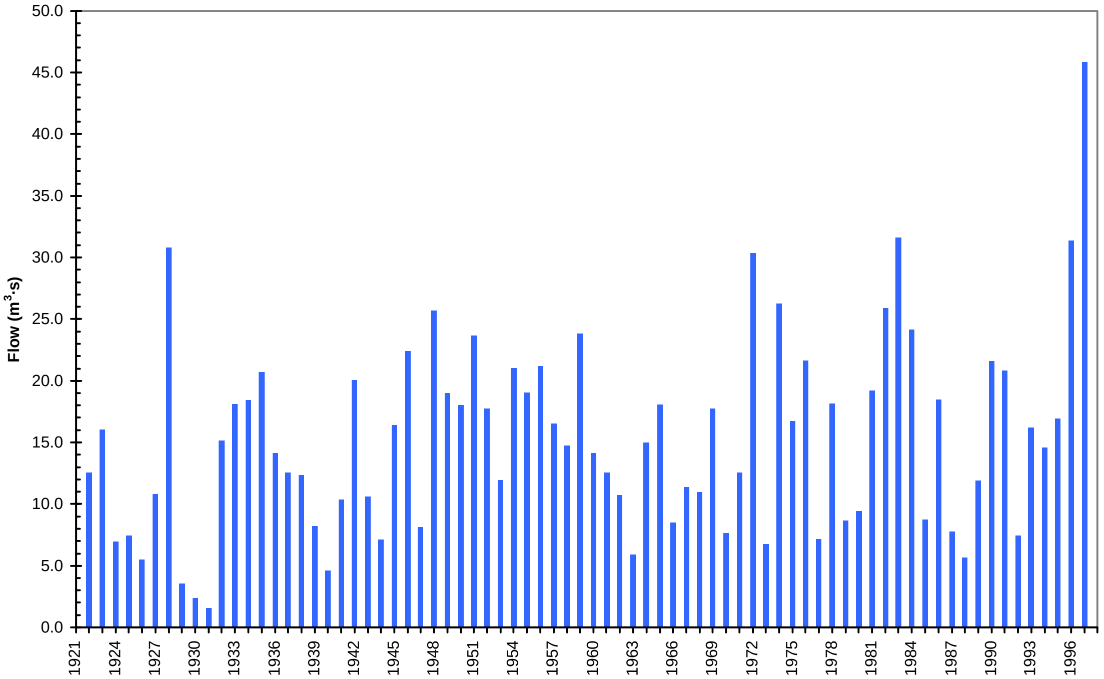


Figure A1. Mean Annual Flows at Okanagan River at Penticton - Station No. 08NM050.

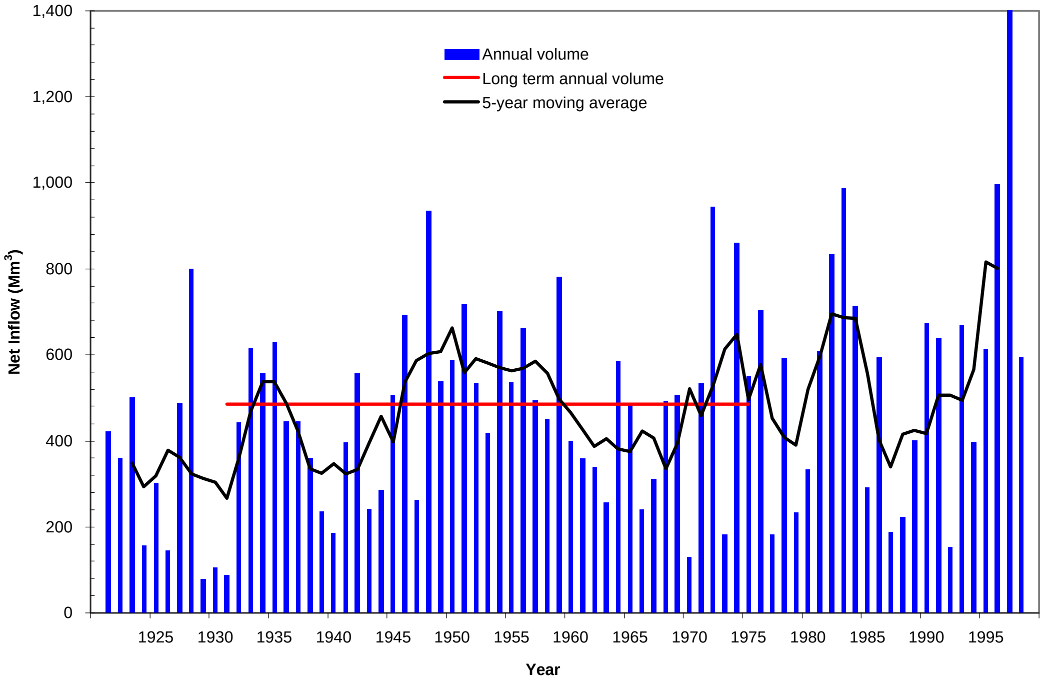


Figure A2.1 Okanagan Lake Annual Net Inflow Volume (for the period 1921 to 1998)

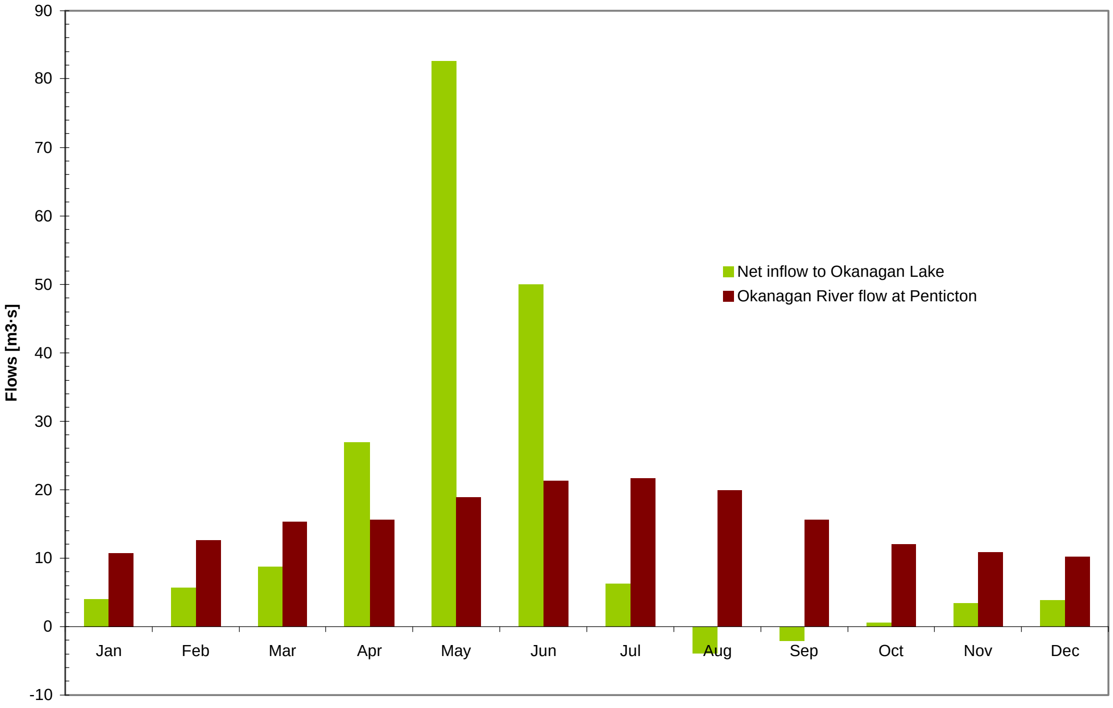


Figure A2.2 Okanagan Lake Net Inflow and Outflow at Penticton (average value over 78 years, for the period 1921 to 1999)

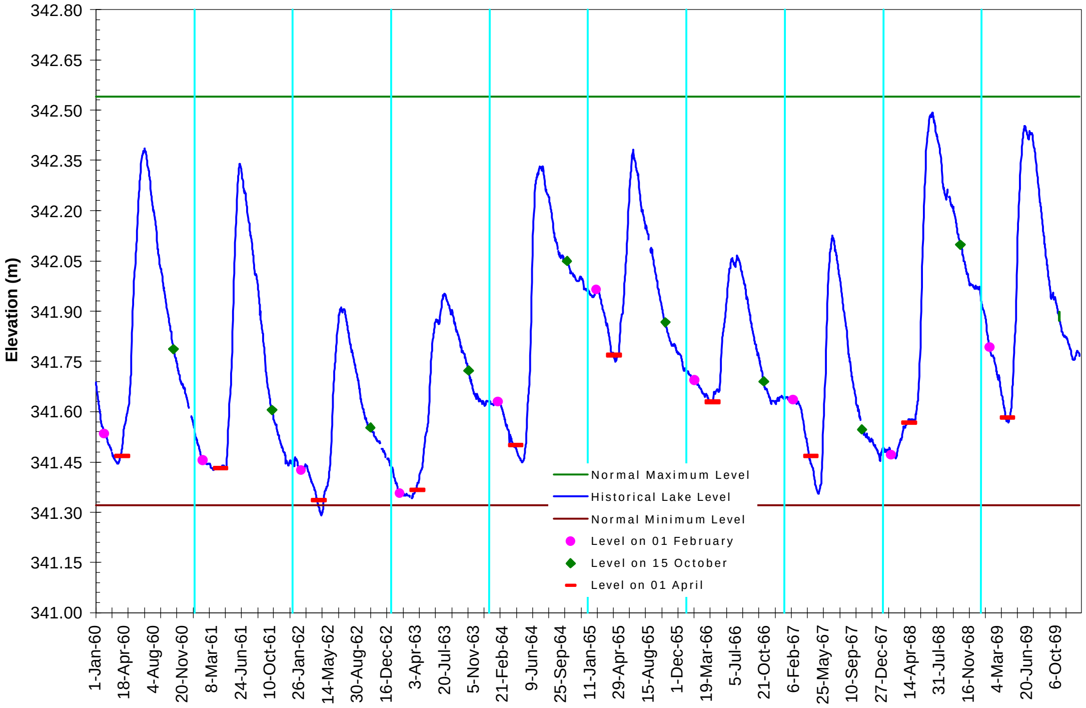


Figure A3.1 Okanagan Lake Historical Water Surface Levels, 1960-1969.

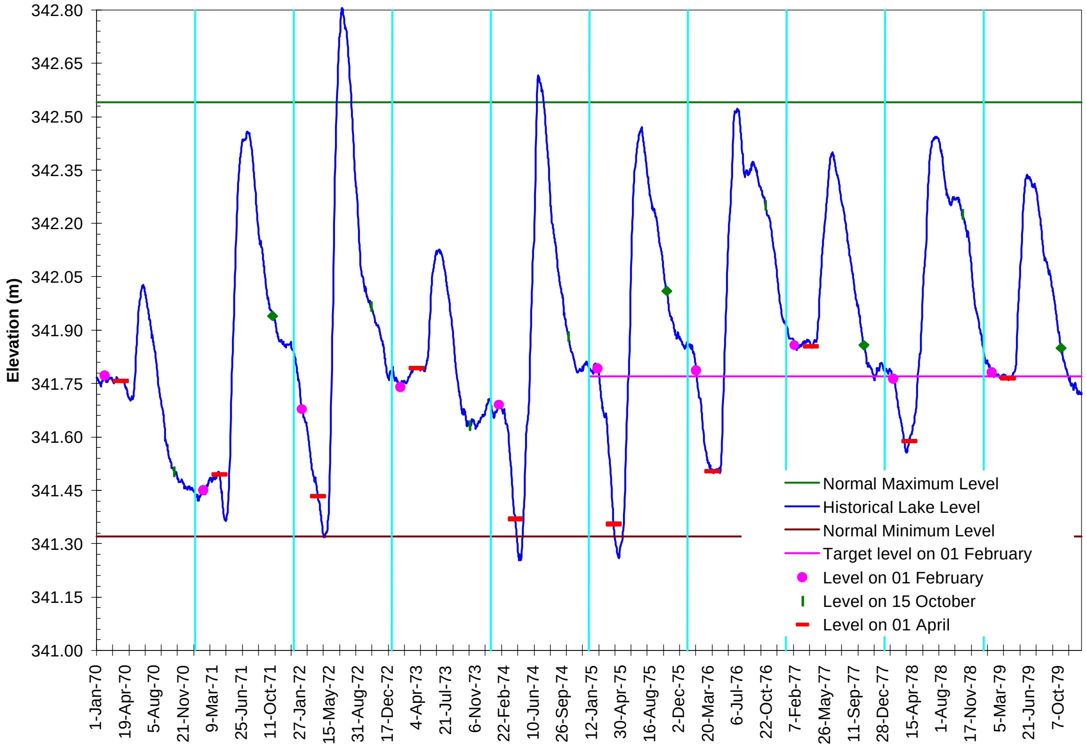


Figure A3.2 Okanagan Lake Historical Water Surface Levels, 1970-1979.

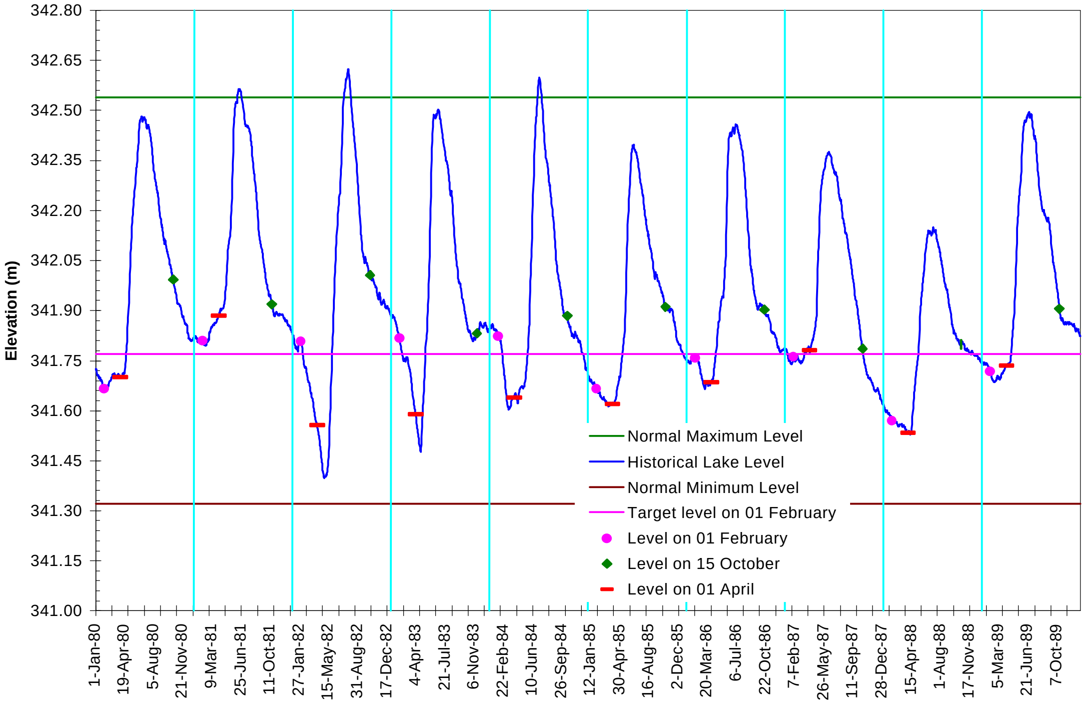


Figure A3.3 Okanagan Lake Historical Water Surface Levels, 1980-1989.

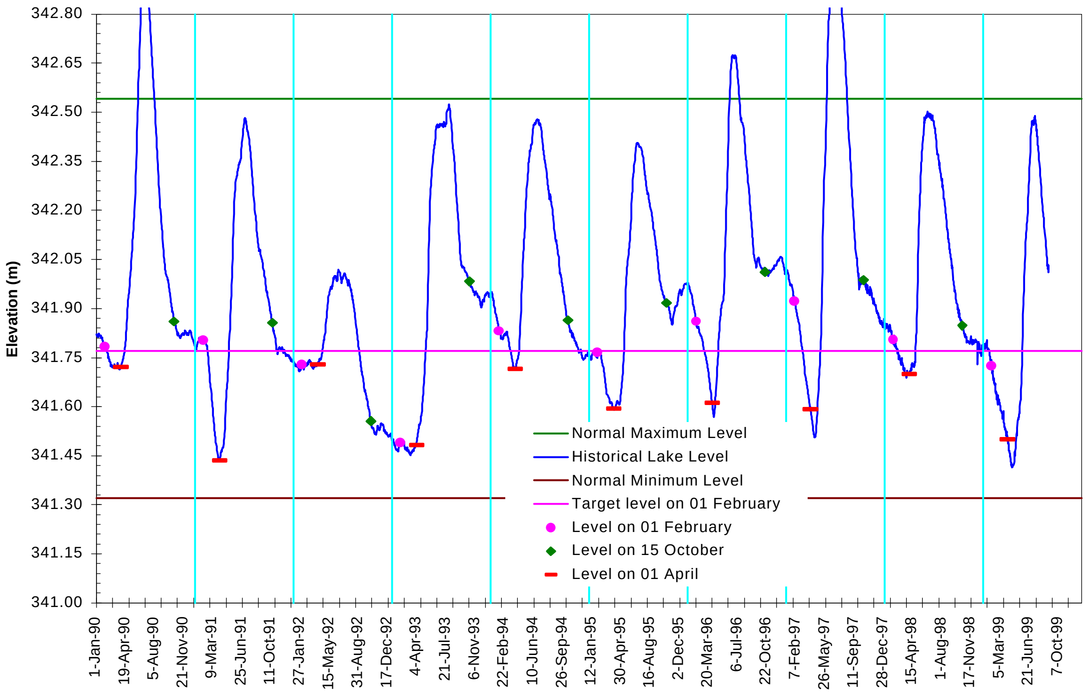


Figure A3.4 Okanagan Lake Historical Water Surface Levels, 1990-1999.

APPENDIX B. Historical Air Photos Okanagan Lake at the Outlet

Figure B.1 1938 Photo.

Figure B.2 1954 Photo (approximate scale 1:5,000).

Figure B.3 1977 Photo (approximate scale 1:12,000).

Figure B.4 1996 Photo (approximate scale 1:15,000).

PROGRESS REPORT

ESTABLISHMENT OF A LONG-TERM FLOW MONITORING PROGRAM ON OKANAGAN LAKE TRIBUTARIES

by

Robert J. Kirk[1]

INTRODUCTION

In the Okanagan region of British Columbia the water resource is severely limited by a combination of low precipitation, hot dry summers and growing human demand. This problem is particularly evident on Okanagan Lake where water shortages in many of the tributary streams have played a major role in the long-term decline of the kokanee (*Oncorhynchus nerka)* population. On most streams fish minimum flow data has not been collected in recent years and as a result, it is unclear how current flow regimes are impacting kokanee survival. The Okanagan Lake Action Plan described in detail by Ashley and Shepherd (1996) identified the need for long-term stream flow monitoring and investigation of potential flow restoration strategies.

Okanagan Lake has 46 named tributaries of which 20 are known to support either rainbow trout (*Oncorhynchus mykiss*) or kokanee (Shepherd 1990, MS). Water licenses issued to service domestic and irrigation needs in the Okanagan Valley have placed an excessive demand on a very limited resource in many of these streams. As a result, these streams often become partially or totally de-watered, threatening the life cycle of resident and lacustrine salmonids. Flow data from Okanagan Lake tributary streams are either outdated, having been collected prior to the 1980s, or are insufficient to determine water level requirements and the effects of overuse on the indigenous fish populations (Ward et al. *in* Ashley et al. 1999; Ptolemy pers comm.).

This report outlines the methodology and results of the first year of a monitoring program designed to document current flow conditions. In conjunction with flow monitoring, water temperatures were also recorded. It is important to note that this is the first year of a long-term monitoring program, therefore, the data may not be representative of typical conditions and demands placed upon the water resource. Several more years of data are required before any firm conclusions and recommendations can be made.

BACKGROUND

One of the primary objectives of the OLAP is to ensure that remaining stream habitat is protected and maintained. Several priority remedial initiatives have already been undertaken in a long-term effort to reverse the deterioration of some of the primary spawning streams. The first of these initiatives are described in Chapter 1 of Ashley et al. (1998; 1999). The need for better base flow information has also been identified as a priority thus leading to this present work.

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In early1999, a committee of staff from the Penticton office of the Ministry of Environment Lands and Parks (MELP), Ward and Associates, and BC Conservation Foundation (BCCF) contractors compiled a summary of historical stream flow data. This information included but was not limited to a review of historical documents, information on current water licenses as well as the locations of current and historical water stations from the Water Survey of Canada (WSC). This committee then prioritized all the tributaries according to their importance to fish and degree of data available. Twelve tributaries were selected and sample stations were then designated for long-term monitoring. Streams chosen included Naramata, Trout, Prairie Valley, Eneas, Peachland, Trepanier, Powers, McDougall, Lambly, Shorts, Thomson Brook, and Bellevue. It should be noted that several of the larger streams, namely Mission and Kelowna creeks, were not included in this study due to their size and the relatively extensive amount of data available on flows and water levels. Streams at the north end of the lake (Nashwhito, Equeisis, and Whitemans creeks) were monitored separately by the Westbank First Nation but the results were not available at the time of writing.

METHODS

In late spring of 1999, field site inspections were conducted by agency representatives and the primary contractors (BCCF and Ward and Associates) to determine location of all staff gauges and flow monitoring transects. R. Ptolemy of the Ministry of Fisheries, Victoria, provided some initial direction on methodology and training.

Staff Gauge Installation

Temporal fluctuations in water levels were measured using standard aluminum stream gauges (1.3 m x 0.15 cm) calibrated in cm. One gauge was installed in the creek at each sample station in a location that was likely to remain watered all year and easily visible to project technicians. A 2 m section of T-bar was pounded into the substrate at the selected location and the gauge was mounted flush to the ground and attached to the bar using wire and plastic cable ties. A benchmark (standard 10 cm bolt) was established on a nearby permanent structure (i.e., bridge abutments, large trees) and spray painted fluorescent orange. The gauge was tied-in to the benchmark by measuring the distance and height at which the benchmark was level with the gauge.

Gauges were read each time the technicians visited the site and the height in cm was recorded in their field notebooks. Gauge levels and flow measurements were taken once every two weeks from June to October 1999.

The following presents a brief description of the location of each sample station. Locations are given in kilometers upstream of the creek mouth.

Naramata Creek

Four stations were established along the length of this creek. A headwater site (5.0 km) was placed immediately downstream of the Naramata Irrigation District Pumphouse off of the KVR rail line. A second station (2.5 km) was located above Naramata Road, a third station (1.2 km) was at the bridge on 8th Avenue and the final station was established above the bridge (0.1 km) at 1st Avenue.

Trout Creek

Three stations were established on the creek. The uppermost station was immediately upstream of the Summerland diversion flume (7.0 km). The middle site was immediately downstream of the deeply incised canyon on the lowlands (3.0 km) and the final site was adjacent to Sun-Oka Provincial Park (0.5 km).

Prairie Valley Creek

Fish passage in this creek is limited to the initial 70 metres upstream of the lake. After this point the creek is culverted as it works its way through Summerland. The one sample station (0.5 km) was located immediately below the second culvert upstream from the lake.

Eneas Creek

This creek flows through Summerland and is culverted through much of its upper reaches. One sample station (0.8 km) was established in the lower portion upstream of Lakeshore Road.

Peachland Creek

Due to a barrier created by Hardy Falls, only the first 1.2-km of this creek are accessible to migrating salmonids. The sample station (0.5 km) was established downstream of the first bridge above the highway.

Trepanier Creek

Two stations were established on this creek. One station was established near the mouth approximately (0.1 km) above the lakeshore road crossing. The other station (1.3 km) was above the trailer park situated on the north side of the highway.

Powers Creek

Three stations were established along this large creek in Westbank. The lower station was approximately 1.2 km upstream of the creek mouth. The middle station (1.4 km) was immediately upstream of the Gelately field diversion pipe and the upper station (3.0 km) was upstream of the highway crossing. It is interesting to note that due to the increased rainfall, the diversion was not used at all this season.

McDougall Creek

This small creek flows through Westbank and is located near Bartley Road. Two stations were established along the creek, one in the undeveloped highlands (8.0 km), and one across from the Crystal Springs housing development (3.5 km).

Lambly Creek

This creek is located in the northwest end of Westbank and discharges into Okanagan Lake through Bear Creek Provincial Park. One station (0.7 km) was used to monitor stream flow and was established downstream of the first bridge within the Park.

Shorts Creek

Shorts Creek is situated on the westside of the lake at the north end of the study area and flows through Fintry Provincial Park. Two stations were established to monitor flows through this large creek. The lower station is approximately 0.5 km upstream of the mouth, while the upper station (2.3 km) was located approximately 150 m above the highway crossing.

Thomson Brook

This small Kelowna watercourse is connected to Okanagan Lake via a series of agricultural sloughs. The sample station was established downstream of the confluence with the slough on the Thomson Farm.

Bellevue Creek

This creek flows into Kelowna from the mountains at the southeast end of the city. One station was established along the lower reaches (2.0 km) at the Parot Road crossing while the upper station was located above the South Okanagan Management Irrigation District (SOMID) diversion (6.0 km).

Flow Measurements

Linear transects were established at each site and measurements were taken along this line during every site visit. Attempts were made to visit each creek weekly and conduct a full cross-sectional analysis.

Marsch-McBirney Model # 2000 digital flow meters were used to measure water discharge at 15 (or 20) points along the transect. The interval between readings was determined by dividing the wetted width of the smaller streams by 15 and larger ones by 20. At each point along the transect, water depth, velocity (m sec) and the substrate type were measured and recorded. Date stamped photographs were taken to document the conditions both upstream and downstream of the transect.

Field data was later input into a computer model, which calculated and created discharge curves for each sampling session.

Habitat Assessment

A detailed assessment of fish habitat characteristics at each sample site was conducted to characterize changes in habitat conditions over the course of the summer. Habitat characteristics in the vicinity of each transect were assessed according to protocols developed by MELP (R. Ptolemy, Victoria Fisheries, pers. comm). These protocols are a simplified version of those currently used province-wide described by Johnston and Slaney (1996), Slaney and Zaldokas (1997) of the Watershed Restoration Program (WRP). Site photographs were also taken to visually describe general fish habitat characteristics as well as channel characteristics in the vicinity of the sampling transect.

Reach length was defined as 20 times the wetted width of the channel and extended in an upstream direction. Within the reach, individual habitat units were subjectively identified and gross measurements taken on each habitat unit. These measurements included: stream name; reach length; habitat class (run, riffle, pool, etc.); length of habitat unit; wetted width; channel width; area; mean depth; maximum depth; percent in-stream log cover; percent of instream boulder cover, percent of instream vegetation; percent of overstream vegetation; percentage of cutbanks in the reach; general turbidity; reach gradient; D_{max}; D_{90}; dominant substrate; subdominant substrate; degree of compaction; ambient air; and water temperature.

In addition to the work described above, diversion volumes were monitored at various licensed intakes on Trout Creek and Trepanier Creek. This data will be used to determine if the diversion volume is in compliance with the water license. The reader is referred to Ward et al. (2000 *in* this Action Plan Report) for further information.

Temperature Monitoring

Eighteen “Stow-away Tidbit” temperature recorders (Onset Computer Corporation) were utilized for monitoring stream temperatures. Each thermister was calibrated then placed in the vicinity of the site staff gauge. Locations were not flagged or made conspicuous in any other way in the hope of limiting disturbance or theft. Temperature data will be returned from the recorders prior to freshet (late March 2000), after which temperature monitoring will be re-initiated for the year 2000 program.

Recorders were calibrated to take readings every hour and were installed at the following locations:

Stream Name	# of Units	Serial #'s
Naramata Creek	2	335, 317
Trout Creek	3	903, 902, 864
Prairie Valley Creek	1	857
Eneas Creek	1	900
Peachland Creek	1	865
Trepanier Creek	2	326, 333
Powers Creek	1	303
McDougall Creek	1	327
Lambly Creek	1	325
Shorts Creek	1	300
Thomson Brook	1	894
Bellevue Creek	2	314, 906

RESULTS AND DISCUSSION

Initial field work commenced June 20, 1999, on Trepanier Creek and monitoring of the 12 streams continued daily until October 15th at which point water levels appeared to be stabilized for the winter. Overall, the summer weather conditions in the entire Okanagan Valley were unusual with below normal temperatures and above normal rainfall throughout the sampling period (Env. Can. 1999). Consequently, agricultural demands for water from the tributaries were well below normal and none of the creeks were observed to be in danger of de-watering.

The following presents a brief summary of results obtained from the first year of the flow-monitoring program on various tributaries to Okanagan Lake (Table 1). Fish habitat characteristics are currently being analyzed and will presented in the 2001 Action Plan report. Site photographs are contained in a series of catalogued photo-binders currently in the possession of the MELP Fisheries Office, Penticton.

Table 1. Summary of work completed on each stream in the 1999 baseline flow-monitoring program on Okanagan Lake.

Creek Name	**Length (km)**	**No. of Stations**	**Velocity Measures**	**Water Level Readings**	**Habitat Assessments**
Naramata	N/A	4	51	90	8
Trout	72.5	3	33	61	6
Prairie Valley	N/A	1	13	25	3
Eneas	24.2	1	13	25	3
Peachland	24.2	1	10	22	3
Trepanier	27.4	2	25	48	6
Powers	25.8	3	31	56	7
McDougall	14.5	2	22	43	7
Lambly	20.9	1	15	26	3
Shorts	25.8	2	26	47	8
Thomson	N/A	1	13	21	3
Bellevue	17.7	2	26	39	7

Water levels dropped on all creeks throughout the study period from the initiation of monitoring (post-freshet) in June. The levels appeared to be stabilized by mid-October (Figs. 1–23). Discharge displayed similar trends generally decreasing from June through to October. The observed increases in discharge (Figs. 1-23) were most likely due to storm events. In the case of heavily utilized systems (i.e., Naramata and Trout creek) changes in measured flows were most likely the result of water diverted from the creek for domestic and or irrigation purposes (Figs. 1-23).

The 1999 data reflects normal discharges based on what little historical data is available for these streams. It is interesting to note that, despite the above normal precipitation received in 1999, five of the study creeks (i.e., Trout, McDougall, Lambly, Shorts, Bellevue) had brief periods in the fall when they did not maintain recommended minimum flows needed to sustain spawning salmonids (Ptolemy pers comm.). It is not known what effect these brief water shortages had but it underlines the precarious state of these important spawning streams. The inability of a stream to supply adequate flows consistently during the entire year is most likely to severely impair the spawning success of Okanagan Lake rainbow trout and kokanee.

Water temperature data was not available at the time this report was completed. As noted earlier, the recorders will be collected in the spring of 2000 and the data will be downloaded at that time. An assessment of the 1999 temperature regimes will be included in the Year 5 OLAP Annual Report.

Two of the temperature recorders were vandalized (i.e., removed) during the course of the summer. Both Trepanier Creek sites and lower Bellevue Creek had very high pedestrian traffic and often showed signs of site disturbance. One thermister was lost at each site and was replaced. As of the end of the program in October no other sites had been disturbed.

CONCLUSIONS

Flows were monitored and water temperatures recorded on 12 Okanagan Lake tributaries from July through to October. Based on the field measurements it was concluded that for the most part all study streams sustained adequate water levels for fish throughout the summer. There were brief periods in the fall when some creeks dropped below the suggested minimum limits. The impacts of these lower flows on fish or fish eggs are unknown.

It is believed that high(er) water levels observed in the systems were due to above normal rainfall and below normal temperatures that occurred throughout the summer of 1999. These flows were not likely due to changes in domestic or agricultural water use patterns. More data will be required to determine which streams are being over utilized and at what time of the year this is occurring.

RECOMMENDATIONS

The following recommendations are put forth to facilitate the planning of next year's program.

1. Continue monitoring all streams in 2000, for both temporal flow water level fluctuations, and water temperature.

2. Incorporate monitoring of diurnal fluctuations on those creeks with suspected non-compliant users.

3. Intensify flow measurements when kokanee are spawning to ensure minimum levels are maintained.

4. Add more streams to the monitoring program if staffing and funding permit.

5. To alleviate the storage of large quantities of photographs in the office it is suggested that digital cameras be utilized to capture and store site images on CD's and the MELP server.

6. A more thorough investigation of individual license compliance should be initiated throughout the study area.

REFERENCES

Ashley, K.I. and B.G. Shepherd. 1996. Okanagan Lake Workshop Report and Action Plan. Fisheries Project Report No. RD 45. Ministry of Environment, Lands and Parks, Province of British Columbia. 120 pp.

Ashley, K., Bruce Shepherd, Dale Sebastian, Lisa Thompson, Lidija Vidmanic, Dr. Peter Ward, Hansen A. Yassien, Laurie McEachern, Rick Nordin, Dr. Dave Lasenby, Janice Quirt, J.D. Whall, Dr. Peter Dill, Dr. Eric Taylor, Susan Pollard, Cecilia Wong, Jan den Dulk, George Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Ashley, K.A., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, and G. Scholten. 1999. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. 78. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Environment Canada. 1999. Canadian Meteorological Survey data found on its website at: www.weather.ec.gc.ca

Johnson, N.T. and P.A. Slaney. 1996. Fish Habitat Assessment Procedures. Watershed Restoration Technical Circular No. 8 revised April 1996. Watershed Restoration Program, Ministry of Environment, Lands and Parks and Ministry of Forests, BC Government.

Slaney P. A. and D. Zaldokas. 1997. Fish Habitat Rehabilitation Procedures Watershed Restoration Technical Circular No. 9. Watershed Restoration Program. Ministry of Environment, Lands and Parks and Ministry of Forests, BC Government.

Shepherd, B.G. 1990. Okanagan Lake Management Plan, 1990-1995. BC Min. Env., Recreational Fish. Progr., Penticton, BC.

Naramata Canyon (headwater)		
Date (1999)	Flow (cms)	Gauge (m)
7/14/99	0.1000	0.41
7/20/99	0.0486	0.40
8/12/99	0.0564	0.39
8/18/99	0.1550	0.44
8/24/99	0.3040	0.37
8/31/99	0.2256	0.47
9/2/99	0.1873	0.46
9/8/99	0.1364	0.45
9/10/99	0.1057	0.40
9/16/99	0.1079	0.41
9/21/99	0.5049	0.39
9/28/99	0.1176	0.43

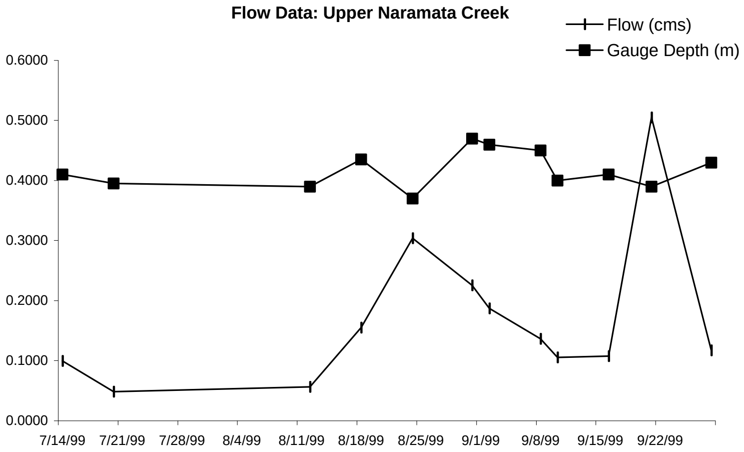


Figure 1. Flow Data - Upper Naramata Creek

Naramata at Naramata Rd		
Date (1999)	Flow (cms)	Gauge (m)
7/8/99	0.7024	0.39
7/12/99	0.1064	0.39
7/20/99	0.0732	0.29
8/12/99	0.0179	0.24
8/18/99	0.1550	0.32
8/24/99	0.4056	0.26
8/31/99	0.2731	0.35
9/3/99	0.2090	0.34
9/8/99	0.1251	0.31
9/10/99	0.0938	0.30
9/16/99	0.0961	0.30
9/21/99	0.0508	0.27
9/28/99	0.1113	0.31

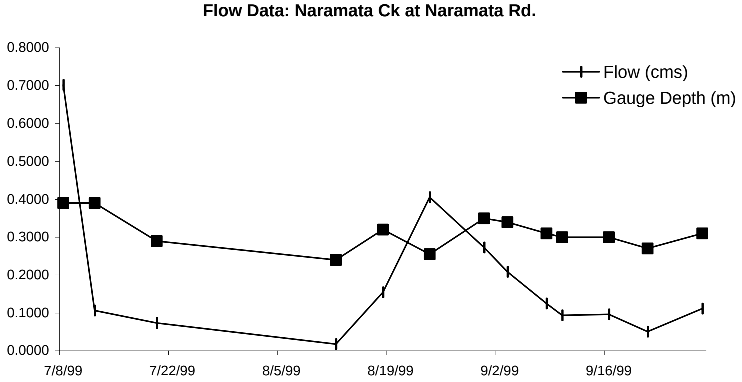


Figure 2: Flow Data - Naramata Creek at Naramata Road

Naramata at the 8th St. Bridge		
Date (1999)	Flow (cms)	Gauge (m)
7/8/99	0.4286	0.31
7/12/99	0.0839	0.19
7/20/99	0.0646	0.19
8/12/99	0.0537	0.17
8/18/99	0.1446	0.23
8/24/99	0.0286	0.15
8/31/99	0.2156	0.25
9/2/99	0.1807	0.28
9/8/99	0.1813	0.21
9/10/99	0.0975	0.20
9/16/99	0.1020	0.21
9/21/99	0.0791	0.17
9/28/99	0.1451	0.21

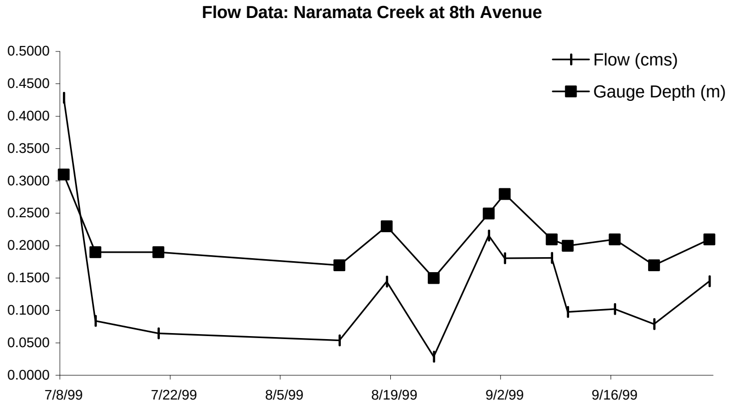


Figure 3. Flow Data - Naramata Creek at 8th Avenue

Naramata at the 1st St. Bridge

Flow Data: Naramata Creek Mouth

Date (1999)	Flow (cms)	Gauge (m)
7/8/99	0.4411	0.35
7/12/99	0.1262	0.24
7/20/99	0.0569	0.19
8/12/99	0.0435	0.19
8/18/99	0.1649	0.25
8/24/99	0.0239	0.16
8/31/99	0.2258	0.29
9/2/99	0.1809	0.28
9/8/99	0.1302	0.27
9/10/99	0.1091	0.25
9/16/99	0.1126	0.24
9/21/99	0.0636	0.20
9/28/99	0.1427	0.25

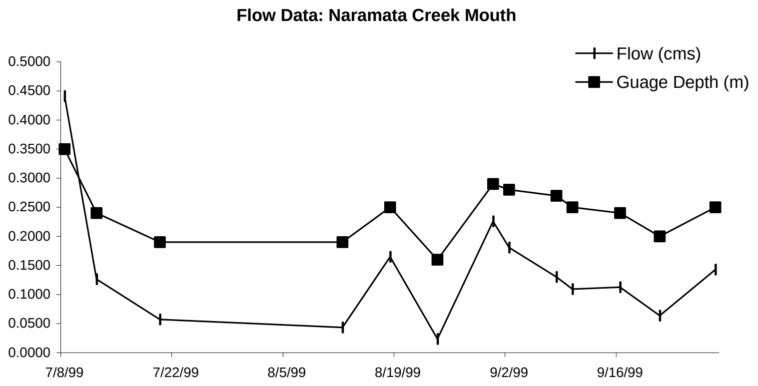


Figure 4. Flow Data - Naramata Creek Mouth

Trout Creek Diversion		
Date (1999)	Flow (cms)	Gauge (m)
7/7/99	4.1696	0.68
7/20/99	2.2570	0.59
7/29/99	1.2624	0.53
8/6/99	1.3841	0.55
8/18/99	1.4896	0.59
8/26/99	1.1284	0.49
9/2/99	0.8950	0.58
9/8/99	0.5777	0.53
9/10/99	0.5222	0.49
9/16/99	0.6315	0.52
9/28/99	0.7750	0.55
9/30/99	1.0872	0.55

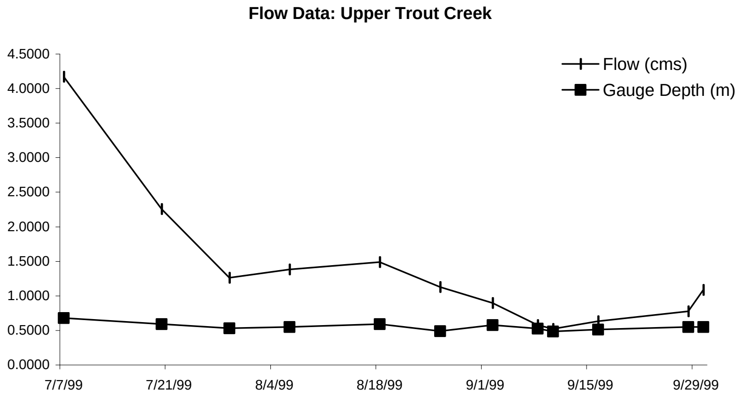


Figure 5. Flow Data - Upper Trout Creek

Trout Creek at the Canyon		
Date (1999)	Flow (cms)	Gauge (m)
7/14/99	1.2745	0.58
7/20/99	1.6691	0.61
7/29/99	0.2739	0.37
8/18/99	1.5389	0.62
8/26/99	0.2142	0.37
9/2/99	0.7681	0.59
9/8/99	0.6257	0.50
9/10/99	0.2258	0.41
9/16/99	0.3508	0.44
9/21/99	0.3694	0.41
9/28/99	0.6668	0.54

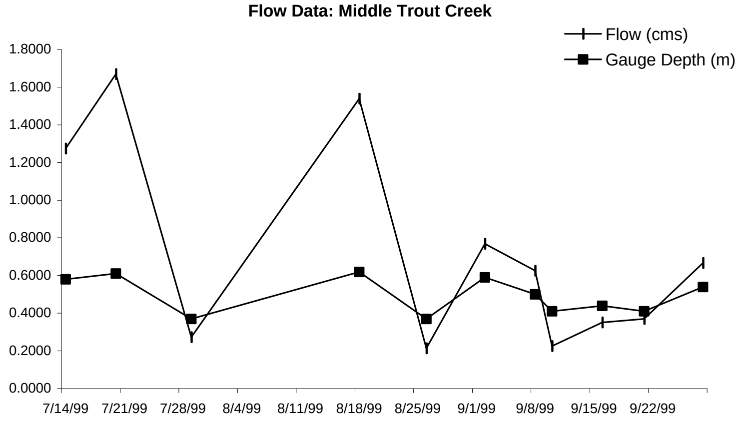


Figure 6. Flow Data - Middle Trout Creek

Trout Creek at the Mouth		
Date (1999)	Flow (cms)	Gauge (m)
7/8/99	6.4653	0.87
7/20/99	0.9774	0.76
7/29/99	0.3912	0.64
8/18/99	1.2523	0.38
8/26/99	1.6390	0.39
9/10/99	0.1875	0.39
9/16/99	0.2301	0.42
9/21/99	0.1721	0.41
9/28/99	0.6009	0.49

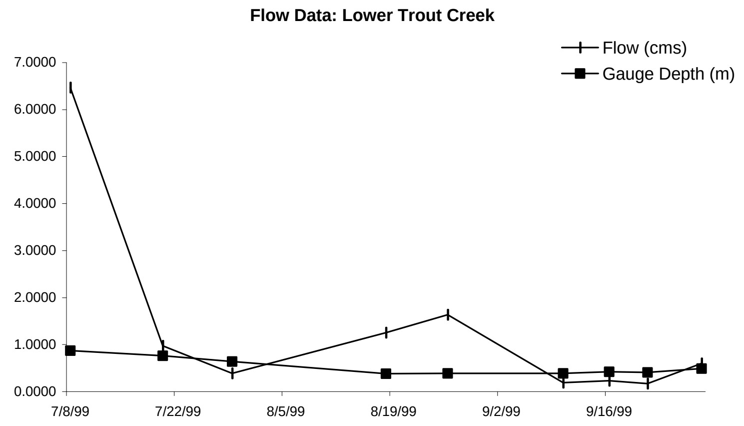


Figure 7. Flow Data - Lower Trout Creek

Prairie Valley		
Date (1999)	Flow (cms)	Gauge (m)
7/7/99	0.0655	0.17
7/22/99	0.0366	0.15
8/12/99	0.0394	0.17
8/19/99	0.0669	0.15
8/23/99	0.0876	0.20
8/31/99	0.0777	0.19
9/2/99	0.0881	0.18
9/8/99	0.0831	0.19
9/10/99	0.0750	0.19
9/16/99	0.0755	0.19
9/21/99	0.0769	0.19
9/28/99	0.0859	0.19
9/30/99	0.0675	0.19

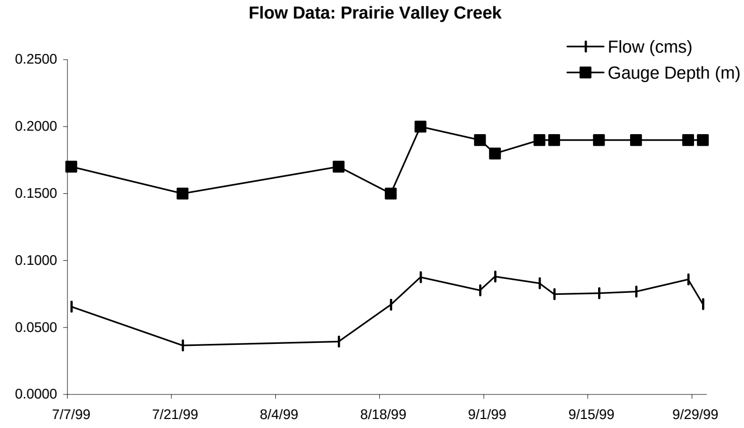


Figure 8. Flow Data - Prairie Valley Creek

Eneas		
Date (1999)	Flow (cms)	Gauge (m)
7/7/99	0.2693	0.43
7/12/99	0.1400	0.37
8/12/99	0.0868	0.35
8/19/99	0.1002	0.37
8/23/99	0.1056	0.37
8/31/99	0.1209	0.37
9/2/99	0.1002	0.37
9/8/99	0.3287	0.51
9/10/99	0.2972	0.50
9/16/99	0.3294	0.52
9/21/99	0.2552	0.52
9/28/99	0.0882	0.34
9/30/99	0.2519	0.43

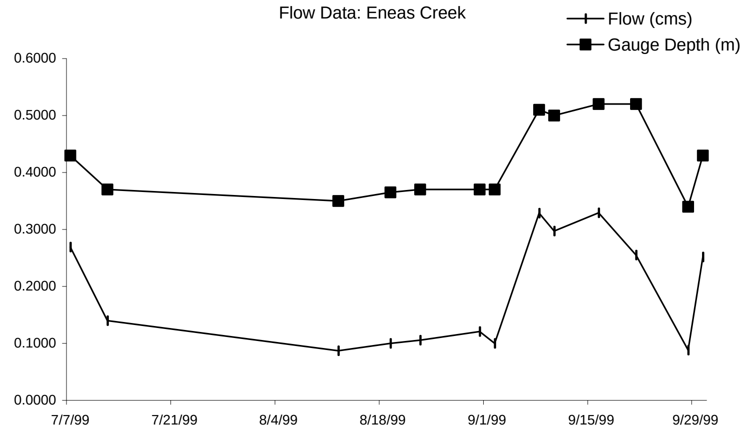


Figure 9. Flow Data - Eneas Creek

Peachland		
Date (1999)	Flow (cms)	Gauge (m)
7/6/99	0.8782	0.71
7/12/99	0.3485	0.65
8/17/99	0.3026	0.50
8/23/99	0.2701	0.65
8/31/99	0.4016	0.65
9/2/99	0.3820	0.65
9/8/99	0.3842	0.66
9/10/99	0.3484	0.65
9/16/99	0.3214	0.65
9/30/99	0.3299	0.60

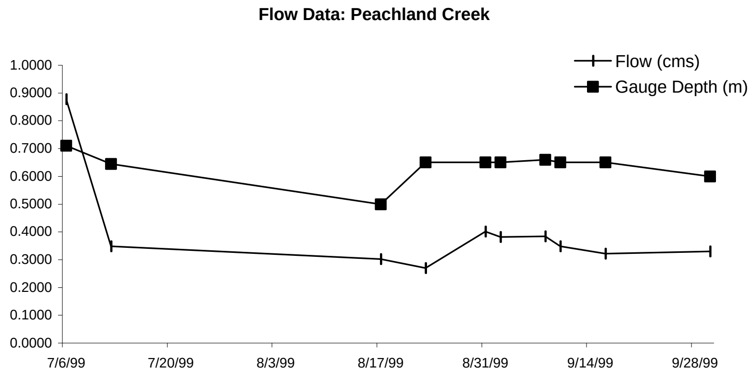


Figure 10. Flow Data - Peachland Creek

Tepanier Creek at the Mouth		
Date (1999)	Flow (cms)	Gauge (m)
6/30/99	2.4722	0.47
7/20/99	1.1440	0.35
7/29/99	0.6595	0.30
8/6/99	0.4066	0.27
8/26/99	0.2845	0.29
8/31/99	0.2705	0.26
9/2/99	0.2942	0.26
9/8/99	0.2537	0.26
9/10/99	0.1791	0.25
9/16/99	0.1615	0.23
9/21/99	0.3363	0.22
9/28/99	0.2965	0.29
9/30/99	0.4036	0.29

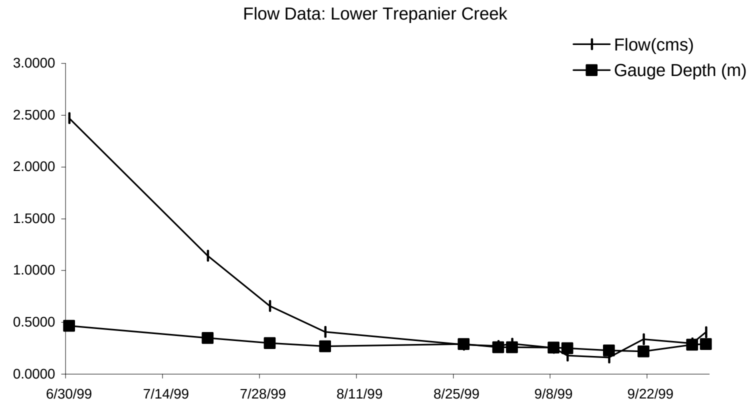


Figure 11. Flow Data - Lower Trepanier Creek

Trepanier Creek Footbridge		
Date (1999)	Flow (cms)	Gauge (m)
7/7/99	2.8393	0.50
7/20/99	1.1405	0.38
7/29/99	0.6527	0.33
8/26/99	0.3131	0.25
8/31/99	0.3616	0.26
9/8/99	0.3109	0.24
9/10/99	0.2314	0.23
9/16/99	0.1967	0.21
9/21/99	0.2168	0.21
9/28/99	0.3506	0.27
9/30/99	0.4452	0.27

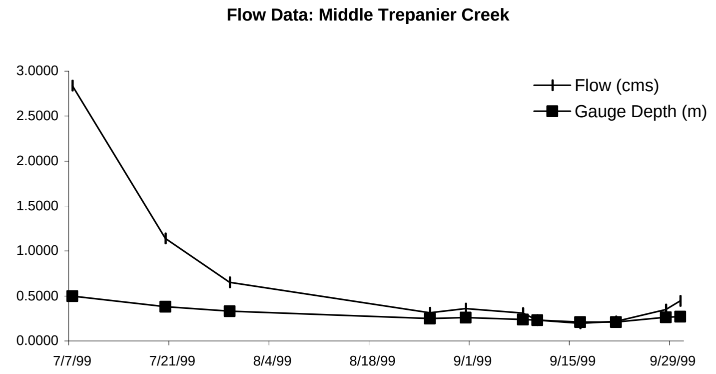


Figure 12. Flow Data - Middle Trepanier Creek

Powers Creek at the Mouth		
Date (1999)	Flow (cms)	Gauge (m)
7/7/99	0.7150	0.51
7/21/99	0.5896	0.47
7/29/99	0.3844	0.46
8/5/99	0.5806	0.46
8/26/99	0.3096	0.40
8/31/99	0.7093	0.47
9/7/99	0.4391	0.44
9/15/99	0.2767	0.39
9/20/99	0.1835	0.36
9/29/99	0.3465	0.40

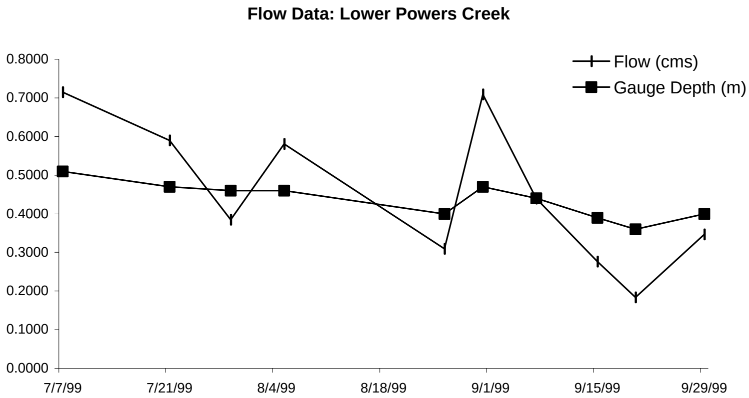


Figure 13. Flow Data - Lower Powers Creek

Powers Creek u/s of Diversion		
Date (1999)	Flow (cms)	Gauge (m)
7/6/99	0.8802	0.49
7/21/99	0.5576	0.46
7/29/99	0.4373	0.45
8/5/99	0.5126	0.45
8/26/99	0.3104	0.40
8/31/99	0.5188	0.47
9/7/99	0.4804	0.45
9/15/99	0.2467	0.41
9/20/99	0.1791	0.39
9/29/99	0.4059	0.42
10/7/99	0.3609	0.42

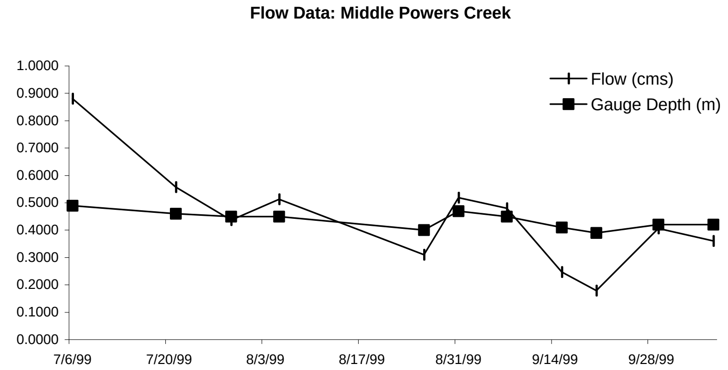


Figure 14. Flow Data - Middle Powers Creek

Powers Creek Canyon		
Date (1999)	Flow (cms)	Gauge (m)
7/7/99	0.9501	0.23
7/21/99	0.7749	0.22
7/29/99	0.4938	0.20
8/5/99	0.5624	0.20
8/26/99	0.2834	0.17
8/31/99	0.5907	0.21
9/7/99	0.4409	0.20
9/15/99	0.2130	0.16
9/20/99	0.0969	0.14
9/29/99	0.3531	0.17
10/7/99	0.2681	0.17

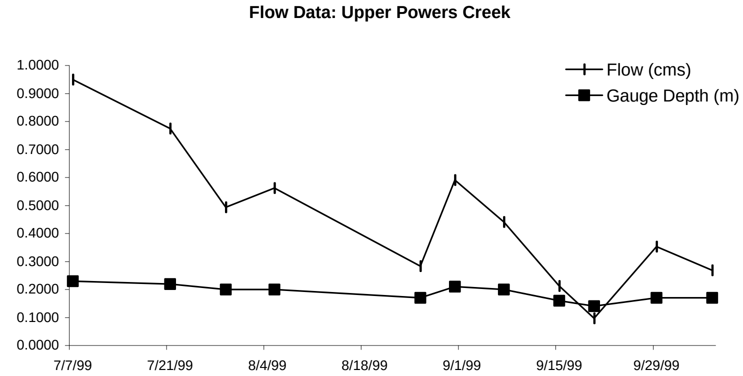


Figure 15. Flow Data - Upper Powers Creek

McDougall Creek Upper End		
Date (1999)	Flow (cms)	Gauge (m)
7/9/99	0.1783	0.48
7/30/99	0.0446	0.35
8/19/99	0.0210	0.31
9/1/99	0.0169	0.28
9/7/99	0.0325	0.29
9/15/99	0.0208	0.27
9/20/99	0.0320	0.26
9/24/99	0.0093	0.25
9/29/99	0.0202	0.25
10/7/99	0.0122	0.25

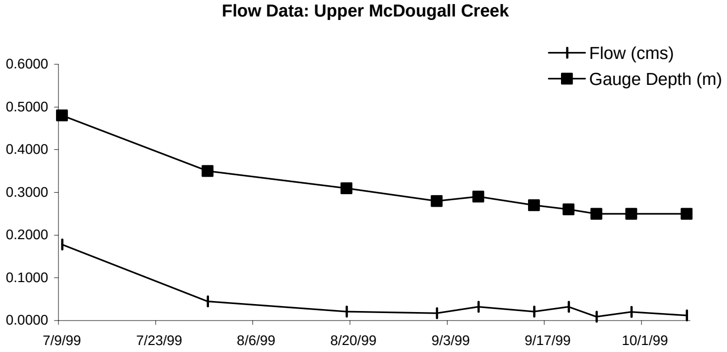


Figure 16. Flow Data - Upper McDougall Creek

McDougall Creek Lower End		
Date (1999)	Flow (cms)	Gauge (m)
7/6/99	0.1742	0.27
7/22/99	0.0605	0.20
7/30/99	0.0363	0.18
8/19/99	0.0220	0.17
8/23/99	0.0097	0.15
8/31/99	0.0264	0.18
9/7/99	0.0225	0.16
9/15/99	0.0112	0.15
9/20/99	0.0106	0.15
9/24/99	0.0070	0.13
9/29/99	0.0114	0.14
10/7/99	0.0107	0.14

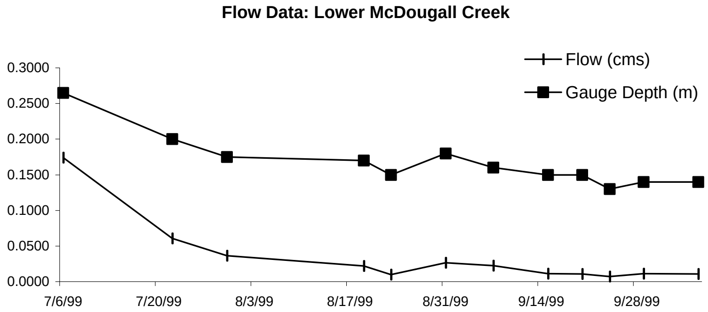


Figure 17. Flow Data - Lower McDougall Creek

Lambly		
Date (1999)	Flow (cms)	Gauge (m)
7/9/99	2.3315	0.80
7/13/99	1.1094	0.69
7/26/99	0.4973	0.57
8/2/99	0.2029	0.47
8/17/99	0.1955	0.45
8/23/99	0.0928	0.42
8/30/99	0.0997	0.44
9/3/99	0.0973	0.44
9/7/99	0.1085	0.47
9/9/99	0.1084	0.45
9/15/99	0.0774	0.45
9/20/99	0.0683	0.44
9/24/99	0.0859	0.44
9/28/99	0.1583	0.45
10/7/99	0.1382	0.45

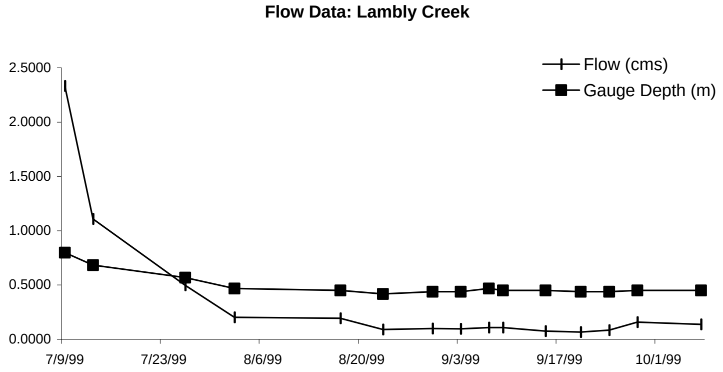


Figure 18. Flow Data - Lambly Creek

Shorts Creek Upper End		
Date (1999)	Flow (cms)	Gauge (m)
7/9/99	2.4916	0.88
7/13/99	1.3445	0.35
7/26/99	0.6700	0.29
8/2/99	0.3456	0.25
8/17/99	0.3254	0.24
8/23/99	0.1524	0.20
8/30/99	0.0839	0.18
9/3/99	0.0716	0.18
9/9/99	0.1153	0.18
9/15/99	0.0676	0.16
9/24/99	0.0531	0.15
9/22/99	0.0935	0.15
10/7/99	0.0925	0.15

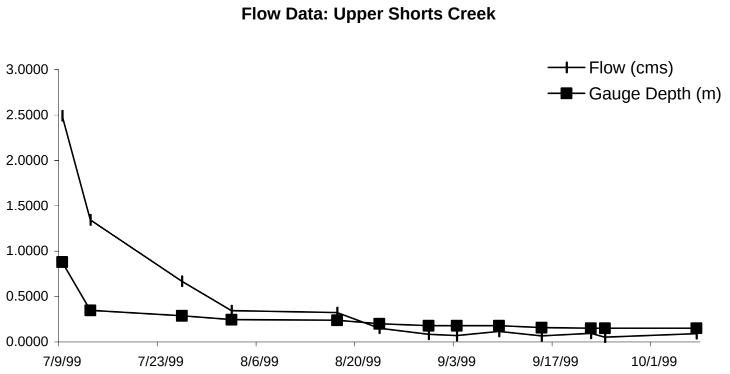


Figure 19. Flow Data - Upper Shorts Creek

Shorts Creek Lower End		
Date (1999)	Flow (cms)	Gauge (m)
7/9/99	2.2255	1.10
7/19/99	0.9171	1.00
7/26/99	0.6074	0.96
8/2/99	0.2498	0.91
8/17/99	0.2534	0.86
8/23/99	0.1311	0.84
8/30/99	0.0621	0.84
9/3/99	0.0942	0.84
9/9/99	0.0406	0.85
9/15/99	0.0102	0.82
9/24/99	0.0063	0.80
9/28/99	0.0721	0.80
10/7/99	0.0402	0.80

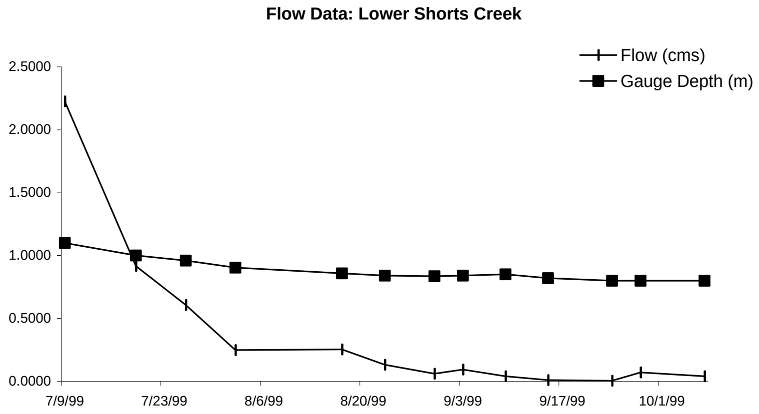
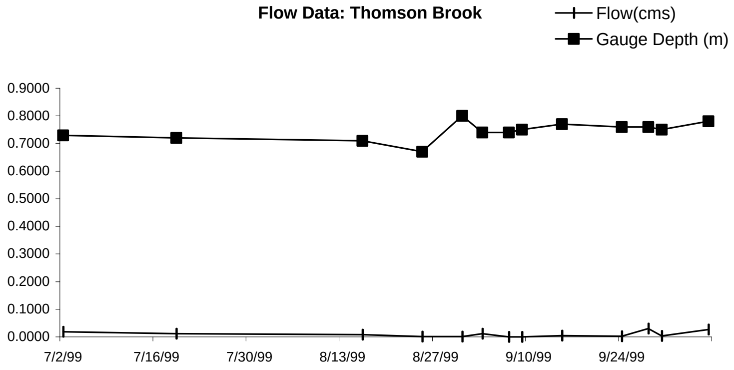


Figure 20. Flow Data - Lower Shorts Creek

Thompson Brook		
Date (1999)	Flow (cms)	Gauge (m)
7/2/99	0.0190	0.73
7/19/99	0.0115	0.72
8/16/99	0.0085	0.71
8/25/99	0.0012	0.67
8/31/99	0.0009	0.80
9/3/99	0.0120	0.74
9/7/99	0.0000	0.74
9/9/99	0.0000	0.75
9/15/99	0.0045	0.77
9/24/99	0.0023	0.76
9/28/99	0.0303	0.76
9/30/99	0.0039	0.75
10/7/99	0.0272	0.78



Note: there is 0.35m of silty muck on the bottom of Thomson Brook

Figure 21. Flow Data - Thomson Brook

CHAPTER 2

MONITORING PROGRAM

This component of the Action Plan involves routine data collection of annual limnological and fisheries information. It involves work that should be conducted an on-going basis to ensure a long-term data base is maintained to follow trends in water chemistry, plankton, mysids, kokanee and rainbow trout in Okanagan Lake. Emphasis has been placed on standardizing and collection of zooplankton, in-lake kokanee abundance estimates and shore and stream spawner counts.

PROGRESS REPORT

PHYSICAL AND CHEMICAL LIMNOLOGY - OKANAGAN LAKE

1999

by

Robert J. Kirk[1]

INTRODUCTION

Long-term decline in the number of kokanee (*Oncorhynchus nerka*) in Okanagan Lake led to the formation and initiation of the Okanagan Lake Action Plan (OLAP) in 1996. This plan was designed to gain a better understanding of whole lake biological relationships, define limiting factors and identify and implement measures to restore numbers of kokanee to historically viable numbers (Ashley and Shepherd 1996). A cornerstone of the OLAP is the long-term monitoring of basic limnological parameters that will be used to ascertain changes in the lake over time.

This report briefly summarizes the results of the fourth year of limnology data collected on Okanagan Lake and presents some basic comparisons with data gathered over the previous three years.

METHODS

Sample stations used for OLAP were originally derived from water chemistry stations utilized by the Ministry of Environment, Lands and Parks (MELP) Fisheries and Pollution Abatement Branches (Map 2). Analysis of previous data has resulted in seven stations being sampled throughout the year (Table 1). Each station is sampled once each month with the exception of OK4, which is sampled seasonally, i.e., once in the spring (April), summer (August), and fall (November).

Table 1. Sampling stations used in limnological sampling Okanagan Lake, 1999 (from McEachern *in* Ashley et al. 1999).

Site ID	Site No.	Site Name	Depth (m)
OK1	0500454	South Prairie Creek	90
OK3	E223295	Rattlesnake Island	140
OK4	0500236	Downstream of the Kelowna Sewage Treatment Plant	90
OK5	0500456	Upstream of the Kelowna Sewage Treatment Plant	146
OK6	0500730	North of Okanagan Centre	225
OK7	E206611	At the Vernon Sewage Outfall Pipe	90
OK8	0500239	Centre of Armstrong Arm	55

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[1] BC Conservation Foundation. Penticton Field Office. 4680 Sage Mesa Drive, Penticton, BC, V2A 7K8

Physical Limnology

Vertical temperature and dissolved oxygen profiles were recorded monthly at each station. A YSI digital oxygen meter was used to take readings every 2 m from the surface to 20 m at which point readings were taken every 4 m down to 44 m.

Standard Secchi disc transparency, a relative measure of water clarity, was taken at each station at the same time the oxygen and temperature profiles were taken. Depth in meters was determined by lowering the disc until the viewer lost sight of the disc in the water column. The depth at which the disc is no longer visible is considered the secchi depth.

Water Chemistry

At each station, a Van Dorn sample bottle was used to obtain discrete samples of lake water at 45 m and 20 m depths. These samples were placed in one-litre polyethylene bottles, labeled and placed on ice to await shipment to the lab. An integrated tube sample from the surface to 10 m was obtained by using a tygon tube with an inside diameter of one inch. This sample was bottled and preserved similar to the discrete samples.

Samples to determine low level soluble reactive phosphate (SRP) were taken from an integrated aliquot drawn off using a syringe with a 20-micron filter attached to the tip. This 50-ml sample was placed in a brown glass bottle, labeled and placed on ice for shipping.

All water samples were shipped within twenty-four hours of capture to the Environment Canada Laboratories, Pacific Environmental Centre (PESC), North Vancouver, BC. There they were analyzed for major nutrients (nitrogen – ammonia, nitrite, nitrite+nitrate; phosphorus – total dissolved and total). All data is currently on file at the Penticton Office of the MELP.

Phytoplankton, zooplankton and *Mysis relicta* sampling was conducted in conjunction with the activities described above. McEachern (*in* Ashley et al. 1999) has previously described sampling methods and results for these components and the 1999 results are presented by Wilson elsewhere in this 2000 Action Plan report.

RESULTS AND DISCUSSION

Physical Limnology

Historically, Okanagan Lake reaches its maximum thermal stratification in July, with surface temperatures usually >20ºC (Fig. 1). In 1999, the surface temperatures were considerably colder than the previous three years (Fig. 1) with 20ºC the maximum recorded for July. Despite below normal summer air temperatures in 1999 (Env. Can. 1999), the upper limit of the hypolimnion was once again observed to be at 20 m and held steady at that depth until the fall at which point the lake began to undergo thermal mixing in late October and early November (Fig. 2). During the winter the water column was isothermal with temperature values ranging from 3-5ºC (Fig. 3). The lake displayed a typical orthograde dissolved oxygen profile found in most oligotrophic lakes in summer (Cole 1983). Such lakes have the lowest concentrations of oxygen at their surface and the highest levels found within the hypolimnion (Fig. 4). As suggested by McEachern (*in* Ashley et al. 1999) the low surface concentrations of oxygen likely result from increased temperatures since the solubility of oxygen in water decreases with increasing temperature.

Armstrong Arm has been described as mesotrophic by McEachern (*in* Ashley et al. 1999). Such waterbodies are generally more productive than oligotrophic lakes, which may account for the decrease in oxygen throughout the hypolimnion (Fig. 4). The very low oxygen concentrations below 40 m in Armstrong Arm (Fig. 4) are suggested to be the reason few mysids are found in this area in the fall (see McEachern *in* Ashley et al. 1999).

From 1996-1999 secchi disc transparencies have been lower at the north end of the lake (sites OK 5 to OK 7) with the lowest readings found in the highly productive Armstrong Arm (OK8) (Fig. 5). Seasonally, the readings are highest in the spring and fall with the lowest readings observed in the summer.

Water Chemistry

Total nitrogen concentrations in the main body of Okanagan Lake (OK1 to OK7) have remained relatively stable for the past four years at all sample depths with concentrations in the range of 0.17 to 0.23 mg l (Figs. 6, 7, 8). Armstrong Arm (OK8) consistently displays higher overall concentrations (~ 0.30 mg l) due to its inherently higher productivity, shallower depth and inputs from non-point sources and intensive agriculture, particularly cattle ranches. These higher levels were present at all three depth ranges sampled.

Nitrite-nitrate nitrogen levels consistently display seasonal variability. The highest levels have been observed in the spring and fall (Figs. 9, 10, 11). This is due in part to enrichment coming from nutrient rich meltwater and rainwater flowing into the lake from the surrounding watershed. This influence is most evident in the 0-10 m samples and decreases with depth. Due to biological uptake, epilimnetic concentrations in the upper water column drop to undetectable levels (i.e., below 0.05 mg l) by early summer at all stations.

The 20 m and 45 m samples displayed much higher nitrate+nitrogen levels in Armstrong Arm than all of the other stations that have remained relatively consistent both seasonally and annually throughout the program (Figs. 10 and 11). These increases are most likely due to the inherent nature of this area and its much shallower depth. There appears to be a slight decreasing trend in this parameter at the 20 m depth that will have to be monitored throughout future sampling sessions (Fig. 10).

Concentrations of total phosphorus (TP in Figs. 12, 13, 14) display moderate seasonal variability across the sampling period. For the past four years, phosphorus levels have been highest in the spring and fall, with the largest annual fluctuations occurring in Armstrong Arm (OK8) at all sampling depths. Armstrong Arm also has the highest levels of total phosphorus. The 1999 samples collected were consistent with data collected over the previous three years.

Total dissolved phosphorus (Figs. 15, 16, 17) levels are fairly consistent in the main body of the lake below 20 m. From the surface to 10 m there appears to be more variability throughout the year. There also appears to be a slight downward trend in TDP levels over the course of the program from 1996 to 1999.

Lake productivity is most often limited by the relative availability of key nutrients, particularly total nitrogen and total phosphorus (Cole 1983). When the ratio of nitrogen to phosphorus falls below 15:1 nitrogen can actually limit phytoplankton production (see Jensen *in* Ashley et al. 1999; Stockner in this OLAP report). Phosphorus tends to be limiting when the ratio is above 15:1 but ratios between 10 and 15 indicate that neither nutrient is limiting (McEachern *in* Ashley et al. 1999).

It has generally been assumed that Okanagan Lake is phosphorus limited and the data from 1996-1999 supports this assumption (Fig. 18). It is noteworthy though that occasionally nitrogen limitation may occur (i.e., July to September in Fig. 18). Jensen (*in* Ashley et al. 1999) reported that Armstrong Arm surface water is limited by nitrate nitrogen in the spring months and this is illustrated in Figure 19 for all four years. Nitrogen limitation in the rest of the lake appears to have been restricted to brief periods in the summer of 1997. The time and location of phosphorus vs nitrogen limitation and impact on phytoplankton growth is very important to zooplankton hence fish growth. Clearly, continuation of limnological sampling to determine N:P ratios is essential for understanding the dynamics of Okanagan Lake phytoplankton productivity. Stockner (in this Action Plan report) discusses this issue in greater detail and more sampling is planned for the 2000 season.

Chlorophyll *a*, a photosynthetic pigment in plants, is used as another measure of lake productivity (Cole 1983). Figure 20 indicates that 1999 levels were once again relatively stable after large fluctuations noted in 1998 by McEachern (*in* Ashley et al. 1999). It also appears that an overall upward trend is developing across the lake.

CONCLUSIONS

For the fourth year, monthly water chemistry samples were collected at seven stations on Okanagan Lake as part of the Okanagan Lake Action Plan. The limnology of Okanagan Lake has been described in previous OLAP reports (Ashley et al. 1998 and 1999) and the 1999 sampling results were very similar to previous year’s data. This base sampling program is expected to continue for several more years since the data assists in understanding the physical and biological dynamics of the lake.

From a limnological perspective, Armstrong Arm continues to be quite different from the rest of the lake. In general, despite being both nitrogen and phosphorus limiting it is more productive than the rest of the lake. It has higher levels of nitrogen and phosphorus and it annually displays low levels of hypolimnial oxygen in the fall. The fact that both nitrogen and phosphors appear to be limiting nutrients will be examined in detail through experiments to be initiated in year 5 (2000) of the OLAP.

RECOMMENDATIONS

The following recommendations are put forth to guide future planning with regard to limnological sampling:

1. Continue to monitor the same parameters sampled in 1999 during the year 2000 program;

2. Continue to monitor possible trends in phosphorus (downward) and chlorophyll *a* (upward) that appear to be developing over the four year course of the program; and

3. Ensure that all data is centrally located and managed in an easily accessible format.

4. With a minimum of four years of data it will be possible in future to include some statistical analysis of data in order to more accurately compare parameters and identify trends.

REFERENCES

Ashley, K.I. and B.G. Shepherd. 1996. Okanagan Lake Workshop Report and Action Plan. Fisheries Project Report No. RD 45. Ministry of Environment, Lands and Parks, Province of British Columbia. 120 pp.

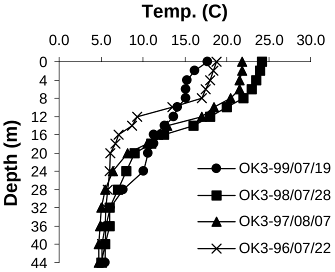
Ashley, K., Bruce Shepherd, Dale Sebastian, Lisa Thompson, Lidija Vidmanic, Dr. Peter Ward, Hansen A. Yassien, Laurie McEachern, Rick Nordin, Dr. Dave Lasenby, Janice Quirt, J.D. Whall, Dr. Peter Dill, Dr. Eric Taylor, Susan Pollard, Cecilia Wong, Jan den Dulk, George Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Ashley, K.A., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, and G. Scholten. 1999. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. 78. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

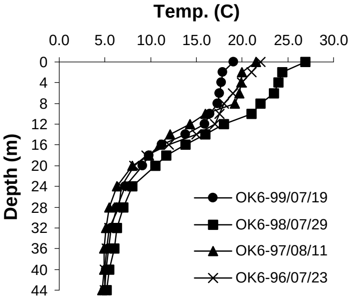
Cole, G.A. 1983. Textbook of Limnology. C.V. Moseby Company. St. Louis. 401 pp.

Environment Canada. 1999. Canadian Meteorological Survey data found on its website at: www.weather.ec.gc.ca

OK3-96/07/22		**OK3-97/08/07**		**OK3-98/07/28**		**OK3-99/07/19**	
Temp	Depth	Temp.	Depth	Temp.	Depth	Temp.	Depth
18.8	0	21.8	0	24.2	0	17.7	0
18.4	2	21.8	2	24.0	2	16.2	2
18.0	4	21.5	4	23.5	4	15.3	4
17.5	6	21.5	6	23.0	6	15.1	6
17.0	8	20.5	8	22.0	8	15.1	8
13.5	10	18.5	10	20.0	10	14.1	10
9.3	12	17.0	12	18.0	12	13.7	12
8.7	14	12.9	14	16.0	14	12.6	14
7.1	16	11.8	16	12.5	16	11.3	16
6.7	18	10.5	18	11.0	18	11.3	18
6.1	20	8.2	20	9.0	20	10.6	20
6.0	24	6.4	24	8.0	24	10.1	24
5.8	28	5.5	28	7.0	28	7.6	28
5.6	32	5.0	32	6.0	32	6.1	32
5.5	36	4.9	36	6.0	36	5.6	36
5.1	40	4.7	40	5.5	40	5.5	40
5.1	44	4.7	44	5.0	44	5.5	44



OK6-96/07/23		OK6-97/08/11		OK6-98/07/29		OK6-99/07/19	
Temp	Depth	Temp.	Depth	Temp.	Depth	Temp.	Depth
22.0	0	21.5	0	26.9	0	19.1	0
21.0	2	20.0	2	24.4	2	17.9	2
20.0	4	19.9	4	24.0	4	17.7	4
19.0	6	19.7	6	23.5	6	17.5	6
18.0	8	19.2	8	22.0	8	17.3	8
17.5	10	16.0	10	21.0	10	16.5	10
17.0	12	14.3	12	18.0	12	15.9	12
15.0	14	12.1	14	16.0	14	13.8	14
12.0	16	11.0	16	13.8	16	11.2	16
9.5	18	9.8	18	11.7	18	9.8	18
8.2	20	8.0	20	10.5	20	9.1	20
6.8	24	6.3	24	8.0	24	7.2	24
6.5	28	5.5	28	7.0	28	6.3	28
5.5	32	5.1	32	6.3	32	5.7	32
5.2	36	4.9	36	6.0	36	5.4	36
5.0	40	4.9	40	5.5	40	5.1	40
5.0	44	4.7	44	5.2	44	5.0	44



OK8-96/07/23		OK8-97/07/09		OK8-98/07/29		OK8-99/07/19	
Temp	Depth	Temp	Depth	Temp	Depth	Temp	Depth
22.0	0	21.8	0	26.6	0	20.0	0
21.0	2	21.2	2	25.4	2	19.2	2
20.5	4	21.0	4	24.5	4	18.5	4
19.7	6	19.3	6	22.7	6	18.4	6
19.5	8	15.5	8	20.8	8	15.6	8
19.1	10	13.5	10	18.6	10	13.7	10
16.0	12	11.6	12	16.5	12	12.2	12
11.3	14	8.8	14	12.0	14	11.2	14
9.3	16	8.0	16	10.2	16	9.1	16
8.2	18	7.7	18	9.0	18	8.4	18
6.9	20	7.3	20	8.2	20	8.0	20
7.5	24	7.0	24	7.0	24	7.7	24
7.0	28	6.7	28	6.1	28	7.5	28
6.9	32	6.3	32	5.8	32	7.2	32
6.8	36	6.3	36	5.6	36	6.2	36
6.8	40	6.3	40	5.5	40	6.1	40
7.0	44	6.3	44	5.5	44	6.0	44

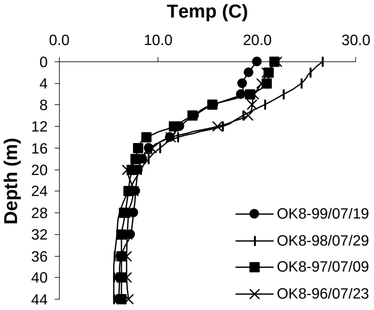
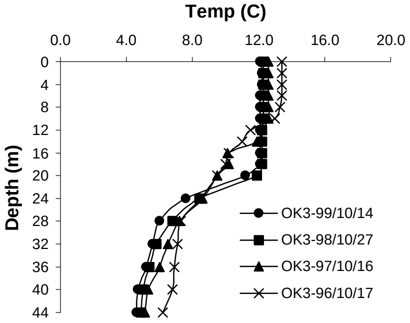
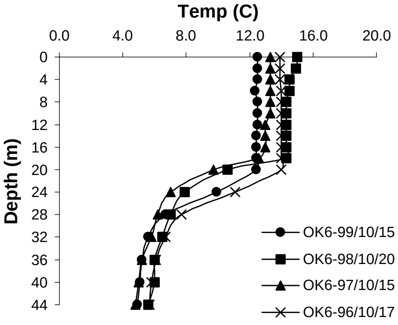


Figure 1. Okanagan Lake summer temperature profiles (ºC) at Stations OK3, OK6 and 1996 - 1999

OK3-96/10/17		OK3-97/10/16		OK3-98/10/27		OK3-99/10/14	
Temp	Depth	Temp.	Depth	Temp.	Depth	Temp.	Depth
13.4	0	12.6	0	12.3	0	12.1	0
13.4	2	12.6	2	12.3	2	12.2	2
13.4	4	12.6	4	12.3	4	12.2	4
13.4	6	12.6	6	12.3	6	12.1	6
13.3	8	12.6	8	12.3	8	12.1	8
13.0	10	12.6	10	12.3	10	12.1	10
11.5	12	12.2	12	12.2	12	12.1	12
11.0	14	11.9	14	12.2	14	12.1	14
10.2	16	10.1	16	12.2	16	12.1	16
10.0	18	10.2	18	12.2	18	12.1	18
9.5	20	9.5	20	11.9	20	11.2	20
8.5	24	8.6	24	8.4	24	7.6	24
7.3	28	7.2	28	6.8	28	6.0	28
7.1	32	6.5	32	5.8	32	5.6	32
6.9	36	6.0	36	5.4	36	5.2	36
6.8	40	5.3	40	5.0	40	4.7	40
6.2	44	5.1	44	4.9	44	4.6	44



OK6-96/10/17		OK6-97/10/15		OK6-98/10/20		OK6-99/10/15	
Temp	Depth	Temp.	Depth	Temp.	Depth	Temp.	Depth
13.9	0	13.3	0	15.0	0	12.5	0
13.9	2	13.3	2	14.9	2	12.5	2
13.9	4	13.3	4	14.5	4	12.5	4
14.0	6	13.3	6	14.5	6	12.4	6
14.0	8	13.3	8	14.3	8	12.5	8
14.0	10	13.3	10	14.3	10	12.5	10
14.0	12	13.0	12	14.3	12	12.5	12
14.0	14	13.0	14	14.3	14	12.4	14
14.0	16	13.0	16	14.3	16	12.4	16
14.0	18	12.6	18	14.3	18	12.4	18
14.0	20	9.7	20	10.6	20	12.4	20
11.1	24	7.0	24	7.9	24	9.9	24
7.7	28	6.2	28	7.0	28	6.7	28
6.7	32	5.8	32	6.5	32	5.6	32
6.1	36	5.2	36	6.0	36	5.2	36
5.8	40	5.0	40	6.0	40	5.1	40
5.7	44	4.8	44	5.6	44	4.9	44



OK8-96/10/23		OK8-97/10/15		OK8-98/10/1		OK8-99/10/15	
Temp	Depth	Temp.	Depth	Temp.	Depth	Temp.	Depth
11.7	0	12.5	0	17.8	0	11.5	0
11.7	2	12.5	2	17.8	2	11.6	2
11.7	4	12.5	4	17.5	4	11.5	4
11.7	6	12.5	6	17.5	6	11.5	6
11.5	8	12.5	8	17.5	8	11.5	8
11.5	10	12.5	10	17.4	10	11.5	10
11.5	12	12.5	12	17.2	12	11.5	12
11.5	14	12.5	14	13.5	14	11.5	14
11.3	16	12.0	16	11.0	16	11.5	16
11.0	18	9.2	18	9.8	18	10.3	18
10.1	20	8.5	20	8.9	20	9.5	20
9.0	24	7.7	24	7.3	24	7.8	24
8.0	28	7.0	28	6.3	28	6.8	28
7.1	32	6.8	32	5.9	32	6.4	32
7.0	36	6.6	36	5.8	36	6.2	36
7.0	40	6.5	40	5.5	40	6.1	40
6.9	44	6.5	44	5.5	44	6.1	44

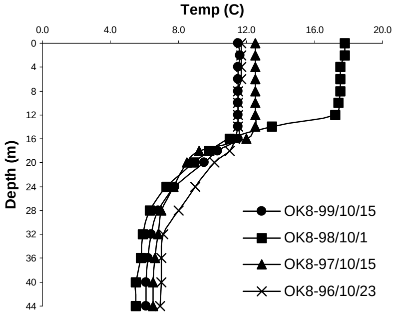
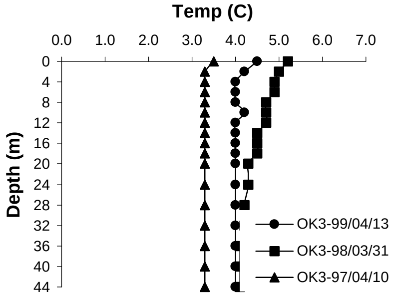
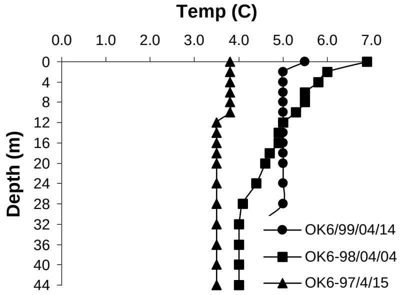


Figure 2. Okanagan Lake fall temperature profiles(ºC) at Stations OK3, OK6 and OK8, 1996-1999

OK3-97/04/10		OK3-98/03/31		OK3-99/04/13	
Temp.	Depth	Temp.	Depth	Temp.	Depth
3.5	0	5.2	0	4.5	0
3.3	2	5.0	2	4.2	2
3.3	4	4.9	4	4.0	4
3.3	6	4.9	6	4.0	6
3.3	8	4.7	8	4.0	8
3.3	10	4.7	10	4.2	10
3.3	12	4.7	12	4.0	12
3.3	14	4.5	14	4.0	14
3.3	16	4.5	16	4.0	16
3.3	18	4.5	18	4.0	18
3.3	20	4.3	20	4.0	20
3.3	24	4.3	24	4.0	24
3.3	28	4.2	28	4.0	28
3.3	32	4.2	32	4.0	32
3.3	36	4.1	36	4.0	36
3.3	40	4.1	40	4.0	40
3.3	44	4.1	44	4.0	44



OK6-97/4/15		OK6-98/04/04		OK6/99/04/14	
Temp.	Depth	Temp.	Depth	Temp.	Depth
3.8	0	6.9	0	5.5	0
3.8	2	6.0	2	5.0	2
3.8	4	5.8	4	5.0	4
3.8	6	5.5	6	5.0	6
3.8	8	5.5	8	5.0	8
3.8	10	5.3	10	5.0	10
3.5	12	5.0	12	5.0	12
3.5	14	4.9	14	5.0	14
3.5	16	4.9	16	5.0	16
3.5	18	4.7	18	5.0	18
3.5	20	4.6	20	5.0	20
3.5	24	4.4	24	5.0	24
3.5	28	4.1	28	5.0	28
3.5	32	4.0	32	4.5	32
3.5	36	4.0	36	4.5	36
3.5	40	4.0	40	4.5	40
3.5	44	4.0	44	4.5	44



OK8-97/04/15		OK8-98/04/02		OK6/99/04/14	
Temp.	Depth	Temp.	Depth	Temp.	Depth
6.5	0	7.0	0	6.5	0
6.0	2	6.8	2	6.5	2
5.3	4	6.3	4	6.0	4
5.1	6	6.0	6	6.0	6
5.1	8	5.5	8	6.0	8
5.1	10	5.5	10	6.0	10
5.0	12	5.3	12	6.0	12
5.0	14	5.3	14	6.0	14
4.5	16	5.3	16	6.0	16
4.3	18	5.0	18	6.0	18
4.0	20	5.0	20	5.5	20
3.8	24	5.0	24	5.5	24
3.5	28	4.1	28	5.0	28
3.5	32	4.0	32	4.5	32
3.5	36	4.0	36	4.5	36
3.3	40	4.0	40	4.5	40
3.3	44	4.0	44	4.5	44

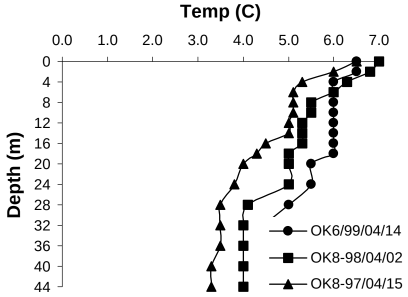
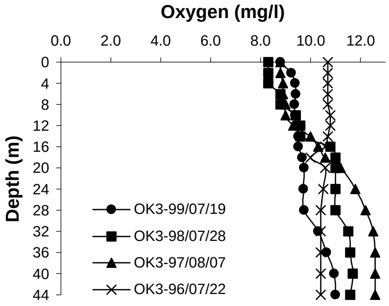
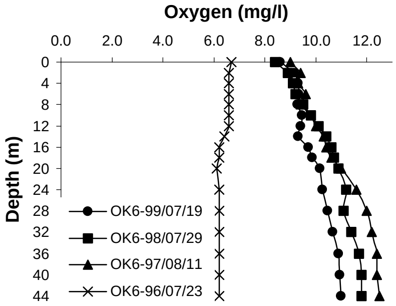


Figure 3: Okanagan Lake spring/winter temperature profiles(ºC) at Stations OK3, OK6 and 1996-1999

OK3-96/07/22		OK3-97/08/07		OK3-98/07/28		OK3-99/07/19	
Oxygen	Depth	Oxygen	Depth	Oxygen	Depth	Oxygen	Depth
10.7	0	8.8	0	8.3	0	8.8	0
10.7	2	8.8	2	8.3	2	9.2	2
10.7	4	8.9	4	8.3	4	9.4	4
10.7	6	8.9	6	8.8	6	9.4	6
10.7	8	9.0	8	8.8	8	9.4	8
10.8	10	9.0	10	9.4	10	9.4	10
10.8	12	9.3	12	9.6	12	9.4	12
10.7	14	10.0	14	9.6	14	9.5	14
10.6	16	10.3	16	10.8	16	9.5	16
10.0	18	10.6	18	11.0	18	9.7	18
10.6	20	11.2	20	11.0	20	9.8	20
10.5	24	11.8	24	11.0	24	9.7	24
10.4	28	12.2	28	11.0	28	9.8	28
10.4	32	12.5	32	11.5	32	10.3	32
10.4	36	12.6	36	11.6	36	10.6	36
10.4	40	12.6	40	11.7	40	11.0	40
10.4	44	12.6	44	11.6	44	11.0	44



OK6-96/07/23		OK6-97/08/11		OK6-98/07/29		OK6-99/07/19	
Oxygen	Depth	Oxygen	Depth	Oxygen	Depth	Oxygen	Depth
6.7	0	9.0	0	8.4	0	8.6	0
6.6	2	9.4	2	8.9	2	9.2	2
6.6	4	9.3	4	9.1	4	9.3	4
6.6	6	9.6	6	9.2	6	9.3	6
6.6	8	9.4	8	9.5	8	9.3	8
6.6	10	9.8	10	9.8	10	9.5	10
6.6	12	10.0	12	10.1	12	9.4	12
6.4	14	10.3	14	10.4	14	9.3	14
6.2	16	10.4	16	10.6	16	9.7	16
6.2	18	10.6	18	10.7	18	9.9	18
6.1	20	11.0	20	10.9	20	10.2	20
6.2	24	11.6	24	11.2	24	10.3	24
6.2	28	12.0	28	11.1	28	10.5	28
6.2	32	12.2	32	11.4	32	10.7	32
6.2	36	12.4	36	11.7	36	10.9	36
6.2	40	12.4	40	11.8	40	11.0	40
6.2	44	12.5	44	11.8	44	11.0	44



OK8-96/07/23		OK8-97/08/10		OK8-98/07/29		OK8-99/07/19	
Oxygen	Depth	Oxygen	Depth	Oxygen	Depth	Oxygen	Depth
5.8	0	9.3	0	9.0	0	8.3	0
5.7	2	9.4	2	9.2	2	9.0	2
5.6	4	9.4	4	9.5	4	9.1	4
5.1	6	9.2	6	9.8	6	9.1	6
5.3	8	9.1	8	9.0	8	8.9	8
5.2	10	9.1	10	8.9	10	8.8	10
4.4	12	8.0	12	8.2	12	8.3	12
3.8	14	6.9	14	7.3	14	7.5	14
3.6	16	6.5	16	6.2	16	7.2	16
3.5	18	6.2	18	6.4	18	6.9	18
3.4	20	6.3	20	6.4	20	6.7	20
3.2	24	6.0	24	6.3	24	6.5	24
3.2	28	5.7	28	6.1	28	6.3	28
3.0	32	5.4	32	5.6	32	6.2	32
2.8	36	5.1	36	5.2	36	6.2	36
2.6	40	4.9	40	4.7	40	5.9	40
2.2	44	4.8	44	3.8	44	5.4	44

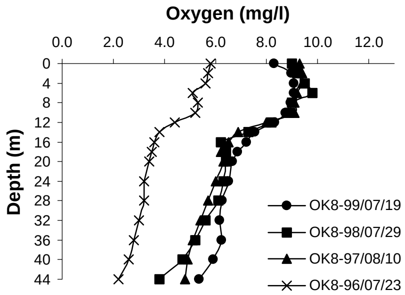
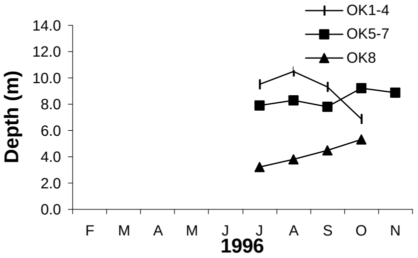
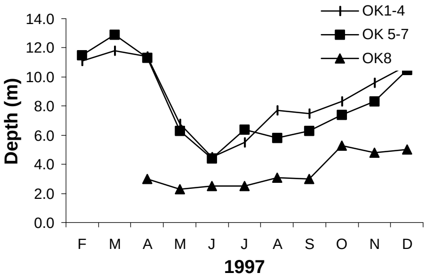


Figure 4. Okanagan Lake mid-summer oxygen profiles at Stations OK3, OK6 and OK8, 1996-1999

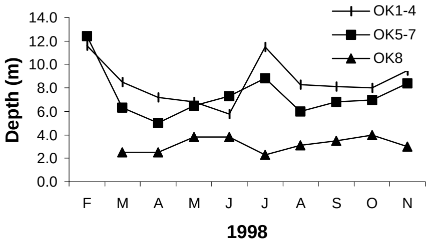
1996	OK1-4	OK5-7	OK8
F			
M			
A			
M			
J			
J	9.5	7.9	3.2
A	10.5	8.3	3.8
S	9.3	7.8	4.5
O	6.9	9.2	5.3
N		8.9	



1997	OK1-4	OK5-7	OK8
F	11.1	11.5	
M	11.8	12.9	
A	11.4	11.3	3.0
M	6.8	6.3	2.3
J	4.5	4.4	2.5
J	5.5	6.4	2.5
A	7.7	5.8	3.1
S	7.5	6.3	3.0
O	8.3	7.4	5.3
N	9.6	8.3	4.8
D	10.8	10.5	5.0



1998	OK1-4	OK5-7	OK8
F	11.6	12.4	
M	8.5	6.3	2.5
A	7.2	5.0	2.5
M	6.8	6.5	3.8
J	5.8	7.3	3.8
J	11.5	8.8	2.3
A	8.3	6.0	3.1
S	8.1	6.8	3.5
O	8.0	7.0	4.0
N	9.5	8.4	3.0



1999	OK1-4	OK5-7	OK8
F			
M			
A	8.4	6.5	3.1
M	4.5	4.4	2.5
J	3.5	4.8	2.5
J	5.5	6.3	3.0
A	7.3	6.5	3.0
S	8.5	7.3	3.0
O	5.5	5.5	4.5
N	6.0	6.1	5.0

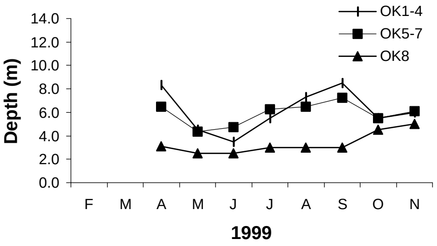


Figure 5. Okanagan Lake secchi depth transparancies at Stations OK4, OK7 and OK8, 1996-

		OK1-	OK5-7	OK8
	J	0.20	0.23	0.31
	A	0.18	0.16	0.18
1996	S	0.19	0.20	0.22
	O	0.20	0.19	0.26
	N		0.19	
	F	0.21	0.21	
	M	0.21	0.21	
	A	0.21	0.23	0.32
	M	0.20	0.20	0.31
	J	0.17	0.20	0.31
1997	J	0.18	0.20	0.23
	A	0.18	0.25	0.33
	S	0.19	0.21	0.26
	O	0.25	0.30	0.30
	N	0.19	0.18	0.23
	D	0.22	0.23	0.33
	F	0.22	0.25	
	M	0.19	0.21	0.27
	A	0.28	0.26	0.37
	M	0.24	0.21	0.22
1998	J	0.17	0.19	0.23
	J	0.16	0.19	0.21
	A	0.19	0.20	0.19
	S	0.16	0.18	0.25
	O	0.16	0.21	0.25
	N	0.26	0.23	0.31
	F	0.23	0.22	0.25
	M			
	A	0.25	0.26	0.29
	M	0.24	0.22	0.25
1999	J	0.20	0.23	0.23
	J	0.23	0.22	0.25
	A	0.23	0.23	0.24
	S	0.24	0.24	0.24
	O	0.24	0.19	0.23
	N	0.25	0.24	0.26

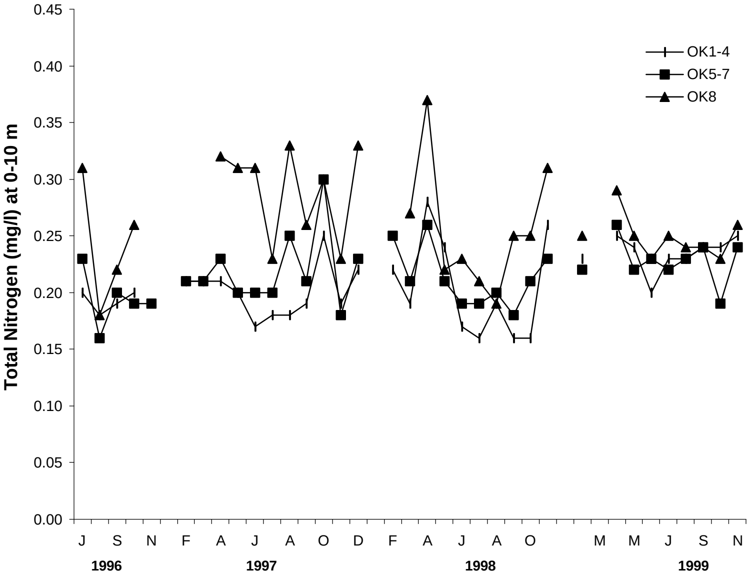


Figure 6. Okanagan Lake total nitrogen concentrations (TN) at 0 to 10 m at Stations OK4, OK7, and OK8

		OK1-4	OK5-7	OK8
1996	J	0.19	0.17	0.31
	A	0.18	0.16	0.24
	S	0.18	0.22	0.31
	O	0.19	0.18	0.27
	N		0.19	
1997	F	0.22	0.21	
	M	0.21	0.20	
	A	0.21	0.22	0.40
	M	0.20	0.20	0.37
	J	0.19	0.18	0.35
	J	0.19	0.18	0.29
	A	0.18	0.24	0.36
	S	0.20	0.20	0.32
	O	0.20	0.20	0.24
	N	0.19	0.17	0.21
	D	0.22	0.23	0.29
1998	F	0.23	0.25	
	M	0.20	0.21	0.37
	A	0.30	0.24	0.40
	M	0.23	0.18	0.27
	J	0.20	0.18	0.30
	J	0.20	0.22	0.26
	A	0.22	0.21	0.30
	S	0.17	0.18	0.30
	O	0.15	0.22	0.29
	N	0.26	0.25	0.37
1999	F	0.22		0.24
	M			
	A	0.23	0.23	0.21
	M	0.21	0.21	0.27
	J	0.22	0.28	0.28
	J	0.21	0.24	0.27
	A	0.22	0.20	0.28
	S	0.20	0.19	0.30
	O	0.26	0.20	0.43
	N	0.26	0.22	0.26

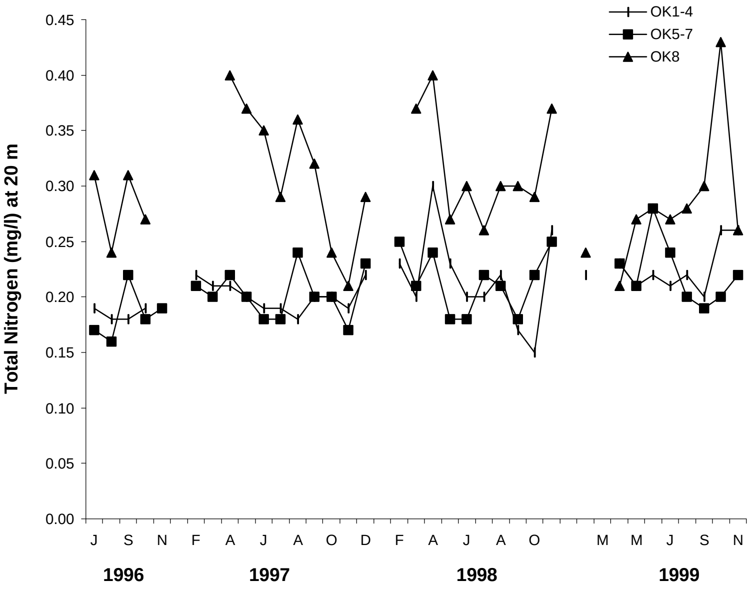


Figure 7. Okanagan Lake total nitrogen concentration (TN) at 20 m at Stations OK4, OK7, and OK8 from 1996 -1999

		OK1-4	OK5-7	OK8
1996	J	0.21	0.21	0.40
	A	0.18	0.16	0.39
	S	0.20	0.23	0.47
	O	0.20	0.20	0.47
	N		0.18	
1997	F	0.21	0.21	
	M	0.21	0.20	
	A	0.22	0.22	0.68
	M	0.19	0.19	0.51
	J	0.18	0.19	0.37
	J	0.20	0.15	0.40
	A	0.19	0.26	0.52
	S	0.21	0.20	0.47
	O	0.25	0.20	0.60
	N	0.20	0.18	0.46
	D	0.22	0.22	0.30
1998	F	0.21	0.24	
	M	0.20	0.22	0.37
	A	0.29	0.27	0.46
	M	0.25	0.20	0.41
	J	0.24	0.20	0.46
	J	0.22	0.20	0.46
	A	0.23	0.27	0.46
	S	0.21	0.21	0.50
	O	0.19	0.24	0.51
	N	0.28	0.26	0.55
1999	F	0.22		0.24
	M			
	A	0.23	0.24	0.26
	M	0.23	0.22	0.29
	J	0.24	0.27	0.34
	J	0.24	0.24	0.42
	A	0.25	0.25	0.46
	S	0.27	0.26	0.48
	O	0.24	0.21	0.25
	N	0.25	0.27	0.52

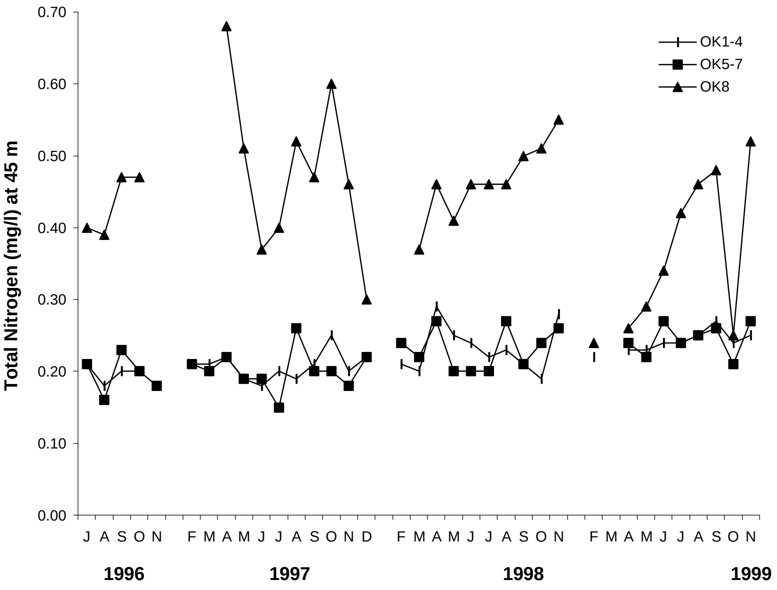


Figure 8. Okanagan Lake total nitrogen concentrations (TN) at 45 m at Stations OK4, OK7, and OK8 from 1996-1999

		OK1-4	OK5-7	OK8
	J	0	0	0
	A	0.009	0.02	0
1996	S	0	0	0.03
	O	0.001	0	0
	N		0.02	
	F	0.056	0.05	
	M	0.057	0.05	
	A	0.042	0.04	0.02
	M	0.028	0.01	0
	J	0.001	0	0
1997	J	0.001	0	0
	A	0.001	0	0
	S	0.001	0	0
	O	0.003	0	0
	N	0.041	0.01	0.03
	D	0.051	0.04	0.07
	F	0.063	0.06	
	M	0.055	0.03	
	A	0.046	0	
	M	0.043	0	
1998	J	0	0	
	J	0	0	
	A	0	0	
	S	0	0	
	O	0	0	
	N	0.061	0.02	0.01
	F	0.086	0.078	0.000
	M			
	A	0.075	0.038	0.004
	M	0.036	0.021	0.002
1999	J	0.005	0.002	0.000
	J	0.003	0.002	0.000
	A	0.003	0.002	0.002
	S	0.002	0.002	0.002
	O	0.003	0.003	0.003
	N	0.025	0.006	0.004

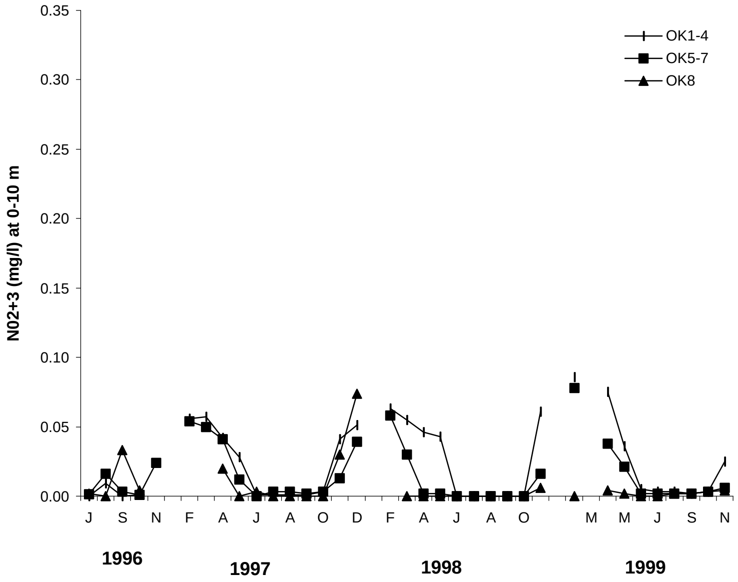


Figure 9. Okanagan Lake nitrate-nitrogen (NO 2-3 at 0-10 m at Stations OK4, OK7 and OK8, from 1996-1999

		OK1-4	OK5-7	OK8
1996	J	0.019	0.02	0.11
	A	0.012	0.02	0.12
	S	0.006	0.01	0.12
	O	0.032	0	0.18
	N		0.02	
1997	F	0.059	0.06	
	M	0.057	0.05	
	A	0.045	0.04	0.08
	M	0.03	0.03	0.14
	J	0.023	0.01	0.11
	J	0.028	0.02	0.11
	A	0.011	0.01	0.11
	S	0	0	0.12
	O	0.016	0.01	0.04
	N	0.05	0.02	0.03
	D	0.053	0.04	0.07
1998	F	0.063	0.06	
	M	0.055	0.05	0.03
	A	0.054	0.01	0.08
	M	0.054	0.01	0.08
	J	0.034	0.02	0.08
	J	0.014	0.01	0.1
	A	0.022	0.01	0.09
	S	0.014	0.01	0.07
	O	0.004	0.01	0.09
	N	0.062	0.01	0.01
1999	F	0.084		0.003
	M			
	A	0.076	0.040	0.012
	M	0.047	0.014	0.012
	J	0.045	0.035	0.050
	J	0.039	0.007	0.000
	A	0.040	0.028	0.000
	S	0.002	0.027	0.000
	O	0.043	0.002	0.031
	N	0.046	0.005	0.005

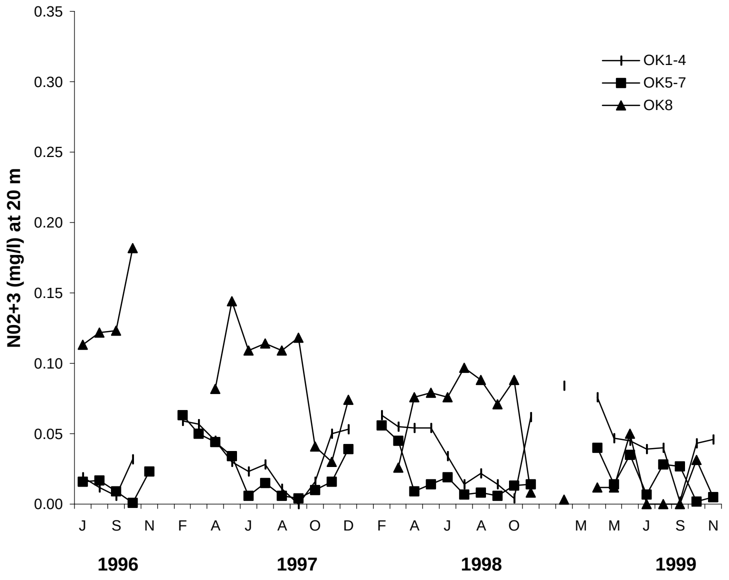


Figure 10. Okanagan Lake nitrate-nitrogen (NO 2-3) at 20 m at Stations OK4, OK7 and OK8, from 1996-1999

		OK1-4	OK5-7	OK8
1996	J	0.043	0.05	0.18
	A	0.057	0.06	0.26
	S	0.068	0.06	0.29
	O	0.059	0.06	0.29
	N		0.03	
1997	F	0.064	0.07	
	M	0.057	0.05	
	A	0.044	0.04	0.34
	M	0.039	0.06	0.27
	J	0.049	0.05	0.17
	J	0.064	0.06	0.22
	A	0.067	0.06	0.23
	S	0.065	0.06	0.28
	O	0.078	0.07	0.33
	N	0.063	0.07	0.32
	D	0.055	0.04	0.07
1998	F	0.063	0.06	
	M	0.062	0.06	0.13
	A	0.067	0.06	0.15
	M	0.082	0.07	0.21
	J	0.079	0.08	0.24
	J	0.093	0.08	0.27
	A	0.092	0.08	0.29
	S	0.09	0.08	0.31
	O	0.082	0.08	0.33
	N	0.092	0.08	0.32
1999	F	0.084		
	M			
	A	0.078	0.051	0.020
	M	0.074	0.063	0.064
	J	0.078	0.037	0.002
	J	0.088	0.071	0.184
	A	0.089	0.076	0.080
	S	0.054	0.086	0.286
	O	0.090	0.090	0.082
	N	0.083	0.090	0.268

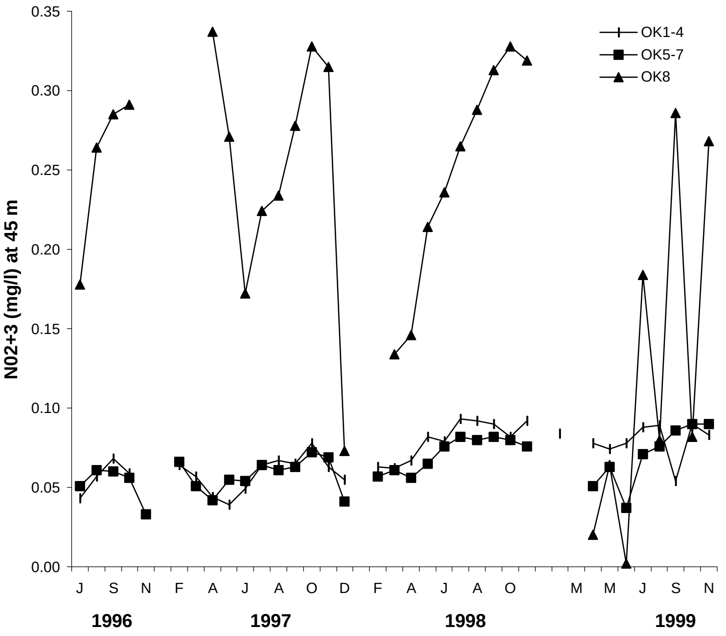


Figure 11. Okanagan Lake nitrate-nitrogen (NO 2-3) at 45 m at Stations OK4, OK7, and OK8, from 1996-1999

		OK1-4	OK5-7	OK8
1996	J	0.012	0.008	0.014
	A	0.008	0.01	0.013
	S	0.007	0.01	0.021
	O	0.006	0.008	0.014
	N		0.015	
1997	F	0.009	0.012	
	M	0.008	0.008	
	A	0.01	0.013	0.031
	M	0.008	0.011	0.024
	J	0.013	0.015	0.024
	J	0.014	0.011	0.017
	A	0.013	0.024	0.036
	S	0.008	0.008	0.014
	O	0.012	0.011	0.018
	N	0.012	0.013	0.019
	D	0.009	0.008	0.031
1998	F	0.007	0.009	
	M	0.002	0.008	0.020
	A	0.004	0.006	0.009
	M	0.001	0.007	0.009
	J	0.006	0.008	0.011
	J	0.007	0.007	0.006
	A	0.007	0.007	0.011
	S	0.006	0.007	0.008
	O	0.008	0.008	0.015
	N	0.006	0.008	0.027
1999	F	0.007	0.012	0.027
	M			
	A	0.007	0.011	0.023
	M	0.008	0.009	0.017
	J	0.005	0.004	0.006
	J	0.008	0.006	0.010
	A	0.008	0.007	0.010
	S	0.008	0.008	0.011
	O	0.009	0.009	0.014
	N	0.009	0.009	0.021

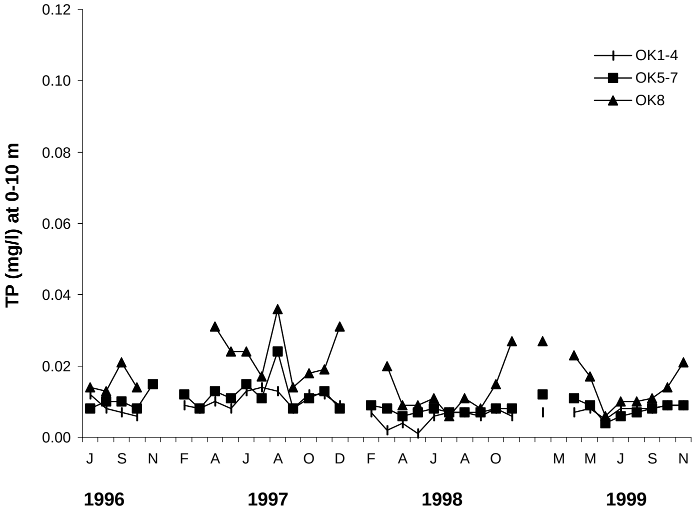


Figure 12. Okanagan Lake total phosphorus (TP) concentrations at 0-10 m at Stations OK4, OK7 and OK8, from 1996-1999

		OK1-4	OK5-7	OK8
1996	J	0.012	0.008	0.022
	A	0.009	0.009	0.017
	S	0.006	0.017	0.021
	O	0.006	0.005	0.019
	N		0.013	
1997	F	0.008	0.01	
	M	0.008	0.009	
	A	0.01	0.013	0.035
	M	0.007	0.01	0.035
	J	0.011	0.013	0.025
	J	0.011	0.012	0.023
	A	0.012	0.023	0.04
	S	0.01	0.007	0.081
	O	0.01	0.01	0.019
	N	0.013	0.013	0.019
	D	0.009	0.009	0.029
1998	F	0.007	0.011	
	M	0.004	0.008	0.02
	A	0.005	0.004	0.008
	M	0.002	0.006	0.011
	J	0.005	0.006	0.013
	J	0.005	0.007	0.012
	A	0.008	0.008	0.007
	S	0.007	0.008	0.017
	O	0.008	0.009	0.042
	N	0.006	0.008	0.025
1999	F	0.006		0.030
	M			
	A	0.006	0.011	0.018
	M	0.008	0.012	0.013
	J	0.004	0.003	0.008
	J	0.006	0.008	0.013
	A	0.006	0.008	0.011
	S	0.007	0.009	0.011
	O	0.008	0.009	0.102
	N	0.009	0.01	0.020

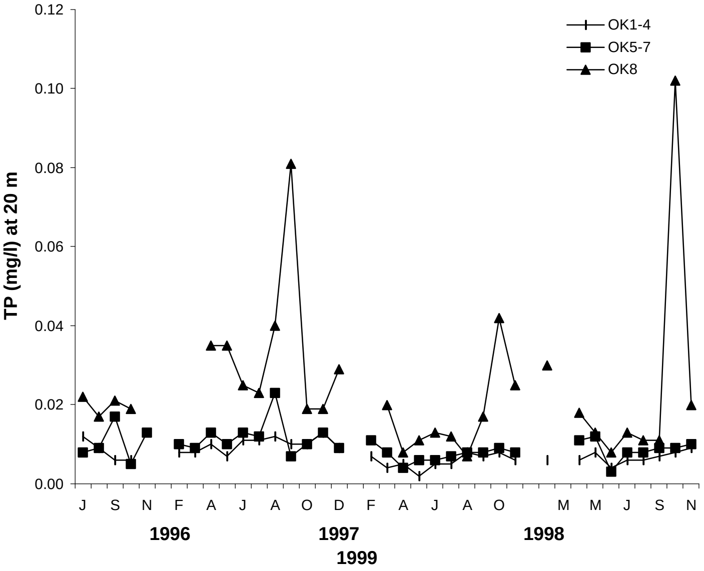


Figure 13. Okanagan Lake total phosphorus (TP) concentrations at 20 m at Stations OK4, OK7 and OK8, from 1996-1999

		OK1-4	OK5-7	OK8
1996	J	0.008	0.006	0.049
	A	0.007	0.008	0.069
	S	0.005	0.008	0.092
	O	0.007	0.006	0.103
	N		0.012	
1997	F	0.008	0.01	
	M	0.006	0.009	
	A	0.01	0.013	0.068
	M	0.007	0.008	0.042
	J	0.012	0.01	0.036
	J	0.009	0.008	0.042
	A	0.009	0.023	0.082
	S	0.007	0.006	0.08
	O	0.01	0.009	0.105
	N	0.016	0.01	0.104
	D	0.009	0.009	0.029
1998	F	0.008	0.009	
	M	0.003	0.007	0.028
	A	0.007	0.004	0.012
	M	0.003	0.005	0.037
	J	0.005	0.005	0.038
	J	0.005	0.006	0.048
	A	0.007	0.007	0.066
	S	0.006	0.006	0.075
	O	0.008	0.007	0.097
	N	0.006	0.007	0.09
1999	F	0.006		0.03
	M			
	A	0.007	0.011	0.024
	M	0.007	0.007	0.022
	J	0.004	0.003	0.011
	J	0.005	0.005	0.057
	A	0.006	0.006	0.077
	S	0.006	0.008	0.098
	O	0.008	0.009	0.027
	N	0.009	0.008	0.111

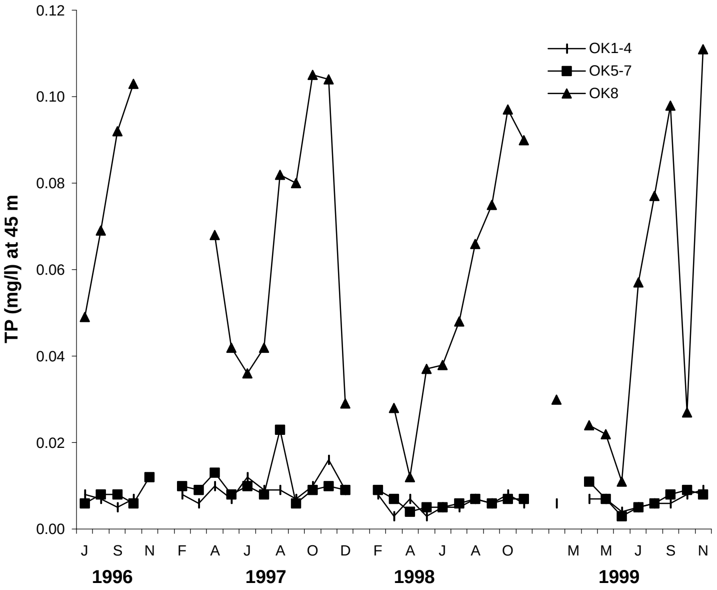


Figure 14. Okanagan Lake total phosphorus (TP) concentrations at 45 m at Stations OK4, OK7 and OK8, from 1996-1999

		OK1-4	OK5-7	OK8
	J	0.005	0.008	0.014
	A	0.005	0.010	0.013
1996	S	0.001	0.010	0.021
	O	0.002	0.008	0.014
	N		0.015	
	F	0.007	0.007	
	M	0.005	0.006	
	A	0.007	0.007	0.008
	M	0.007	0.007	0.008
	J	0.008	0.006	0.008
1997	J	0.014	0.011	0.017
	A	0.008	0.010	0.009
	S	0.005	0.004	0.005
	O	0.008	0.008	0.008
	N	0.009	0.007	0.009
	D	0.008	0.005	0.024
	F	0.005	0.006	
	M	0.000	0.000	0.000
	A	0.000	0.000	0.000
	M	0.002	0.003	0.005
1998	J	0.005	0.004	0.003
	J	0.003	0.005	0.004
	A	0.005	0.004	0.006
	S	0.000	0.000	0.000
	O	0.001	0.002	0.002
	N	0.002	0.003	0.012
	F	0.004	0.007	0.010
	M			
	A	0.004	0.005	0.005
	M	0.004	0.004	0.005
1999	J	0.003	0.002	0.003
	J	0.003	0.002	0.003
	A	0.003	0.003	0.004
	S	0.004	0.004	0.004
	O	0.005	0.006	0.007
	N	0.006	0.005	0.011

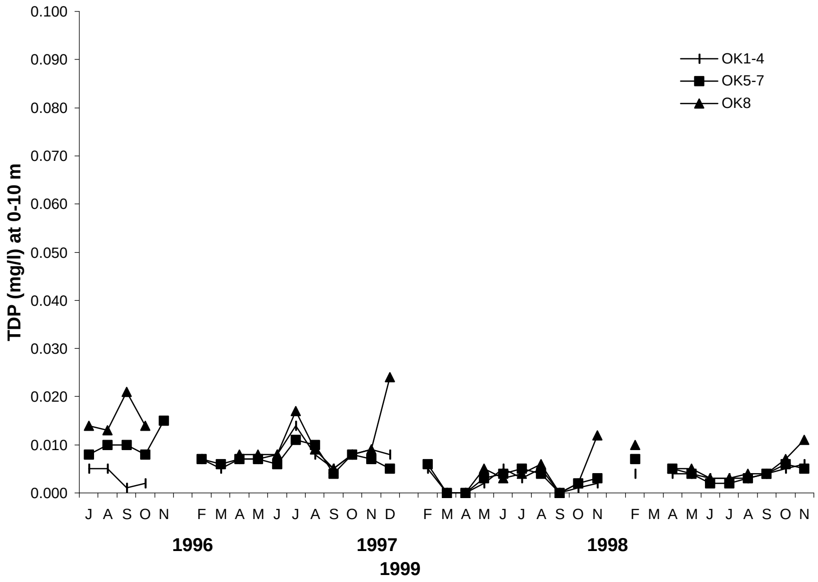


Figure 15. Okanagan Lake total disolved phosphorus (TDP) at 0-10 m at Stations OK4, OK7 and OK8, from 1996-1999

		OK1-4	OK5-7	OK8
1996	J	0.006	0.012	0.027
	A	0.005	0.004	0.011
	S	0.001	0.004	0.010
	O	0.004	0.002	0.011
	N		0.007	
1997	F	0.007	0.008	
	M	0.007	0.006	
	A	0.007	0.009	0.035
	M	0.005	0.006	0.035
	J	0.007	0.007	0.025
	J	0.011	0.012	0.023
	A	0.007	0.010	0.040
	S	0.005	0.003	0.081
	O	0.007	0.007	0.019
	N	0.008	0.008	0.019
	D	0.006	0.006	0.029
1998	F	0.006	0.006	
	M	0.001	0.000	0.000
	A	0.000	0.000	0.000
	M	0.002	0.005	0.005
	J	0.003	0.004	0.006
	J	0.005	0.004	0.006
	A	0.005	0.003	0.007
	S	0.002	0.001	0.011
	O	0.002	0.004	0.028
	N	0.003	0.003	0.012
1999	F	0.005		0.009
	M			
	A	0.004	0.005	0.005
	M	0.004	0.003	0.005
	J	0.003	0.002	0.005
	J	0.002	0.003	0.009
	A	0.003	0.003	0.007
	S	0.004	0.003	0.006
	O	0.005	0.005	0.075
	N	0.006	0.006	0.010

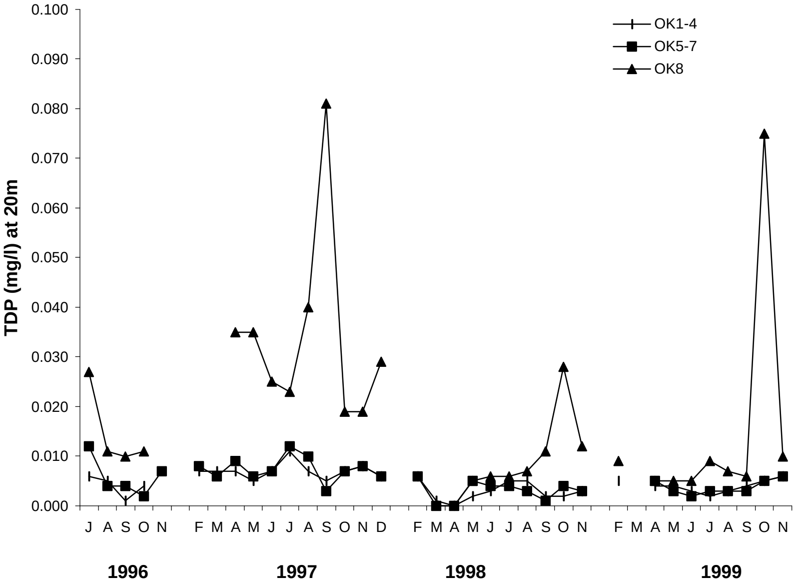


Figure 16. Okanagan Lake total disolved phosphorus (TDP) at 20 m at Stations OK4, OK7 and OK8, from 1996-1999

		OK1-4	OK5-7	OK8
	J	0.007	0.008	0.054
	A	0.005	0.005	0.059
1996	S	0.002	0.004	0.078
	O	0.003	0.004	0.090
	N		0.006	
	F	0.006	0.010	
	M	0.006	0.006	
	A	0.007	0.008	0.049
	M	0.007	0.007	0.034
	J	0.007	0.008	0.024
1997	J	0.009	0.008	0.042
	A	0.008	0.009	0.055
	S	0.004	0.005	0.008
	O	0.008	0.009	0.008
	N	0.008	0.006	0.010
	D	0.006	0.006	0.022
	F	0.006	0.005	
	M	0.001	0.000	0.010
	A	0.000	0.000	0.000
	M	0.003	0.003	0.028
1998	J	0.003	0.003	0.032
	J	0.004	0.005	0.041
	A	0.005	0.003	0.059
	S	0.001	0.002	0.064
	O	0.003	0.004	0.074
	N	0.005	0.004	0.087
	F	0.004		0.009
	M			
	A	0.005	0.005	0.010
	M	0.004	0.003	0.011
1999	J	0.002	0.003	0.019
	J	0.002	0.003	0.050
	A	0.003	0.003	0.066
	S	0.004	0.004	0.087
	O	0.005	0.005	0.013
	N	0.006	0.006	0.090

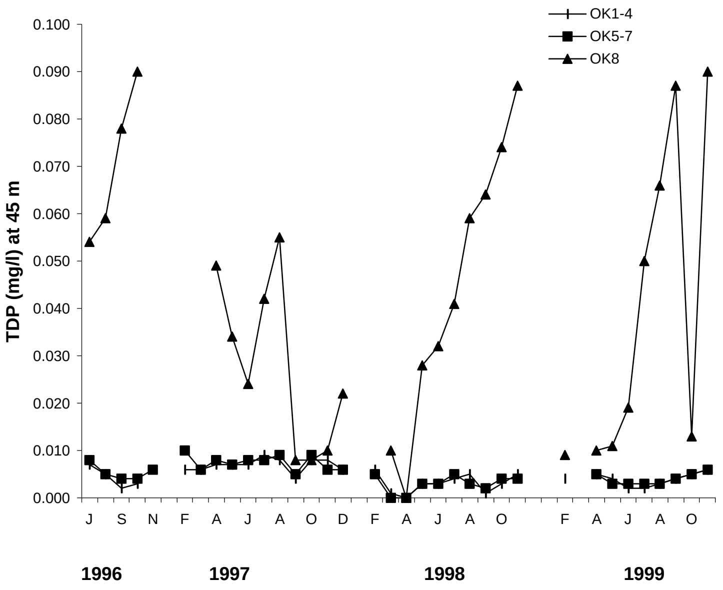


Figure 17. Okanagan Lake total disolved phosphorus (TDP) at 45 m at Stations OK4, OK7 and OK8, from 1996-1999

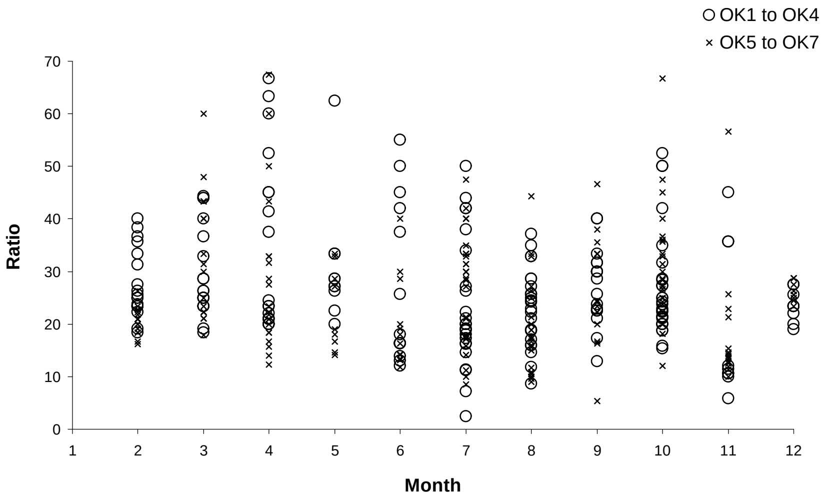


Figure 18. TN:TP ratios North and South Okanagan Lake, 1996-1999 (Armstrong excluded)

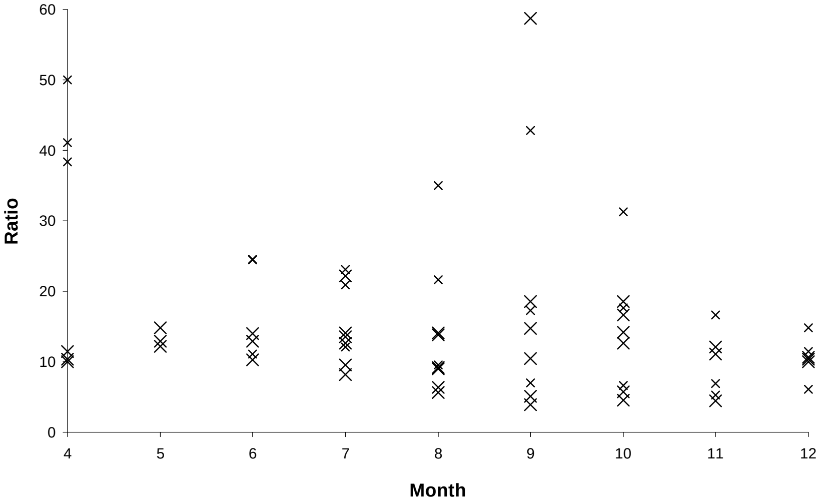


Figure 19. TN:TP ratios for Armstrong Arm 1996-1999 combined

		OK1-4	OK5-7	OK8
	J	1.1	1.7	3.9
	A	1.3	1.8	2.9
###	S	1.2	1.5	2.6
	O	1.3	1.5	4.1
	N		1.6	
	F	1.6	1.7	
	M	1.1	1.2	
	A	2.1	2.5	7.9
	M	2.2	2.6	7
	J	2.7	3.3	5.5
###	J	2.4	2.8	5.7
	A	2.2	3.3	4.3
	S	1.4	1.4	7.3
	O	3.1	4	4.3
	N	2.3	2.3	2.5
	D	1.3	1.8	4.5
	F	1.3	1	
	M	6.9	7.8	6.5
	A	6.2	5.2	4.3
	M	1.8	3	2.2
###	J	2.5	3.1	3.7
	J	1.3	0.8	2.9
	A	7.9	12.2	13
	S	3.4	5.3	4.8
	O	3.4	3.8	7.3
	N	0	0.4	2.4
	F	0.0	0.2	0.4
	M			
	A	3.2	4.3	3.7
	M	4.0	4.5	5.9
###	J	4.3	3.5	4.8
	J	4.6	7.5	6.4
	A	5.2	6.2	5.8
	S	7.8	5.5	5.4
	O	7.5	7.2	7.0
	N	4.6	3.7	7.1

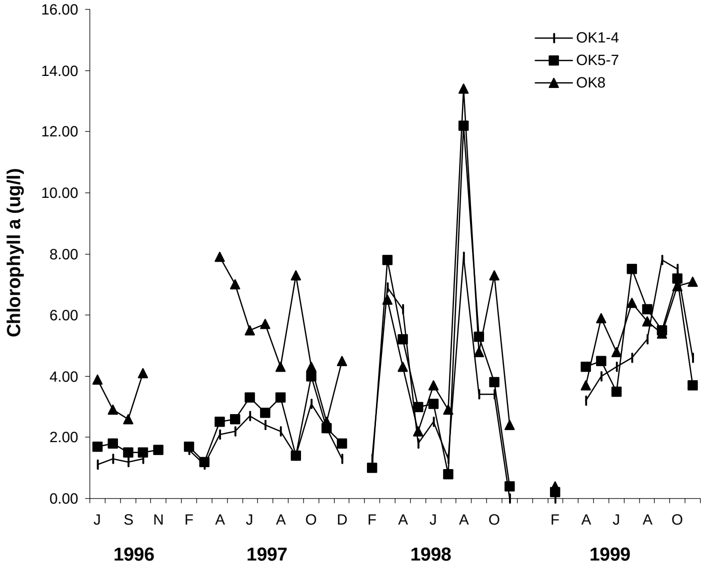


Figure 20. Okanagan Lake chlorophyll *a* concentrations at 0-10 m at Stations OK4, OK7 and OK8, from 1996-1999

PHYTOPLANKTON POPULATIONS IN OKANAGAN LAKE, BRITISH COLUMBIA, 1999

by

John G. Stockner, Ph.D[1]

INTRODUCTION

Background

A comprehensive limnological study of the Okanagan Basin lakes was conducted from 1969-1972 as part of the *Canada - British Columbia Okanagan Basin Agreement* in 1969. Okanagan Lake, the largest of the basin lakes, was described as a deep, narrow BC interior, fjord-type, oligotrophic lake with low nutrients, low to moderate plankton biomass and moderate fish production (Stockner and Northcote, 1974; Stockner and Pinsent 1974). At the time of these studies 'red flags' had been raised as there were spreading concerns about recurrent blue-green algal blooms in the Vernon and Armstrong Arms and mid-lake in the vicinity of Westbank and Kelowna region (Map 1). Furthermore there was also growing public concern for what some described as 'explosive' growths of macrophyte beds (*Myriophyllum spicatum*) in shallow regions of the lake subject to anthropogenic influence e.g., Vernon Arm, Armstrong, Kelowna foreshore.

Over the next three decades nutrient removal from most point sources by sewage treatment plants (STP) has been implemented to prevent any further deterioration of water quality. Despite this major initiative unanticipated rate of population growth and settlement within the drainage basin, particularly over the last decade, has resulted in some of the highest total phosphorus (TP) concentrations ever observed (V. Jenson *in* Ashley et al. 1999).

There has been a second more ominous sign of potential 'bottlenecks' to efficient carbon (C) flow in the food web of Okanagan Lake. During the last two decades observations (see Andrusak in this OLAP report) and anecdotal public reports have opined of an alarming decline of rainbow trout and kokanee stocks. Causes of the decline have been attributed to either competition for forage by the introduced freshwater shrimp (*Mysis relicta*) or to deteriorating water quality or to a combination of both factors (Ashley et al. 1999). Part of the Okanagan Lake Action Plan (OLAP) is aimed at documenting the current trophic state of Okanagan Lake. One component of the OLAP that was launched in the spring 1999 was a more intensive examination of the phytoplankton populations. The study included a first look at microbial populations (e.g., flagellates, pico-cyanobacteria and ciliates), phytoplankton species composition and seasonal succession, and population abundance and biovolume (biomass). This report presents, discusses and summarizes major population trends for the growing season - April to November 1999.

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Study Limitations

As a caveat it should be noted that number of stations (5), sampling frequency (monthly) and effort (1 sample and station, depth-integrated 0-10 m) allows only a ‘first impression’ of phytoplankton population abundance, diversity and spatiotemporal variability. No attempts were made to measure rates of photosynthesis (primary production) or examine vertical population structure, deep production peaks, etc. Hence, interpretations of phytoplankton population trends reported here are based only on two variables:

1. Abundance by species and Class expressed as cells· mL.
2. Species and class biovolume or biomass estimates expressed as mm^3· L. Because of these limitations, this report should be considered as an ‘overview’ rather than a detailed synthesis of the Okanagan Lake phytoplankton community dynamic. Where possible interpretations based on abundance and biomass estimates have been made. However, these interpretations will be limited in scope and open to further discussion as additional data become available and are further integrated with data presented here.

METHODS

Sampling Protocol

A single, depth integrated (0-10 m) sample from each of 5 stations (OK 1, 3, 6, 7, and 8[2]) were taken monthly along a north and south axis of Okanagan Lake from April to November 1999 (Map 2). Stations 1 and 3 were representative of pelagic conditions in the south basin of the lake, off South Prairie Creek (90 m) and Rattlesnake Island (140 m), respectively. Station 6 was the deepest (225 m) station located mid-lake off North Okanagan Centre. Stations 7 and 8 were located in the north basin off Vernon Arm (90 m) and Armstrong Arm (55 m). These stations reflect enriched conditions from the various point and non-point discharges from municipalities of Vernon and Armstrong.

Enumeration Protocol

Each phytoplankton sample was preserved in acid Lugol’s iodine preservative. Prior to quantitative enumeration the samples were gently shaken for 60 seconds, carefully poured into 25 mL settling chambers and then allowed to settle for a minimum of 24 hr. Counts were done using a Carl Zeiss inverted phase-contrast plankton microscope. Counting followed a two step process:

- several (5 to 10) random fields were examined at 250X magnification (16X objective) for large micro-phytoplankton (20-200 µm), e.g., diatoms, dinoflagellates, filamentous blue-greens; and
- all cells within a random transect (ranging from 10 to 15 mm) were counted at high power (100X objective = 1562X magnification) that permitted a semi-quantitative enumeration of minute (<2 µ) autotrophic picoplankton cells (0.2-2.0 µm) [Class Cyanophyceae] as well as

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[2] Three samples were counted from OK4, but the data was insufficient to use in this report.

small, delicate auto-, mixo- and heterotrophic nano-flagellates (2.0-20.0 μm) [Classes Chrysophyceae and Cryptophyceae].

Observations of the number of ciliates in each sample were noted on the count sheets. In total, between 250-300 cells were enumerated in each sample to assure statistical consistency and accuracy (Lund et al. 1958). A species list of phytoplankton from Okanagan Lake, together with estimates of their respective cell biovolumes, is presented in Appendixes 1 and 2.

RESULTS

Lake Summaries and Seasonal Trends

In both density and biomass the phytoplankton populations of Okanagan Lake in 1999 followed a clear north and south gradient. The lowest average phytoplankton abundance and biovolume occurred in the south basin near Penticton and the highest in the north in Armstrong and Vernon Arms (Map 2, Table 1). Major phytoplankton increases (blooms, >10X increases) were not apparent in Okanagan Lake. Only smaller, seasonal population increases (2-3X) were noted, with the larger peaks observed in the more productive northern portions, e.g., OK 7 and 8, and the smallest at OK 1 (Map 2, Fig. 2).

Table 1. Station and lake average phytoplankton density and biovolume in 1999.

Station	OK 1	OK 3	OK 6	OK 7	OK 8	Lake Average
Abundance (cells· mL)	4,780	5,059	5,262	5,951	5,720	5,354
Biovolume (mm^3· L)	0.56	0.73	0.83	0.84	0.88	0.77

There was some interesting population trends among stations along the north and south lake axis. Perhaps the most notable was the difference in the onset of the spring phytoplankton increase. By the middle of April (first sampling date), the spring phytoplankton (largely diatoms and picocyanobacteria) increase was at its peak at OK 6 and 7, while further south populations were still low, increasing to peak numbers a month later in early June (Figs. 1 and 2). The August population depression was well depicted at all stations, and was followed by rather striking increases of filamentous blue-greens (Cyanobacteria) in September and October. They remained dominant until well into November when they were gradually dispersed by the onset of deep mixing episodes.

Trends in Species and Groups

At all stations in Okanagan Lake Cyanophycean blue-greens were numerically the dominant group followed by Chryso- and Cryptophycean nano-flagellates, and diatoms or Bacillariophytes (Fig. 1). Green algae or Chlorophytes and dinoflagellates were of least significance in both their contributions to density and biomass. In the spring at all stations minute and ubiquitous autotrophic picoplankters (1.5-2.0 μ), mainly *Synechococcus* sp., contributed significantly to total phytoplankton densities but only moderately to total biomass because of their small size. Their populations attained densities of >15,000 cells· mL[3] in June at OK 7 and 8 but were less than 8,000-10,000 cells· mL at remaining stations. Autotrophic picoplankton populations declined sharply by July and August with the onset of major increases of colonial blue-greens (e.g., *Oscillatoria spp., Anabaena, Lyngbya, Aphanizomenon,* etc.). The large, colonial blue-greens were the predominant contributors to total phytoplankton biovolume at all stations from August to November. Small nano-flagellates (2-12 μ) (*Cryptomonas, Chrysochromulina, Rhodomonas, Chroomonas, Dinobryon,* etc.) were important contributors to phytoplankton density and total biomass at all stations throughout the growing season, but most notably concurrent with the spring diatom and picoplankton increase.

Diatom populations were predominant only during the early spring and the common genera listed by numerical dominance were *Cyclotella*, *Fragilaria*, *Asterionella*, *Aulicoseira* and *Rhizosolenia*. A distinct fall diatom increase was not observed at any station, and sampling occurred well into the transition phase of the lake's mixing cycle (mid-November). The least abundant phytoplankters were dinoflagellates (Dinophycea) and green algae (Chlorophyceae). Though species of each class were present at all stations throughout the growing season (e.g., *Peridinium, Gymnodinium, Ankistrodesmus, Oocystis*, etc.) their populations never attained densities sufficient to predominate either total phytoplankton abundance or biovolume. A listing of the phytoplankton species present in Okanagan Lake is provided in Appendix 1.

DISCUSSION

The spring and early summer (March to June) phytoplankton species assemblages of Okanagan Lake were typical of those found in lakes of low nutrient status, dominated by picoplankton, a great diversity of nano-flagellates, and several diatoms, e.g., *Cyclotella* spp., *Rhizosolenia, Fragilaria* spp. (Stockner and Shortreed 1994). The spring assemblages can further be characterized by their low populations sizes, low biomass and absence of major seasonal successional trends, e.g., spring 'blooms' (Stockner 1987). But the July to November predominance of a mixed assemblage of colonial N_2 fixing blue-green algae is atypical for oligotrophic systems and a condition ***rarely,*** if ever, seen in other large interior BC lakes or reservoirs, e.g., Kootenay, Arrow, and Duncan.

The Cyanophycean picoplankter *Synechococcus* was the most abundant phytoplankter in Okanagan Lake at all stations in 1999, attaining densities of between 10,000 - 15,000 cells· mL at OK7 and OK8 in May. However, because of their small cell size they were the major contributors

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[3] For among station and between lake comparisons a correction factor of 3.0X was applied to the *Synechococcus* counts from Okanagan Lake. The Utermohl (1958) method used here has limitations for counting cells <2μ (long settling times, low resolution) (Stockner and MacIsaac 1996). Comparisons of Utermohl pico- counts with those determined by the preferred auto-fluorescence method show that Utermohl values should be corrected by a factor that ranges between 3.0 – 3.5X to provide a minimum estimate comparable to picoplankton densities computed by auto-fluorescence (J. Stockner, Uppsala University, Institute of Limnology, unpublished data).

to biovolume at most stations. Picoplankton densities were minimal estimates, but nonetheless Okanagan Lake populations were about the same as seen in several oligotrophic coastal lakes, in high elevation Chilko Lake, and in Yukon River basin lakes (Stockner and Shortreed 1991 and 1994).

Although there were some differences in total abundance among stations (high to low along north and south gradient), the species composition of populations in Okanagan Lake in 1999 were quite similar among the 5 stations sampled. There were some abundance peaks in spring (diatoms, nano-flagellates) and fall (blue-greens) but these increases were neither large nor particularly noticeable. It should be noted that this apparent community stability could be due more to the insufficient sampling frequency (8 samples, April to November) and integrated (0-10 m) nature of the sampling than to the lack of a significant phytoplankton community response to fluctuating spatiotemporal variables.

Autotrophic Picoplankton and Microbial Communities

Numerical dominance of the picoplankter *Synechococcus* together with the diverse and abundant spring assemblage of Chrysophyceae and Cryptophyceae nano-flagellates are clear and unambiguous indicators of the basic oligotrophic condition of Okanagan Lake. The predominance of these groups together with small ciliates in the pelagic phytoplankton community confirms the importance and major role of 'microbial food webs' at this time in mediating carbon metabolism and nutrient fluxes in Okanagan Lake (Stockner and Porter, 1988; Stockner and Shortreed 1991). As the epilimnion becomes NO_3-N deplete, and the community shifts to a prevalence of large colonial cyanobacteria, *Synechococcus* sp. declines sharply. It is well known that during periods of severe N limitation that autotrophic picoplankton populations decline to very low levels because of allellopathic interactions with colonial cyanobacteria (Stockner and Shortreed 1988; Stockner et al. 1999). This pattern of abrupt picoplankton disappearance was prevalent at all stations in Okanagan immediately following nitrate depletion in the epilimnion in May and June.

Nitrogen Limitation

Seasonally, there was only one significant shift in species composition that occurred lake-wide most notably in the north sector. This was the rather abrupt shift from the spring (April to June) pico-cyanobacteria, nanoflagellates and diatom dominance to an assemblage dominated chiefly by colonial cyanobacteria from June to November. This shift was earlier (May) and most pronounced at OK7 and OK8 where the sub-basins are shallower and the influence of anthropogenic inputs from 'point' sources more pronounced, (i.e., Vernon, Armstrong). This major shift in population structure is coincident with NO_3-N depletion from the epilimnion in May and June at all stations. Since the majority of colonial cyanobacteria found in Okanagan Lake are able to fix atmospheric N, it is not surprising that their populations rapidly gain dominance in surface waters when the epilimnetic N:P ratio sharply plummets in June. If one looks at the TDP:NO_3-N ratio in 1999 for the epilimnion in April and May – 30:1, and contrasts this value to the one seen in July, August, and September – 0:5 the explanation for the abrupt shift is readily obvious.

Depletion of NO_3-N and subsequent N limitation of phytoplankton population growth when coupled with a high availability of dissolved P (TDP > 5 µg· L), creates and sustains a predominance of filamentous cyanobacteria in the epilimnion well into November at all stations, but most profoundly so at OK7 and OK8.

Interlake Comparison

Comparison of the average seasonal abundance and biovolume estimates from Okanagan Lake (1999) with Arrow and Williston reservoirs is instructive (Table 2). It is clear that the prevalence of the summer and fall cyanobacteria populations in Okanagan Lake create a 2-fold larger biomass (biovolume) than either reservoir where they are rare or totally absent. However, numerically the populations of the three systems are not significantly different.

Table 2. Abundance and biovolumes of Okanagan Lake, Williston and Arrow reservoirs.

	Year	Okanagan	Williston	Arrow
Abundance (cells· mL)	1999	5,354	4,852	4,777
Biovolume (mm^3· L)	1999	0.77	0.34	0.29

Changes Since 1970s

Has the productive capacity of Okanagan Lake changed substantially since the 1970s? The answer lies in whether or not the nutrient dynamic, annual mass-balance of N and P, and phytoplankton ecology have changed significantly since conditions in the late 1960s reported by Stockner and Pinsent (1974). Fortunately, all water quality data gathered for the past 3 decades by various government agencies for Okanagan Lake has been collated and summarized in the 1999 OLAP report by Jensen (*in* Ashley et al. 1999). Some of the more pertinent points from this report and from assessment of recent data can be summarized as follows:

1. Total phosphorus values slightly increased through the late 1970s and early 1980s, declined briefly through the late 1980s and early 1990s, rose again in the mid-1990s to a peak in 1997 but declined again in 1998 and 1999 to mean values similar to those reported in 1973. TDP has followed a similar pattern.

2. TN and spring NO_3-N values have gradually risen over the past 3 decades but rates of spring NO_3-N depletion have increased and now occur earlier in the season and extend later into the autumn.

3. After May and June, nitrogen is the limiting factor for phytoplankton.

4. Transparency has declined in recent years and phytoplankton biomass (Chl. and Biovolume) has steadily increased.

5. Phytoplankton densities were relatively stable for two decades but have increased in the 1990s; most notable are increases in the blue-green (Cyanophyceae) populations, but not to population levels large enough to be called ‘bloom’ conditions.

6. The fall increase of diatoms that is coincident with deep mixing events in October and November and was prevalent in the 1970s has been eliminated from most stations of Okanagan Lake, most conspicuously from Armstrong and Vernon arms.

SUMMARY

The phytoplankton populations of Okanagan Lake display two prominent features. Firstly, a spring assemblage typical of a moderately productive oligotrophic lake with an initial diatom increase is followed by a microbially dominated food web. Secondly, there is a blue-green algal dominated summer and fall assemblage. This is common in meso-eutrophic lakes induced by nitrate limitation in the epilimnion and sustained by moderate levels of DPN. The lake is spared the plight of typical blue-green ‘blooms’ because of insufficient levels of phosphorus to push the population to levels >10,000-20,000 cells· mL (Stockner and Shortreed 1988). Although there have been subtle changes in the population dynamics (e.g., increases in abundance of blue-greens and the gradual elimination of most of the autumn diatoms) the ambient nutrient concentrations and phytoplankton ecology of the lake has remained remarkably stable considering the scale of development within the drainage basin. Based on the data examined for this report, Okanagan Lake in terms of productive capacity remains an oligotrophic ecosystem, albeit near the high end of the scale, i.e., rapidly approaching mesotrophy!

It appears that average annual rates of primary production have remained constant over the past three decades. However, with the gradual increase of blue-green abundance it would be expected that forage production (mostly large macro-zooplankton) would show further declines from present levels, which are low for a lake of this size and productive state. Zooplankton densities and biomass in Shuswap, Quesnel, Francois, and Fraser lakes are considerably higher! This is because filamentous cyanobacteria are known to be a poor food source for macrozooplankton (Gliwicz 1975). Whether the composition or scarcity of large macro-zooplankton has been significant enough to impact juvenile kokanee growth and or survival over the past few decades is unclear without examination of additional data.

The pollution abatement controls implemented in the late 1970s and early 1980s to remove phosphorus from point sources has obviously saved the lake from the onset of eutrophic state, conditions predicted to occur by the 1990s without implementation of STP nutrient removal (Fleming and Stockner 1975). The removal of N by STP in the valley has further exacerbated the nutrient balance of the lake and has ultimately led to the predominance of the cyanobacteria in the lake. Currently, it appears that the unprecedented population growth seen over the last decade may be further taxing the nutrient balance (N:P), driving the system toward eutrophy at a rapid pace, as evidenced by increasing TN, TP and TDP levels in the late 1990s.

RECOMMENDATIONS

1. Further studies should be done to assess the impact on phytoplankton of restoring a normal N:P balance from May to September, using limno-corrals or whole-lake fertilization techniques. The study should examine phytoplankton communities for shifts in size spectra, edibility, abundance and succession in the presence of a balanced >30:1 N:P ratio. Concurrently, studies to document zooplankton changes (e.g. species changes, density, size, fecundity, etc.) should also be done.

2. Primary production studies (C^{14} assimilation) should be done monthly starting in April 2000, to determine efficiency of phytoplankton growth, and provide rate function estimates of system production (now lacking!). C^{14} studies should be size-fractionated to determine what fraction of carbon flows through the picoplankton to microbial communities.

3. A more detailed examination of the phytoplankton community of the lake is warranted in light of the changes now occurring in the lake and the poor level of understanding of the dynamics of the pelagic ecosystem. Some vertical profile sampling is necessary to document the presence or absence of a deep chlorophyll maximum at the nitrocline.

REFERENCES

Ashley, K., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, G. Scholten, M. Zimmerman, P. Epp, V. Jensen, R. Finnegan. 1999. Okanagan Lake Action Plan Year 3 (1998-99) Report. Fisheries Project Report No. RD 78. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch, Victoria BC.

Fleming, WM and JG Stockner. 1975. Predicting the Impacts of Phosphorus Management Policies on the Eutrophication of Skaha Lake, British Columbia, Canada. Verh. Internat. Verein. Limnol. 19: 241-248.

Gliwicz, ZM. 1975. Effect of Zooplankton Grazing on Photosynthetic Activity and Composition of the Phytoplankton. Verh. Internat. Verein. Limnol. 19: 1490-1497.

Lund JG, Kipling C and ED LeCren. 1958. The Inverted Microscope Method of Estimating Algal Numbers and the Statistical Basis of Estimations by Counting. Hydrobiologia 11:143-170.

Stockner, JG. 1987. Lake Fertilization: The Enrichment Cycle and Lake Sockeye Salmon (Oncorhynchus nerka) Production, pp. 198-215. *In:* H.D. Smith, L. Margolis and C.C. Wood (eds.). Sockeye Salmon (*Oncorhynchus nerka*) Population Biology and Future Management. Can. Spec. Publ. Fish. Aquat. Sci. 96, 486 p.

Stockner, JG. 1991. Autotrophic Picoplankton in Freshwater Ecosystems: The View from the Summit. Int. Rev. gesamten Hydrobiol. 76: 483-492.

Stockner, JG and TG Northcote. 1974. Recent Limnological Studies of Okanagan Basin Lakes and their Contribution to Comprehensive Water Resource Planning. J. Fish. Res. Board Can. 31: 955-976.

Stockner, JG and ME Pinsent. 1974. The Limnology of the Major Okanagan Basin Lakes (Final Report). BC Min. Environ. Wat. Resources. Br., Victoria BC, 260 p.

Stockner JG and KG Porter. 1988. Microbial Food Webs in Fresh Water Planktonic Ecosystems, Carpenter SR (Ed), Complex Interactions in Lake Communities, pp 71-84, Springer Verlag, New York, NY.

Stockner, JG and KS Shortreed. 1988. Response of *Anabaena* and *Synechococcus* to Manipulation of Nitrogen:Phosphorus Ratios in a Lake Fertilization Experiment. Limnol. Oceanogr. 33(6, part 1): 1348-1361.

Stockner JG and KS Shortreed. 1991. Phototrophic Picoplankton: Community Composition, Abundance and Distribution Across a Gradient of Oligotrophic British Columbia and Yukon Territory Lakes. Int. Revue ges. Hydrobiol. 76: 581-601.

Stockner JG and KS Shortreed. 1994. Autotrophic Picoplankton Community Dynamics in a Pre-alpine Lake in British Columbia, Canada. Hydrobiologia 274: 133 142.

Stockner JG and ER MacIsaac. 1996. British Columbia Lake Enrichment Program: Two Decades of Habitat Enhancement for Sockeye Salmon, Reg. Rivers 12:547-561

Stockner, JG, C Callieri, and G Cronberg. 1999. Picoplankton and Other Non-bloom Forming Cyanobacteria in Lakes. *In*: B.A. Whitton and M. Potts. (eds.), The Ecology of Cyanobacteria. Kluwer Press, Amsterdam, Holland.

Utermohl, H, 1958. Zur Vervollkommnung der quantitativen Phytoplankton methodik. Int. Verein. theor. angew. Limnologie, Mitteilung 9.

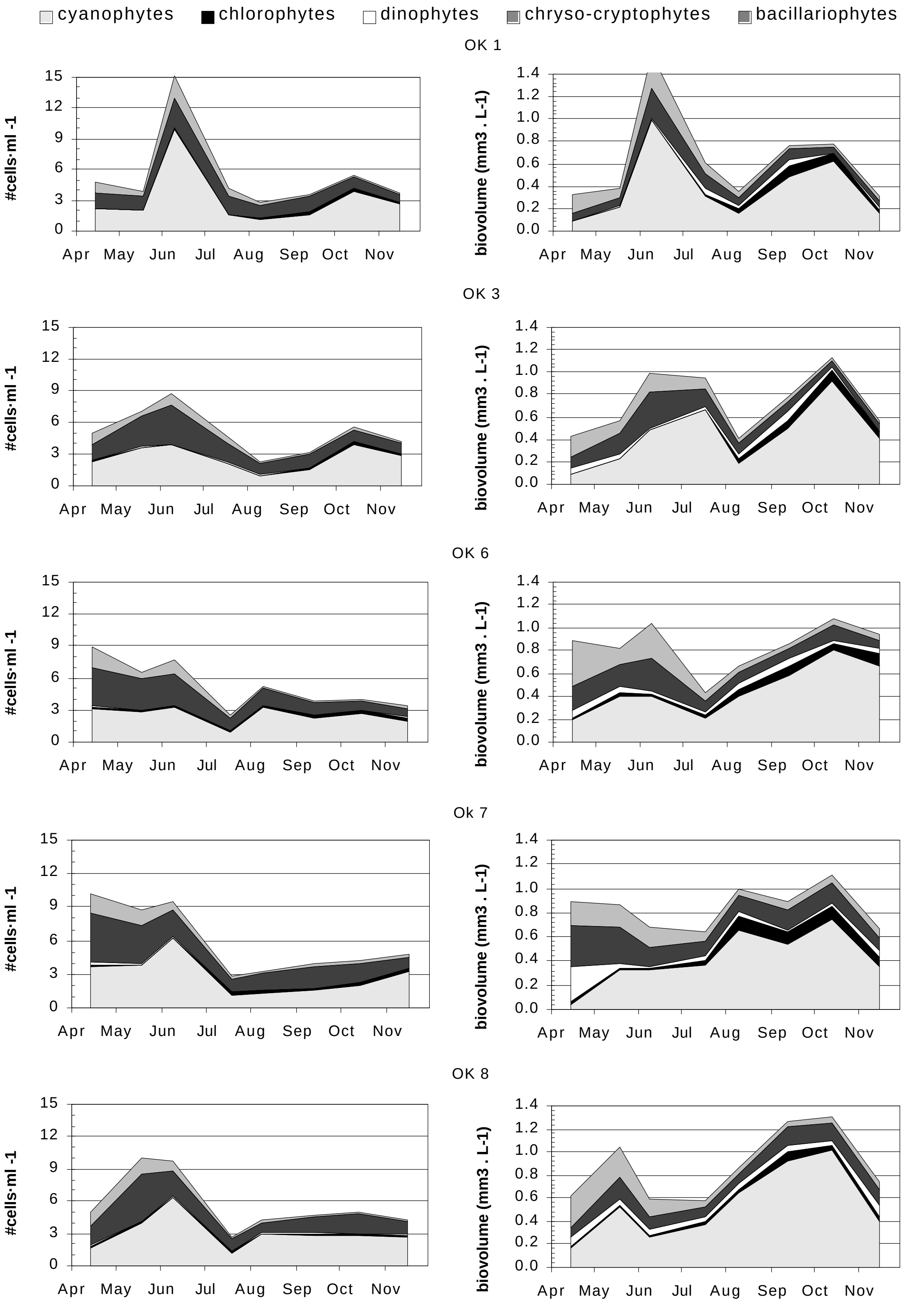

Figure 1. Seasonal (May to November) abundance (in 1,000s) and biomass of the major phytoplankton classes in Okanagan Lake in 1999.

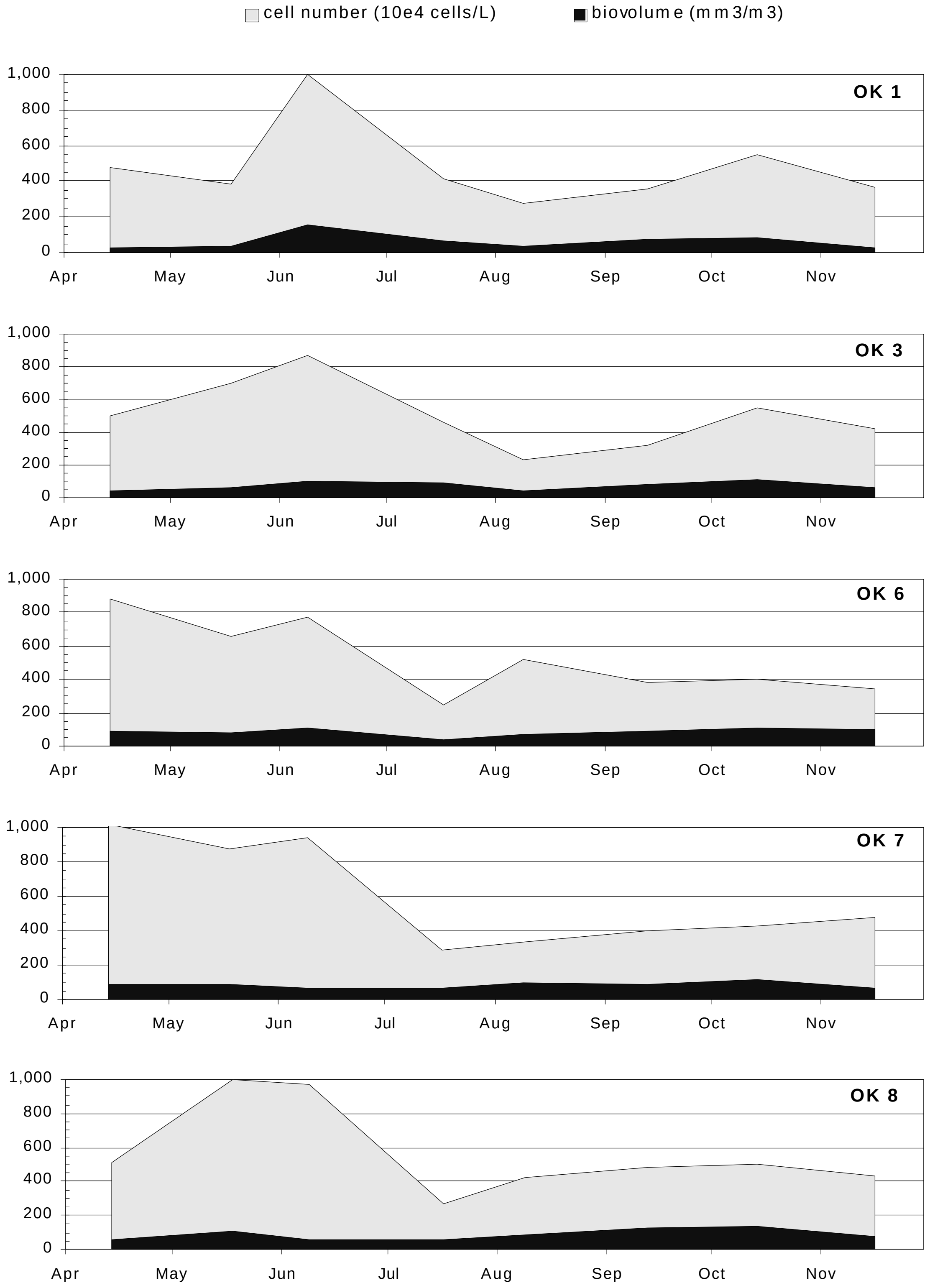

Figure 2. Seasonal (May to October) epilimnetic phytoplankton abundance and biomass in Okanagan Lake in 1999.

Appendix 1. Okanagan Lake Phytoplankton species, codes and biovolumes.

NUMBER	CODE	GROUP	BIOVOLUMES	SPECIES
1	AM	Bacillariophyte	80	Achnanthes sp2
2	AN	Bacillariophyte	100	Achnanthes sp1
3	AY	Bacillariophyte	100	Asterionella formosa var1
4	AZ	Bacillariophyte	120	Asterionella formosa var2
5	CP	Bacillariophyte	200	Cocconeis sp.
6	CU	Bacillariophyte	250	Cyclotella comta var1
7	CZ	Bacillariophyte	500	Cyclotella comta var2
8	CV	Bacillariophyte	50	Cyclotella stelligera var1
9	CR	Bacillariophyte	100	Cyclotella stelligera var2
10	CS	Bacillariophyte	150	Cyclotella stelligera var3
11	CW	Bacillariophyte	50	Cyclotella sp3
12	CT	Bacillariophyte	150	Cyclotella sp2
13	CM	Bacillariophyte	150	Cymbella sp1
14	CO	Bacillariophyte	250	Cymbella sp2
15	DF	Bacillariophyte	150	Diatoma sp.
16	EU	Bacillariophyte	100	Eunotia sp1
17	EV	Bacillariophyte	200	Eunotia sp2
18	EW	Bacillariophyte	500	Eunotia sp3
19	FF	Bacillariophyte	80	Fragilaria construens var2
20	FG	Bacillariophyte	150	Fragilaria construens var3
21	FC	Bacillariophyte	120	Fragilaria crotonensis
22	FS	Bacillariophyte	100	Fragilaria sp.
23	MC	Bacillariophyte	250	Aulicoseira distans var1
24	MD	Bacillariophyte	350	Aulicoseira distans var2
25	MI	Bacillariophyte	200	Aulicoseira italica var1
26	MJ	Bacillariophyte	250	Aulicoseira italica var2
27	MZ	Bacillariophyte	350	Aulicoseira sp.
28	NV	Bacillariophyte	500	Navicula sp.
29	NZ	Bacillariophyte	200	Nitzschia sp.
30	RC	Bacillariophyte	50	Rhizosolenia sp.
31	SE	Bacillariophyte	1,500	Stephanodiscus sp.
32	SN	Bacillariophyte	100	Fragilaria acus var1
33	SO	Bacillariophyte	150	Fragilaria acus var2
34	SU	Bacillariophyte	1,000	Fragilaria ulna
35	SP	Bacillariophyte	200	Fragilaria sp1
36	SR	Bacillariophyte	250	Fragilaria sp3
37	TF	Bacillariophyte	500	Tabellaria fenestrata
38	TB	Bacillariophyte	500	Tabellaria flocculosa
39	BQ	Chryso-Cryptophyte	100	Bitrichia sp3
40	BS	Chryso-Cryptophyte	200	Bitrichia sp4
41	CH	Chryso-Cryptophyte	250	Chilomonas sp.
	CODE	**GROUP**	**BIOVOLUMES**	**SPECIES**

	CODE	GROUP	BIOVOLUMES	SPECIES
42	XX	Chryso-Cryptophyte	20	Chromulina sp1
43	XY	Chryso-Cryptophyte	50	Chromulina sp3
44	CA	Chryso-Cryptophyte	150	Chroomonas acuta var1
45	CB	Chryso-Cryptophyte	200	Chroomonas acuta var2
46	YQ	Chryso-Cryptophyte	500	Chryptomonas sp1
47	YO	Chryso-Cryptophyte	700	Chryptomonas sp4
48	CC	Chryso-Cryptophyte	75	Chrysochromulina sp.
49	DC	Chryso-Cryptophyte	100	Dinobryon cysts
50	DN	Chryso-Cryptophyte	150	Dinobryon sp2
51	DO	Chryso-Cryptophyte	200	Dinobryon sp5
52	DP	Chryso-Cryptophyte	350	Dinobryon sp6
53	KB	Chryso-Cryptophyte	40	Kephyrion sp2
54	KA	Chryso-Cryptophyte	50	Kephyrion sp1
55	MK	Chryso-Cryptophyte	200	Mallomonas sp7
56	MF	Chryso-Cryptophyte	350	Mallomonas sp8
57	MH	Chryso-Cryptophyte	500	Mallomonas sp5
58	ME	Chryso-Cryptophyte	700	Mallomonas sp4
59	MG	Chryso-Cryptophyte	750	Mallomonas sp6
60	ML	Chryso-Cryptophyte	1,500	Mallomonas sp1
61	YZ	Chryso-Cryptophyte	10	Small microflagellates
62	OC	Chryso-Cryptophyte	250	Ochromonas sp.
63	PT	Chryso-Cryptophyte	100	Pseudokephrion sp.
64	PP	Chryso-Cryptophyte	150	Pseudopedinella sp.
65	RM	Chryso-Cryptophyte	60	Rhodomonas sp1
66	RN	Chryso-Cryptophyte	80	Rhodomonas sp2
67	RO	Chryso-Cryptophyte	100	Rhodomonas sp3
68	GT	Dinophyte	100	Gymnodinium sp6
69	GY	Dinophyte	1,000	Gymnodinium sp1
70	GZ	Dinophyte	1,500	Gymnodinium sp2
71	GW	Dinophyte	2,500	Gymnodinium sp5
72	PJ	Dinophyte	350	Peridinium sp4
73	PK	Dinophyte	450	Peridinium sp3
74	XC	Chlorophyte	80	Ankistrodesmus sp3
75	XA	Chlorophyte	100	Ankistrodesmus sp2
76	CL	Chlorophyte	500	Coelastrum sp.
77	CN	Chlorophyte	500	Cosmarium sp.
78	CK	Chlorophyte	200	Crucigenia sp.
79	XU	Chlorophyte	250	Crucigeniella apiculata
80	DM	Chlorophyte	1,000	Desmids
81	EJ	Chlorophyte	100	Elakatothrix sp2
82	EL	Chlorophyte	250	Elakatothrix sp3
83	EK	Chlorophyte	500	Elakatothrix sp1
84	OO	Chlorophyte	500	Oocystis sp.
85	SI	Chlorophyte	60	Scenedesmus sp.

86	SD	Chlorophyte	1,500	Staurodesmus sp.
87	TE	Chlorophyte	50	Tetrahaedron sp.
88	AB	Cyanophyte	300	Anabaena sp1 (small)
89	AC	Cyanophyte	900	Anabaena circinalis
90	AH	Cyanophyte	100	Aphanothecae sp.
91	AP	Cyanophyte	1,500	Aphanizomenon sp.
92	MS	Cyanophyte	20	Merismopedia sp.
93	ZN	Cyanophyte	20	Oscillatoria sp2
94	ZO	Cyanophyte	350	Oscillatoria limnetica
95	SC	Cyanophyte	5	Synechococcus sp.
96	CY	Cyanophyte	10	Synechocystis
97	ST	Chlorophyte	1,000	Staurastrum sp.
98	PL	Chlorophyte	350	Planctonema sp.
99	PS	Chlorophyte	100	Paulschultzia sp.
100	KI	Chlorophyte	50	Kirchneriella sp.
101	CI	Chryso-Cryptophyte	75	Chrysoikos sp.
102	PI	Bacillariophyte	2,000	Pinnularia sp.
103	GG	Bacillariophyte	750	Gomphonema sp.
104	MX	Cyanophyte	500	Microcystis sp.
105	LB	Cyanophyte	500	Lyngbya sp.
106	CX	Chlorophyte	150	Coccomyxa sp.
107	CJ	Bacillariophyte	350	Ceratoneis sp.
108	SX	Chryso-Cryptophyte	75	Stenokalyx
109	GO	Chlorophyte	500	Gonium
110	CE	Dinophyte	5,000	Ceratium
111	QD	Chlorophyte	250	Quadrigula
112	UL	Chlorophyte	700	Ulothrix
113	CD	Chlorophyte	150	Closteriopsis
114	MO	Chlorophyte	200	Monoraphidium
115	SY	Chryso-Cryptophyte	700	Synura
116	LA	Chlorophyte	30	Langerheimia
117	SS	Bacillariophyte	500	Suriella
118	CF	Chryso-Cryptophyte	250	Chrysidiastrum
119	DI	Chlorophyte	900	Dichtyosphaerium
120	OA	Cyanophyte	750	Oscillatoria agardhii

Appendix 2. Phytoplankton Count and Biovolumes.

Lake: OKANAGAN **Station:** 1 **Depth:** 0-10M
Date: 14/04/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	13.82	0.0011
	Fragilaria construens var3	27.65	0.0041
	Fragilaria ulna	13.82	0.0138
	Fragilaria acus var1	69.12	0.0069
	Fragilaria acus var2	27.65	0.0041
	Cyclotella stelligera var3	165.88	0.0249
	Cyclotella sp3	483.81	0.0242
	Cyclotella comta var2	69.12	0.0346
	Stephanodiscus sp.	27.65	0.0415
	Rhizosolenia sp.	96.76	0.0048
	Group total	995.26	0.1601
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	304.11	0.0061
	Chrysochromulina sp.	96.76	0.0073
	Chryptomonas sp4	13.82	0.0097
	Rhodomonas sp3	179.70	0.0180
	Chroomonas acuta var1	165.88	0.0249
	Small microflagellates	760.27	0.0076
	Group total	1520.53	0.0735
Dinophyceae (dinoflagellates)			
	Peridinium sp4	13.82	0.0048
	Group total	13.82	0.0048
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	13.82	0.0011
	Group total	13.82	0.0011
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	1935.22	0.0097
	Oscillatoria sp2	110.58	0.0022
	Oscillatoria limnetica	138.23	0.0484
	Oscillatoria agardhii	27.65	0.0207
	Group total	2211.68	0.0810
	GRAND TOTAL	4755.11	0.3205

Lake: OKANAGAN **Station:** 1 **Depth:** 0-10M
Date: 18/05/99 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	20.27	0.0016
	Asterionella formosa var1	40.55	0.0041
	Fragilaria construens var3	10.14	0.0015
	Fragilaria crotonensis	70.96	0.0085
	Fragilaria acus var1	70.96	0.0071
	Fragilaria acus var2	40.55	0.0061
	Aulicoseira distans var2	20.27	0.0071
	Cyclotella stelligera var3	91.23	0.0137
	Cyclotella sp3	10.14	0.0005
	Cyclotella comta var2	60.82	0.0304
	Navicula sp.	10.14	0.0051
	Nitzschia sp.	10.14	0.0020
	Group total	456.16	0.0877
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	476.43	0.0095
	Chrysochromulina sp.	101.37	0.0076
	Chryptomonas sp4	30.41	0.0213
	Rhodomonas sp3	101.37	0.0101
	Chroomonas acuta var1	50.68	0.0076
	Dinobryon sp5	81.09	0.0162
	Small microflagellates	557.53	0.0056
	Group total	1398.89	0.0780
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Group total	20.27	0.0071
Chlorophyceae (coccoid greens, desmids, etc.)			
	Elakatothrix sp3	10.14	0.0025
	Group total	10.14	0.0025
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	1419.16	0.0071
	Oscillatoria limnetica	476.43	0.1668
	Oscillatoria agardhii	40.55	0.0304
	Aphanothecae sp.	60.82	0.0061
	Group total	1996.96	0.2103
	GRAND TOTAL	3882.42	0.3856

Lake: Okanagan **Station:** 1 **Depth:** 0-10M
Date: 9/6/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	30.41	0.0024
	Asterionella formosa var1	76.03	0.0076
	Fragilaria construens var2	15.21	0.0012
	Fragilaria construens var3	91.23	0.0137
	Fragilaria acus var2	182.46	0.0274
	Cyclotella stelligera var3	745.06	0.1118
	Cyclotella sp3	197.67	0.0099
	Cyclotella comta var2	167.26	0.0836
	Stephanodiscus sp.	15.21	0.0228
	Rhizosolenia sp.	593.01	0.0297
	Navicula sp.	15.21	0.0076
	Group total	2128.74	0.3176
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	760.27	0.0152
	Chrysochromulina sp.	91.23	0.0068
	Chryptomonas sp4	76.03	0.0532
	Rhodomonas sp3	91.23	0.0091
	Chroomonas acuta var1	30.41	0.0046
	Kephyrion sp1	15.21	0.0008
	Mallomonas sp6	15.21	0.0114
	Dinobryon sp5	790.68	0.1581
	Small microflagellates	1064.37	0.0106
	Group total	2934.62	0.2699
Dinophyceae (dinoflagellates)			
	Peridinium sp4	30.41	0.0106
	Group total	30.41	0.0106
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	45.62	0.0036
	Group total	45.62	0.0036
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	4105.43	0.0205
	Oscillatoria limnetica	425.75	0.1490
	Oscillatoria agardhii	288.90	0.2167
	Group total	4820.08	0.3862
	GRAND TOTAL	9959.48	0.9880

Lake: OKANAGAN **Station:** 1 **Depth:** 0-10M
Date: 17/07/99 **Magnif:** 1560

Class	Species	No. Cells/m	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	60.82	0.0049
	Asterionella formosa var1	20.27	0.0020
	Fragilaria construens var3	10.14	0.0015
	Fragilaria acus var1	30.41	0.0030
	Fragilaria acus var2	60.82	0.0091
	Aulicoseira italica var1	10.14	0.0020
	Cyclotella stelligera var3	253.42	0.0380
	Cyclotella sp3	202.74	0.0101
	Cyclotella comta var2	20.27	0.0101
	Rhizosolenia sp.	30.41	0.0015
	Nitzschia sp.	10.14	0.0020
	Navicula sp.	20.27	0.0101
	Group total	729.85	0.0946
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	344.65	0.0069
	Chrysochromulina sp.	273.70	0.0205
	Chryptomonas sp4	20.27	0.0142
	Rhodomonas sp3	273.70	0.0274
	Chroomonas acuta var1	141.92	0.0213
	Pseudokephrion sp.	10.14	0.0010
	Kephyrion sp1	81.09	0.0041
	Dinobryon sp5	182.46	0.0365
	Small microflagellates	506.84	0.0051
	Group total	1834.77	0.1369
Dinophyceae (dinoflagellates)			
	Peridinium sp4	40.55	0.0142
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	20.27	0.0203
	Group total	70.96	0.0497
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	20.27	0.0016
	Oocystis sp.	10.14	0.0051
	Cosmarium sp.	10.14	0.0051
	Group total	40.55	0.0118
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	912.32	0.0046
	Anabaena circinalis	10.14	0.0091
	Oscillatoria limnetica	334.52	0.1171
	Oscillatoria agardhii	202.74	0.1521
	Merismopedia sp.	10.14	0.0002
	Aphanizomenon sp.	20.27	0.0304
	Group total	1490.12	0.3134
	GRAND TOTAL	4166.25	0.6063

Lake: OKANAGAN **Station:** 1 **Depth:** 0-10M
Date: *9/8/99* **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	20.27	0.0016
	Fragilaria acus var1	30.41	0.0030
	Aulicoseira italica var1	10.14	0.0020
	Cyclotella stelligera var3	70.96	0.0106
	Cyclotella sp3	70.96	0.0035
	Cyclotella comta var2	10.14	0.0051
	Stephanodiscus sp.	20.27	0.0304
	Rhizosolenia sp.	10.14	0.0005
	Navicula sp.	20.27	0.0101
	Group total	263.56	0.0670
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	304.11	0.0061
	Chrysochromulina sp.	192.60	0.0144
	Chryptomonas sp4	20.27	0.0142
	Rhodomonas sp3	111.51	0.0112
	Chroomonas acuta var1	30.41	0.0046
	Kephyrion sp1	50.68	0.0025
	Dinobryon sp5	50.68	0.0101
	Small microflagellates	486.57	0.0049
	Bitrichia sp4	10.14	0.0020
	Group total	1256.97	0.0700
Dinophyceae (dinoflagellates)			
	Peridinium sp4	10.14	0.0035
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	10.14	0.0101
	Group total	30.41	0.0289
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	50.68	0.0041
	Oocystis sp.	60.82	0.0304
	Group total	111.51	0.0345
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	810.95	0.0041
	Anabaena circinalis	10.14	0.0091
	Oscillatoria limnetica	172.33	0.0603
	Oscillatoria agardhii	91.23	0.0684
	Aphanothecae sp.	20.27	0.0020
	Aphanizomenon sp.	10.14	0.0152
	Group total	1115.06	0.1591
	GRAND TOTAL	2777.50	0.3595

Lake: OKANAGAN **Station:** 1 **Depth:** 0-10M
Date: 13/09/99 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Fragilaria construens var2	10.14	0.0008
	Fragilaria construens var3	20.27	0.0030
	Fragilaria acus var1	20.27	0.0020
	Fragilaria acus var2	20.27	0.0030
	Cyclotella stelligera var3	10.14	0.0015
	Cyclotella sp3	20.27	0.0010
	Cyclotella comta var2	10.14	0.0051
	Stephanodiscus sp.	10.14	0.0152
	Cymbella sp1	10.14	0.0015
	Group total	141.92	0.0341
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	405.47	0.0081
	Chrysochromulina sp.	182.46	0.0137
	Chryptomonas sp4	40.55	0.0284
	Rhodomonas sp3	152.05	0.0152
	Chroomonas acuta var1	70.96	0.0106
	Pseudokephrion sp.	20.27	0.0020
	Kephyrion sp1	101.37	0.0051
	Dinobryon sp5	30.41	0.0061
	Small microflagellates	496.71	0.0050
	Group total	1500.26	0.0942
Dinophyceae (dinoflagellates)			
	Peridinium sp4	30.41	0.0106
	Gymnodinium sp2	20.27	0.0304
	Gymnodinium sp1	10.14	0.0101
	Group total	60.82	0.0512
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	10.14	0.0008
	Crucigenia sp.	20.27	0.0041
	Cosmarium sp.	20.27	0.0101
	Staurastrum sp.	40.55	0.0405
	Elakatothrix sp3	10.14	0.0025
	Planctonema sp.	131.78	0.0461
	Group total	233.15	0.1042
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	861.63	0.0043
	Anabaena circinalis	50.68	0.0456
	Oscillatoria limnetica	283.83	0.0993
	Oscillatoria agardhii	314.24	0.2357
	Aphanothecae sp.	30.41	0.0030
	Aphanizomenon sp.	50.68	0.0760
	Microcystis sp.	30.41	0.0152
	Group total	1621.90	0.4792
	GRAND TOTAL	3558.04	0.7629

Lake: OKANAGAN **Station:** 1 **Depth:** 0-10M
Date: 14/10/1999 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Fragilaria acus var1	60.82	0.0061
	Cyclotella stelligera var3	30.41	0.0046
	Cyclotella sp3	40.55	0.0020
	Cyclotella comta var2	20.27	0.0101
	Rhizosolenia sp.	70.96	0.0035
	Navicula sp.	10.14	0.0051
	Group total	243.28	0.0322
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	243.28	0.0049
	Chrysochromulina sp.	91.23	0.0068
	Chryptomonas sp4	10.14	0.0071
	Rhodomonas sp3	121.64	0.0122
	Chroomonas acuta var1	40.55	0.0061
	Kephyrion sp1	40.55	0.0020
	Dinobryon sp5	30.41	0.0061
	Small microflagellates	516.98	0.0052
	Group total	1094.78	0.0503
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	30.41	0.0024
	Crucigenia sp.	40.55	0.0081
	Coelastrum sp.	30.41	0.0152
	Planctonema sp.	91.23	0.0319
	Staurastrum sp.	20.27	0.0203
	Group total	212.87	0.0780
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2787.64	0.0139
	Anabaena circinalis	20.27	0.0182
	Oscillatoria limnetica	506.84	0.1774
	Oscillatoria agardhii	435.89	0.3269
	Aphanothecae sp.	40.55	0.0041
	Microcystis sp.	131.78	0.0659
	Aphanizomenon sp.	10.14	0.0152
	Group total	3933.11	0.6216
	GRAND TOTAL	5484.05	0.7822

Lake: OKANAGAN **Station:** 1 **Depth:** 0-10M
Date: 16/11/1999 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	20.27	0.0016
	Fragilaria acus var2	20.27	0.0030
	Aulicoseira italica var1	70.96	0.0142
	Cyclotella sp3	10.14	0.0005
	Cyclotella comta var2	40.55	0.0203
	Group total	162.19	0.0396
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	263.56	0.0053
	Chrysochromulina sp.	70.96	0.0053
	Chryptomonas sp4	60.82	0.0426
	Rhodomonas sp3	30.41	0.0030
	Small microflagellates	273.70	0.0027
	Group total	699.44	0.0589
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp2	10.14	0.0152
	Group total	30.41	0.0223
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	60.82	0.0049
	Oocystis sp.	10.14	0.0051
	Dichtyosphaerium	20.27	0.0182
	Crucigenia sp.	20.27	0.0041
	Group total	111.51	0.0322
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2078.06	0.0104
	Oscillatoria sp2	233.15	0.0047
	Oscillatoria limnetica	293.97	0.1029
	Oscillatoria agardhii	50.68	0.0380
	Group total	2655.86	0.1560
	GRAND TOTAL	3659.41	0.3091

Lake:	OKANAGAN	**Station:**	3	**Depth:** 0-10M
Date:	14/04/1999	**Magnif:**	1560	

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	41.47	0.0033
	Fragilaria construens var3	27.65	0.0041
	Fragilaria ulna	41.47	0.0415
	Fragilaria acus var1	82.94	0.0083
	Fragilaria acus var2	41.47	0.0062
	Cyclotella stelligera var3	193.52	0.0290
	Cyclotella sp3	414.69	0.0207
	Cyclotella comta var2	96.76	0.0484
	Stephanodiscus sp.	13.82	0.0207
	Rhizosolenia sp.	55.29	0.0028
	Group total	1009.08	0.1851
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	317.93	0.0064
	Chrysochromulina sp.	82.94	0.0062
	Chryptomonas sp4	69.12	0.0484
	Rhodomonas sp3	179.70	0.0180
	Chroomonas acuta var1	138.23	0.0207
	Kephyrion sp1	13.82	0.0007
	Small microflagellates	718.80	0.0072
	Group total	1520.53	0.1075
Dinophyceae (dinoflagellates)			
	Peridinium sp4	69.12	0.0242
	Gymnodinium sp1	27.65	0.0276
	Group total	96.76	0.0518
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	41.47	0.0033
	Group total	41.47	0.0033
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2073.45	0.0104
	Oscillatoria limnetica	193.52	0.0677
	Aphanothecae sp.	41.47	0.0041
	Group total	2308.44	0.0822
	GRAND TOTAL	4976.28	0.4300

Lake:	OKANAGAN	**Station:**	3	**Depth:** 0-10M
Date:	18/05/1999	**Magnif:**	1560	

Class	Species	No. Cells/m	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	13.82	0.0011
	Fragilaria construens var2	13.82	0.0011
	Fragilaria acus var1	82.94	0.0083
	Fragilaria acus var2	82.94	0.0124
	Aulicoseira italica var1	41.47	0.0083
	Aulicoseira distans var2	110.58	0.0387
	Cyclotella stelligera var3	55.29	0.0083
	Cyclotella sp3	13.82	0.0007
	Cyclotella comta var2	13.82	0.0069
	Stephanodiscus sp.	13.82	0.0207
	Group total	442.34	0.1066
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	829.38	0.0166
	Chrysochromulina sp.	179.70	0.0135
	Chryptomonas sp4	69.12	0.0484
	Rhodomonas sp3	262.64	0.0263
	Chroomonas acuta var1	82.94	0.0124
	Kephyrion sp1	27.65	0.0014
	Dinobryon sp5	304.11	0.0608
	Small microflagellates	1119.66	0.0112
	Group total	2875.19	0.1906
Dinophyceae (dinoflagellates)			
	Peridinium sp4	69.12	0.0242
	Gymnodinium sp1	13.82	0.0138
	Group total	82.94	0.0380
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	13.82	0.0011
	Elakatothrix sp3	27.65	0.0069
	Group total	41.47	0.0080
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2902.83	0.0145
	Oscillatoria limnetica	552.92	0.1935
	Aphanothecae sp.	138.23	0.0138
	Group total	3593.98	0.2219
	GRAND TOTAL	7035.91	0.5650

Lake: OKANAGAN **Station:** 3 **Depth:** 0-10M
Date: 9/6/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	15.21	0.0012
	Fragilaria crotonensis	76.03	0.0091
	Fragilaria construens var3	121.64	0.0182
	Fragilaria acus var1	258.49	0.0258
	Fragilaria acus var2	152.05	0.0228
	Aulicoseira distans var2	30.41	0.0106
	Cyclotella stelligera var3	243.28	0.0365
	Cyclotella sp3	76.03	0.0038
	Cyclotella comta var2	76.03	0.0380
	Rhizosolenia sp.	91.23	0.0046
	Group total	1140.40	0.1708
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	1064.37	0.0213
	Chrysochromulina sp.	212.87	0.0160
	Chryptomonas sp4	91.23	0.0639
	Rhodomonas sp3	91.23	0.0091
	Chroomonas acuta var1	15.21	0.0023
	Mallomonas sp6	15.21	0.0114
	Dinobryon sp5	973.14	0.1946
	Small microflagellates	1216.42	0.0122
	Group total	3679.68	0.3307
Dinophyceae (dinoflagellates)			
	Peridinium sp4	15.21	0.0053
	Group total	15.21	0.0053
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	15.21	0.0012
	Group total	15.21	0.0012
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2660.93	0.0133
	Oscillatoria limnetica	988.35	0.3459
	Oscillatoria agardhii	136.85	0.1026
	Aphanothecae sp.	30.41	0.0030
	Group total	3816.53	0.4649
	GRAND TOTAL	8667.03	0.9729

Lake: OKANAGAN **Station:** 3 **Depth:** 0-10M
Date: 19/07/1999 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Asterionella formosa var1	10.14	0.0010
	Fragilaria construens var3	10.14	0.0015
	Fragilaria ulna	10.14	0.0101
	Fragilaria acus var1	20.27	0.0020
	Fragilaria acus var2	50.68	0.0076
	Aulicoseira italica var1	10.14	0.0020
	Cyclotella stelligera var3	192.60	0.0289
	Cyclotella sp3	212.87	0.0106
	Cyclotella comta var2	40.55	0.0203
	Stephanodiscus sp.	10.14	0.0152
	Group total	577.80	0.1002
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	516.98	0.0103
	Chrysochromulina sp.	364.93	0.0274
	Chryptomonas sp4	70.96	0.0497
	Rhodomonas sp3	182.46	0.0182
	Chroomonas acuta var1	81.09	0.0122
	Kephyrion sp1	40.55	0.0020
	Dinobryon sp5	131.78	0.0264
	Small microflagellates	476.43	0.0048
	Bitrichia sp4	10.14	0.0020
	Group total	1875.32	0.1530
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp2	10.14	0.0152
	Group total	30.41	0.0223
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	10.14	0.0008
	Cosmarium sp.	10.14	0.0051
	Group total	20.27	0.0059
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	810.95	0.0041
	Oscillatoria limnetica	831.22	0.2909
	Oscillatoria agardhii	486.57	0.3649
	Aphanothecae sp.	10.14	0.0010
	Group total	2138.88	0.6609
	GRAND TOTAL	4642.69	0.9422

Lake: OKANAGAN **Station:** 3 **Depth:** 0-10M
Date: 9/8/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Fragilaria acus var1	20.27	0.0020
	Fragilaria acus var2	10.14	0.0015
	Cyclotella stelligera var3	20.27	0.0030
	Cyclotella sp3	20.27	0.0010
	Cyclotella comta var2	20.27	0.0101
	Stephanodiscus sp.	10.14	0.0152
	Cymbella sp1	10.14	0.0015
	Group total	121.64	0.0353
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	202.74	0.0041
	Chrysochromulina sp.	233.15	0.0175
	Chryptomonas sp4	50.68	0.0355
	Rhodomonas sp3	233.15	0.0233
	Chroomonas acuta var1	91.23	0.0137
	Mallomonas sp6	10.14	0.0076
	Dinobryon sp5	10.14	0.0020
	Small microflagellates	283.83	0.0028
	Group total	1115.06	0.1065
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	10.14	0.0101
	Group total	40.55	0.0324
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	20.27	0.0016
	Crucigenia sp.	20.27	0.0041
	Staurodesmus sp.	10.14	0.0152
	Planctonema sp.	70.96	0.0248
	Group total	121.64	0.0457
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	506.84	0.0025
	Oscillatoria limnetica	233.15	0.0816
	Oscillatoria agardhii	70.96	0.0532
	Aphanothecae sp.	10.14	0.0010
	Aphanizomenon sp.	30.41	0.0456
	Group total	851.50	0.1840
	GRAND TOTAL	2250.39	0.4039

Lake: OKANAGAN **Station:** 3 **Depth:** 0-10M
Date: 13/09/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	20.27	0.0016
	Fragilaria crotonensis	50.68	0.0061
	Fragilaria acus var2	10.14	0.0015
	Cyclotella stelligera var3	50.68	0.0076
	Cyclotella sp3	20.27	0.0010
	Cyclotella comta var2	40.55	0.0203
	Rhizosolenia sp.	40.55	0.0020
	Group total	233.15	0.0401
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	223.01	0.0045
	Chrysochromulina sp.	273.70	0.0205
	Chryptomonas sp4	20.27	0.0142
	Rhodomonas sp3	233.15	0.0233
	Chroomonas acuta var1	101.37	0.0152
	Pseudokephrion sp.	10.14	0.0010
	Dinobryon sp5	20.27	0.0041
	Small microflagellates	375.06	0.0038
	Group total	1256.97	0.0865
Dinophyceae (dinoflagellates)			
	Peridinium sp4	50.68	0.0177
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	50.68	0.0507
	Group total	111.51	0.0836
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	20.27	0.0016
	Coelastrum sp.	10.14	0.0051
	Staurodesmus sp.	20.27	0.0304
	Planctonema sp.	91.23	0.0319
	Group total	141.92	0.0690
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	658.90	0.0033
	Anabaena circinalis	20.27	0.0182
	Oscillatoria limnetica	435.89	0.1526
	Oscillatoria agardhii	192.60	0.1445
	Aphanothecae sp.	20.27	0.0020
	Microcystis sp.	20.27	0.0101
	Aphanizomenon sp.	111.51	0.1673
	Group total	1459.71	0.4980
	GRAND TOTAL	3203.25	0.7773

Lake: OKANAGAN **Station:** 3 **Depth:** 0-10M
Date: 14/10/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	30.41	0.0024
	Fragilaria acus var1	81.09	0.0081
	Cyclotella sp3	10.14	0.0005
	Cyclotella comta var2	30.41	0.0152
	Rhizosolenia sp.	10.14	0.0005
	Group total	162.19	0.0268
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	304.11	0.0061
	Chrysochromulina sp.	121.64	0.0091
	Chryptomonas sp4	30.41	0.0213
	Rhodomonas sp3	131.78	0.0132
	Chroomonas acuta var1	60.82	0.0091
	Kephyrion sp1	20.27	0.0010
	Dinobryon sp5	10.14	0.0020
	Small microflagellates	375.06	0.0038
	Group total	1054.23	0.0656
Dinophyceae (dinoflagellates)			
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	10.14	0.0101
	Group total	20.27	0.0253
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	50.68	0.0041
	Scenedesmus sp.	20.27	0.0012
	Oocystis sp.	20.27	0.0101
	Coelastrum sp.	10.14	0.0051
	Staurastrum sp.	10.14	0.0101
	Cosmarium sp.	10.14	0.0051
	Quadrigula	20.27	0.0051
	Elakatothrix sp3	20.27	0.0051
	Planctonema sp.	141.92	0.0497
	Group total	304.11	0.0955
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2179.43	0.0109
	Anabaena circinalis	10.14	0.0091
	Oscillatoria limnetica	912.32	0.3193
	Oscillatoria agardhii	608.21	0.4562
	Aphanothecae sp.	50.68	0.0051
	Microcystis sp.	152.05	0.0760
	Aphanizomenon sp.	30.41	0.0456
	Group total	3943.24	0.9222
	GRAND TOTAL	5484.05	1.1354

Lake: OKANAGAN **Station:** 3 **Depth:** 0-10M
Date: 16/11/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Fragilaria crotonensis	20.27	0.0024
	Fragilaria acus var1	20.27	0.0020
	Cyclotella sp3	60.82	0.0030
	Cyclotella comta var2	40.55	0.0203
	Nitzschia sp.	10.14	0.0020
	Group total	152.05	0.0298
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	253.42	0.0051
	Chrysochromulina sp.	70.96	0.0053
	Chryptomonas sp4	40.55	0.0284
	Rhodomonas sp3	121.64	0.0122
	Chroomonas acuta var1	50.68	0.0076
	Small microflagellates	405.47	0.0041
	Group total	942.73	0.0626
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	70.96	0.0057
	Crucigenia sp.	20.27	0.0041
	Monoraphidium	20.27	0.0041
	Oocystis sp.	10.14	0.0051
	Dichtyosphaerium	40.55	0.0365
	Staurastrum sp.	10.14	0.0101
	Elakatothrix sp3	10.14	0.0025
	Group total	182.46	0.0680
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	1723.27	0.0086
	Anabaena circinalis	20.27	0.0182
	Oscillatoria sp2	263.56	0.0053
	Oscillatoria limnetica	699.44	0.2448
	Aphanothecae sp.	50.68	0.0051
	Aphanizomenon sp.	40.55	0.0608
	Oscillatoria agardhii	81.09	0.0608
	Group total	2878.87	0.4037
	GRAND TOTAL	4156.12	0.5641

Lake: OKANAGAN **Station:** 4 **Depth:** 0-10M
Date: 18/05/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Asterionella formosa var1	121.64	0.0122
	Fragilaria crotonensis	50.68	0.0061
	Fragilaria acus var1	30.41	0.0030
	Fragilaria acus var2	60.82	0.0091
	Aulicoseira italica var1	40.55	0.0081
	Aulicoseira distans var2	20.27	0.0071
	Cyclotella stelligera var3	182.46	0.0274
	Cyclotella sp3	30.41	0.0015
	Cyclotella comta var2	60.82	0.0304
	Stephanodiscus sp.	10.14	0.0152
	Group total	618.35	0.1209
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	709.58	0.0142
	Chrysochromulina sp.	131.78	0.0099
	Chryptomonas sp4	50.68	0.0355
	Rhodomonas sp3	141.92	0.0142
	Chroomonas acuta var1	50.68	0.0076
	Pseudokephrion sp.	30.41	0.0030
	Dinobryon sp5	223.01	0.0446
	Small microflagellates	861.63	0.0086
	Group total	2199.70	0.1376
Dinophyceae (dinoflagellates)			
	Peridinium sp4	30.41	0.0106
	Gymnodinium sp2	50.68	0.0760
	Group total	81.09	0.0867
Chlorophyceae (coccoid greens, desmids, etc.)			
	Oocystis sp.	20.27	0.0101
	Elakatothrix sp3	30.41	0.0076
	Group total	50.68	0.0177
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2889.01	0.0144
	Oscillatoria limnetica	385.20	0.1348
	Oscillatoria agardhii	60.82	0.0456
	Aphanothecae sp.	20.27	0.0020
	Group total	3355.30	0.1969
	GRAND TOTAL	6305.13	0.5599

Lake: OKANAGAN **Station:** 4 **Depth:** 0-10M
Date: 9/8/99 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	20.27	0.0016
	Fragilaria construens var2	10.14	0.0008
	Fragilaria construens var3	20.27	0.0030
	Fragilaria acus var1	40.55	0.0041
	Cyclotella sp3	10.14	0.0005
	Cyclotella comta var2	20.27	0.0101
	Stephanodiscus sp.	20.27	0.0304
	Rhizosolenia sp.	20.27	0.0010
	Group total	162.19	0.0516
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	273.70	0.0055
	Chrysochromulina sp.	243.28	0.0182
	Chryptomonas sp4	81.09	0.0568
	Rhodomonas sp3	283.83	0.0284
	Chroomonas acuta var1	121.64	0.0182
	Kephyrion sp1	10.14	0.0005
	Dinobryon sp5	70.96	0.0142
	Small microflagellates	344.65	0.0034
	Group total	1429.30	0.1453
Dinophyceae (dinoflagellates)			
	Peridinium sp4	10.14	0.0035
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	40.55	0.0405
	Group total	60.82	0.0593
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	40.55	0.0032
	Oocystis sp.	20.27	0.0101
	Planctonema sp.	141.92	0.0497
	Elakatothrix sp3	40.55	0.0101
	Group total	243.28	0.0732
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	658.90	0.0033
	Anabaena circinalis	20.27	0.0182
	Oscillatoria limnetica	314.24	0.1100
	Oscillatoria agardhii	111.51	0.0836
	Microcystis sp.	10.14	0.0051
	Aphanizomenon sp.	30.41	0.0456
	Group total	1145.47	0.2658
	GRAND TOTAL	3041.06	0.5952

Lake: OKANAGAN **Station:** 4 **Depth:** 0-10M
Date: 16/11/99 **Magnif:** 1560

Class	Species		No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)				
	Achnanthes sp2		10.14	0.0008
	Asterionella formosa var1		10.14	0.0010
	Fragilaria construens var3		30.41	0.0046
	Fragilaria acus var1		30.41	0.0030
	Aulicoseira italica var1		50.68	0.0101
	Cyclotella sp3		20.27	0.0010
	Cyclotella comta var2		91.23	0.0456
	Rhizosolenia sp.		50.68	0.0025
	Cymbella sp2		20.27	0.0051
	Navicula sp.		20.27	0.0101
		Group total	334.52	0.0839
Chryso- & Cryptophyceae (flagellates)				
	Chromulina sp1		192.60	0.0039
	Chrysochromulina sp.		70.96	0.0053
	Chryptomonas sp4		40.55	0.0284
	Rhodomonas sp3		70.96	0.0071
	Chroomonas acuta var1		30.41	0.0046
	Small microflagellates		324.38	0.0032
		Group total	729.85	0.0525
Dinophyceae (dinoflagellates)				
	Peridinium sp4		30.41	0.0106
	Gymnodinium sp2		10.14	0.0152
		Group total	40.55	0.0258
Chlorophyceae (coccoid greens, desmids, etc.)				
	Ankistrodesmus sp3		111.51	0.0089
	Monoraphidium		20.27	0.0041
	Oocystis sp.		20.27	0.0101
	Dichtyosphaerium		30.41	0.0274
	Staurastrum sp.		10.14	0.0101
	Elakatothrix sp3		20.27	0.0051
		Group total	212.87	0.0657
Cyanophyceae (blue-greens)				
	Synechococcus sp. (<2 um)		1875.32	0.0094
	Anabaena circinalis		30.41	0.0274
	Oscillatoria sp2		273.70	0.0055
	Oscillatoria limnetica		547.39	0.1916
	Aphanothecae sp.		10.14	0.0010
	Oscillatoria agardhii		131.78	0.0988
	Aphanizomenon sp.		40.55	0.0608
	Microcystis sp.		20.27	0.0101
		Group total	2929.56	0.4046
		GRAND TOTAL	4247.35	0.6325

Lake: OKANAGAN **Station:** 6 **Depth:** 0-10M
Date: 14/04/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	21.72	0.0017
	Asterionella formosa var1	86.89	0.0087
	Fragilaria construens var3	130.33	0.0195
	Fragilaria ulna	65.17	0.0652
	Fragilaria acus var1	217.22	0.0217
	Fragilaria acus var2	21.72	0.0033
	Aulicoseira distans var2	65.17	0.0228
	Cyclotella stelligera var3	304.11	0.0456
	Cyclotella sp3	629.93	0.0315
	Cyclotella comta var2	21.72	0.0109
	Stephanodiscus sp.	108.61	0.1629
	Rhizosolenia sp.	217.22	0.0109
	Group total	1889.80	0.4047
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	847.15	0.0169
	Chrysochromulina sp.	390.99	0.0293
	Chryptomonas sp4	65.17	0.0456
	Rhodomonas sp3	456.16	0.0456
	Chroomonas acuta var1	304.11	0.0456
	Small microflagellates	1520.53	0.0152
	Group total	3584.11	0.1983
Dinophyceae (dinoflagellates)			
	Peridinium sp4	21.72	0.0076
	Gymnodinium sp1	65.17	0.0652
	Group total	86.89	0.0728
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	86.89	0.0070
	Crucigenia sp.	65.17	0.0130
	Group total	152.05	0.0200
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2498.01	0.0125
	Oscillatoria limnetica	282.38	0.0988
	Oscillatoria agardhii	65.17	0.0489
	Aphanothecae sp.	304.11	0.0304
	Group total	3149.67	0.1906
	GRAND TOTAL	8862.52	0.8864

Lake: OKANAGA **Station:** 6 **Depth:**
Date: 18/05/99 **Magnif:** 1560

Class	Species	No. Cells/mL
Bacillariophyceae (diatoms)		
	Achnanthes sp2	41.47
	Fragilaria construens var3	13.82
	Fragilaria ulna	13.82
	Fragilaria acus var1	124.41
	Aulicoseira italica var1	373.22
	Cyclotella stelligera var3	41.47
	Cyclotella sp3	13.82
	Stephanodiscus sp.	13.82
	Navicula sp.	13.82
	Group total	649.68
Chryso- & Cryptophyceae (flagellates)		
	Chromulina sp1	539.10
	Chrysochromulina sp.	165.88
	Chryptomonas sp4	96.76
	Rhodomonas sp3	262.64
	Chroomonas acuta var1	96.76
	Kephyrion sp1	69.12
	Dinobryon sp5	221.17
	Small microflagellates	1382.30
	Bitrichia sp4	13.82
	Group total	2847.54
Dinophyceae (dinoflagellates)		
	Peridinium sp4	69.12
	Gymnodinium sp2	13.82
	Gymnodinium sp1	13.82
	Group total	96.76
Chlorophyceae (coccoid greens, desmids, etc.)		
	Ankistrodesmus sp3	41.47
	Oocystis sp.	13.82
	Elakatothrix sp3	27.65
	Closteriopsis	41.47
	Group total	124.41
Cyanophyceae (blue-greens)		
	Synechococcus sp. (<2 um)	1589.65
	Oscillatoria limnetica	1078.19
	Aphanothecae sp.	152.05
	Group total	2819.89
	GRAND TOTAL	6538.28

Lake: OKANAGAN **Station:** 6 **Depth:** 0-10M
Date: 9/6/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Asterionella formosa var1	93.57	0.0094
	Fragilaria construens var2	23.39	0.0019
	Fragilaria construens var3	11.70	0.0018
	Fragilaria ulna	11.70	0.0117
	Fragilaria acus var1	140.36	0.0140
	Fragilaria acus var2	35.09	0.0053
	Aulicoseira italica var1	35.09	0.0070
	Cyclotella stelligera var3	666.69	0.1000
	Cyclotella sp3	257.32	0.0129
	Cyclotella comta var2	70.18	0.0351
	Stephanodiscus sp.	70.18	0.1053
	Rhizosolenia sp.	11.70	0.0006
	Group total	1426.96	0.3048
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	888.93	0.0178
	Chrysochromulina sp.	58.48	0.0044
	Chryptomonas sp4	58.48	0.0409
	Rhodomonas sp3	116.96	0.0117
	Chroomonas acuta var1	58.48	0.0088
	Dinobryon sp5	1017.59	0.2035
	Small microflagellates	760.27	0.0076
	Group total	2959.19	0.2947
Dinophyceae (dinoflagellates)			
	Gymnodinium sp2	11.70	0.0175
	Group total	11.70	0.0175
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	58.48	0.0047
	Oocystis sp.	23.39	0.0117
	Elakatothrix sp3	23.39	0.0058
	Group total	105.27	0.0222
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2222.31	0.0111
	Oscillatoria limnetica	970.80	0.3398
	Oscillatoria agardhii	58.48	0.0439
	Aphanothecae sp.	23.39	0.0023
	Group total	3274.99	0.3971
	GRAND TOTAL	7778.10	1.0364

Lake: OKANAGAN **Station:** 6 **Depth:** 0-10M
Date: 19/07/99 **Magnif:** 1560

Class	Species	No. Cells/m	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Fragilaria crotonensis	60.82	0.0073
	Fragilaria construens var3	20.27	0.0030
	Fragilaria acus var1	10.14	0.0010
	Fragilaria acus var2	10.14	0.0015
	Aulicoseira italica var1	10.14	0.0020
	Cyclotella stelligera var3	20.27	0.0030
	Cyclotella sp3	60.82	0.0030
	Cyclotella comta var2	40.55	0.0203
	Stephanodiscus sp.	10.14	0.0152
	Group total	253.42	0.0573
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	202.74	0.0041
	Chrysochromulina sp.	233.15	0.0175
	Chryptomonas sp4	30.41	0.0213
	Rhodomonas sp3	243.28	0.0243
	Chroomonas acuta var1	81.09	0.0122
	Dinobryon sp5	111.51	0.0223
	Small microflagellates	283.83	0.0028
	Group total	1186.01	0.1045
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	10.14	0.0101
	Group total	40.55	0.0324
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	40.55	0.0032
	Oocystis sp.	10.14	0.0051
	Elakatothrix sp3	10.14	0.0025
	Planctonema sp.	20.27	0.0071
	Group total	81.09	0.0179
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	456.16	0.0023
	Anabaena circinalis	10.14	0.0091
	Oscillatoria limnetica	273.70	0.0958
	Oscillatoria agardhii	101.37	0.0760
	Aphanothecae sp.	30.41	0.0030
	Microcystis sp.	20.27	0.0101
	Aphanizomenon sp.	10.14	0.0152
	Group total	902.18	0.2116
	GRAND TOTAL	2463.26	0.4237

Lake: OKANAGAN **Station:** 6 **Depth:** 0-10M
Date: 9/8/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Fragilaria crotonensis	70.96	0.0085
	Cyclotella stelligera var3	20.27	0.0030
	Cyclotella sp3	30.41	0.0015
	Cyclotella comta var2	20.27	0.0101
	Stephanodiscus sp.	20.27	0.0304
	Cymbella sp1	10.14	0.0015
	Group total	182.46	0.0560
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	344.65	0.0069
	Chrysochromulina sp.	182.46	0.0137
	Chryptomonas sp4	30.41	0.0213
	Rhodomonas sp3	202.74	0.0203
	Chroomonas acuta var1	131.78	0.0198
	Dinobryon sp5	40.55	0.0081
	Small microflagellates	648.76	0.0065
	Group total	1581.35	0.0965
Dinophyceae (dinoflagellates)			
	Peridinium sp4	30.41	0.0106
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	20.27	0.0203
	Group total	60.82	0.0461
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	50.68	0.0041
	Oocystis sp.	10.14	0.0051
	Staurodesmus sp.	10.14	0.0152
	Cosmarium sp.	10.14	0.0051
	Planctonema sp.	81.09	0.0284
	Group total	162.19	0.0578
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2584.90	0.0129
	Anabaena circinalis	40.55	0.0365
	Oscillatoria limnetica	375.06	0.1313
	Oscillatoria agardhii	131.78	0.0988
	Merismopedia sp.	10.14	0.0002
	Aphanothecae sp.	20.27	0.0020
	Aphanizomenon sp.	81.09	0.1216
	Group total	3243.80	0.4034
	GRAND TOTAL	5230.63	0.6598

Lake: OKANAGAN **Station:** 6 **Depth:** 0-10M
Date: 13/09/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Fragilaria crotonensis	50.68	0.0061
	Fragilaria acus var1	30.41	0.0030
	Cyclotella stelligera var3	10.14	0.0015
	Cyclotella sp3	20.27	0.0010
	Cyclotella comta var2	20.27	0.0101
	Stephanodiscus sp.	10.14	0.0152
	Rhizosolenia sp.	10.14	0.0005
	Group total	152.05	0.0375
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	304.11	0.0061
	Chrysochromulina sp.	192.60	0.0144
	Chryptomonas sp4	40.55	0.0284
	Rhodomonas sp3	172.33	0.0172
	Chroomonas acuta var1	50.68	0.0076
	Mallomonas sp6	10.14	0.0076
	Dinobryon sp5	10.14	0.0020
	Small microflagellates	354.79	0.0035
	Group total	1135.33	0.0869
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp2	20.27	0.0304
	Gymnodinium sp1	30.41	0.0304
	Group total	70.96	0.0679
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	20.27	0.0016
	Staurodesmus sp.	30.41	0.0456
	Closteriopsis	10.14	0.0015
	Crucigenia sp.	20.27	0.0041
	Planctonema sp.	81.09	0.0284
	Group total	162.19	0.0812
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	1419.16	0.0071
	Anabaena circinalis	60.82	0.0547
	Oscillatoria limnetica	364.93	0.1277
	Oscillatoria agardhii	192.60	0.1445
	Merismopedia sp.	10.14	0.0002
	Aphanothecae sp.	30.41	0.0030
	Microcystis sp.	70.96	0.0355
	Aphanizomenon sp.	141.92	0.2129
	Group total	2290.93	0.5856
	GRAND TOTAL	3811.46	0.8592

Lake: OKANAGAN **Station:** 6 **Depth:** 0-10M
Date: 15/10/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Fragilaria construens var2	40.55	0.0032
	Fragilaria crotonensis	30.41	0.0036
	Fragilaria acus var1	10.14	0.0010
	Cyclotella stelligera var3	20.27	0.0030
	Cyclotella comta var2	10.14	0.0051
	Stephanodiscus sp.	30.41	0.0456
	Group total	141.92	0.0616
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	212.87	0.0043
	Chrysochromulina sp.	101.37	0.0076
	Chryptomonas sp4	60.82	0.0426
	Rhodomonas sp3	152.05	0.0152
	Chroomonas acuta var1	50.68	0.0076
	Mallomonas sp6	10.14	0.0076
	Dinobryon sp5	10.14	0.0020
	Chroomonas acuta var1	314.24	0.0471
	Group total	912.32	0.1340
Dinophyceae (dinoflagellates)			
	Peridinium sp4	10.14	0.0035
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	10.14	0.0101
	Group total	30.41	0.0289
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	60.82	0.0049
	Oocystis sp.	30.41	0.0152
	Crucigenia sp.	20.27	0.0041
	Planctonema sp.	101.37	0.0355
	Group total	212.87	0.0596
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	1368.48	0.0068
	Anabaena circinalis	50.68	0.0456
	Oscillatoria limnetica	699.44	0.2448
	Oscillatoria agardhii	415.61	0.3117
	Aphanothecae sp.	20.27	0.0020
	Microcystis sp.	40.55	0.0203
	Aphanizomenon sp.	111.51	0.1673
	Group total	2706.54	0.7985
	GRAND TOTAL	4004.06	1.0827

Lake: OKANAGAN **Station:** 6 **Depth:** 0-10M
Date: 16/11/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Fragilaria crotonensis	131.78	0.0158
	Fragilaria construens var3	10.14	0.0015
	Fragilaria acus var1	40.55	0.0041
	Fragilaria acus var2	10.14	0.0015
	Aulicoseira distans var2	50.68	0.0177
	Cyclotella sp3	10.14	0.0005
	Cyclotella comta var2	40.55	0.0203
	Navicula sp.	10.14	0.0051
	Group total	314.24	0.0673
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	202.74	0.0041
	Chrysochromulina sp.	91.23	0.0068
	Chryptomonas sp4	30.41	0.0213
	Rhodomonas sp3	101.37	0.0101
	Chroomonas acuta var1	50.68	0.0076
	Mallomonas sp6	20.27	0.0152
	Small microflagellates	283.83	0.0028
	Group total	780.54	0.0680
Dinophyceae (dinoflagellates)			
	Peridinium sp4	10.14	0.0035
	Gymnodinium sp2	20.27	0.0304
	Group total	30.41	0.0340
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	91.23	0.0073
	Crucigenia sp.	40.55	0.0081
	Dichtyosphaerium	50.68	0.0456
	Oocystis sp.	30.41	0.0152
	Monoraphidium	60.82	0.0122
	Staurastrum sp.	20.27	0.0203
	Group total	293.97	0.1087
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	709.58	0.0035
	Anabaena circinalis	20.27	0.0182
	Oscillatoria sp2	263.56	0.0053
	Oscillatoria limnetica	567.66	0.1987
	Aphanothecae sp.	30.41	0.0030
	Aphanizomenon sp.	182.46	0.2737
	Oscillatoria agardhii	223.01	0.1673
	Group total	1996.96	0.6697
	GRAND TOTAL	3416.13	0.9476

Lake: OKANAGAN **Station:** 7 **Depth:** 0-10M
Date: 14/04/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	65.17	0.0052
	Asterionella formosa var1	260.66	0.0261
	Fragilaria construens var3	108.61	0.0163
	Fragilaria acus var1	412.72	0.0413
	Aulicoseira italica var1	108.61	0.0217
	Cyclotella stelligera var3	108.61	0.0163
	Cyclotella sp3	543.05	0.0272
	Stephanodiscus sp.	21.72	0.0326
	Rhizosolenia sp.	65.17	0.0033
	Group total	1694.31	0.1898
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	977.48	0.0195
	Chrysochromulina sp.	369.27	0.0277
	Chryptomonas sp4	86.89	0.0608
	Rhodomonas sp3	716.82	0.0717
	Chroomonas acuta var1	781.99	0.1173
	Mallomonas sp6	43.44	0.0326
	Small microflagellates	1411.92	0.0141
	Group total	4387.82	0.3437
Dinophyceae (dinoflagellates)			
	Peridinium sp4	43.44	0.0152
	Gymnodinium sp2	108.61	0.1629
	Gymnodinium sp1	108.61	0.1086
	Group total	260.66	0.2867
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	217.22	0.0174
	Elakatothrix sp3	21.72	0.0054
	Group total	238.94	0.0228
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	3149.67	0.0157
	Oscillatoria sp2	238.94	0.0048
	Aphanothecae sp.	238.94	0.0239
	Group total	3627.55	0.0444
	GRAND TOTAL	10209.28	0.8876

Lake: OKANAGAN **Station:** 7 **Depth:** 0-10M
Date: 18/05/99 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Asterionella formosa var1	192.60	0.0193
	Fragilaria crotonensis	263.56	0.0316
	Fragilaria acus var1	283.83	0.0284
	Fragilaria acus var2	121.64	0.0182
	Cyclotella stelligera var3	293.97	0.0441
	Cyclotella sp3	91.23	0.0046
	Cyclotella comta var2	91.23	0.0456
	Group total	1338.07	0.1918
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	1084.65	0.0217
	Chrysochromulina sp.	152.05	0.0114
	Chryptomonas sp4	101.37	0.0710
	Rhodomonas sp3	263.56	0.0264
	Chroomonas acuta var1	91.23	0.0137
	Dinobryon sp5	699.44	0.1399
	Small microflagellates	1115.06	0.0112
	Group total	3507.36	0.2951
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp2	20.27	0.0304
	Group total	40.55	0.0375
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	10.14	0.0008
	Scenedesmus sp.	30.41	0.0018
	Dichtyosphaerium	20.27	0.0182
	Group total	60.82	0.0209
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	3041.06	0.0152
	Oscillatoria limnetica	658.90	0.2306
	Oscillatoria agardhii	101.37	0.0760
	Aphanothecae sp.	10.14	0.0010
	Group total	3811.46	0.3229
	GRAND TOTAL	8758.26	0.8682

Lake: OKANAGAN **Station:** 7 **Depth:** 0-10M
Date: 9/6/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Asterionella formosa var1	50.68	0.0051
	Fragilaria acus var1	101.37	0.0101
	Fragilaria acus var2	33.79	0.0051
	Aulicoseira distans var2	50.68	0.0177
	Cyclotella stelligera var3	219.63	0.0329
	Cyclotella sp3	152.05	0.0076
	Cyclotella comta var2	67.58	0.0338
	Stephanodiscus sp.	33.79	0.0507
	Group total	709.58	0.1630
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	658.90	0.0132
	Chrysochromulina sp.	50.68	0.0038
	Chryptomonas sp4	50.68	0.0355
	Rhodomonas sp3	236.53	0.0237
	Chroomonas acuta var1	16.89	0.0025
	Pseudokephrion sp.	16.89	0.0017
	Dinobryon sp5	321.00	0.0642
	Small microflagellates	1098.16	0.0110
	Group total	2449.74	0.1555
Dinophyceae (dinoflagellates)			
	Peridinium sp4	33.79	0.0118
	Group total	33.79	0.0118
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	16.89	0.0014
	Oocystis sp.	33.79	0.0169
	Elakatothrix sp3	16.89	0.0042
	Closteriopsis	16.89	0.0025
	Group total	84.47	0.0250
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	5406.33	0.0270
	Anabaena circinalis	16.89	0.0152
	Oscillatoria limnetica	591.32	0.2070
	Oscillatoria agardhii	84.47	0.0634
	Aphanothecae sp.	84.47	0.0084
	Group total	6183.49	0.3210
	GRAND TOTAL	9461.08	0.6764

Lake: OKANAGAN **Station:** 7 **Depth:** 0-10M
Date: 18/07/95 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Asterionella formosa var1	50.68	0.0051
	Fragilaria acus var1	101.37	0.0101
	Fragilaria acus var2	33.79	0.0051
	Aulicoseira distans var2	50.68	0.0177
	Cyclotella stelligera var3	219.63	0.0329
	Cyclotella sp3	152.05	0.0076
	Cyclotella comta var2	67.58	0.0338
	Stephanodiscus sp.	33.79	0.0507
	Group total	709.58	0.1630
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	658.90	0.0132
	Chrysochromulina sp.	50.68	0.0038
	Chryptomonas sp4	50.68	0.0355
	Rhodomonas sp3	236.53	0.0237
	Chroomonas acuta var1	16.89	0.0025
	Pseudokephrion sp.	16.89	0.0017
	Dinobryon sp5	321.00	0.0642
	Small microflagellates	1098.16	0.0110
	Group total	2449.74	0.1555
Dinophyceae (dinoflagellates)			
	Peridinium sp4	33.79	0.0118
	Group total	33.79	0.0118
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	16.89	0.0014
	Oocystis sp.	33.79	0.0169
	Elakatothrix sp3	16.89	0.0042
	Closteriopsis	16.89	0.0025
	Group total	84.47	0.0250
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	5406.33	0.0270
	Anabaena circinalis	16.89	0.0152
	Oscillatoria limnetica	591.32	0.2070
	Oscillatoria agardhii	84.47	0.0634
	Aphanothecae sp.	84.47	0.0084
	Group total	6183.49	0.3210
	GRAND TOTAL	9461.08	0.6764

Lake: OKANAGAN **Station:** 7 **Depth:** 0-10M
Date: 08/08/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Fragilaria crotonensis	40.55	0.0049
	Fragilaria acus var1	30.41	0.0030
	Fragilaria acus var2	10.14	0.0015
	Aulicoseira italica var1	20.27	0.0041
	Cyclotella stelligera var3	10.14	0.0015
	Cyclotella sp3	40.55	0.0020
	Cyclotella comta var2	20.27	0.0101
	Stephanodiscus sp.	20.27	0.0304
	Rhizosolenia sp.	20.27	0.0010
	Group total	212.87	0.0586
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	344.65	0.0069
	Chrysochromulina sp.	273.70	0.0205
	Chryptomonas sp4	30.41	0.0213
	Rhodomonas sp3	202.74	0.0203
	Chroomonas acuta var1	111.51	0.0167
	Kephyrion sp1	20.27	0.0010
	Dinobryon sp5	172.33	0.0345
	Small microflagellates	334.52	0.0033
	Group total	1490.12	0.1245
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	20.27	0.0203
	Group total	50.68	0.0426
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	40.55	0.0032
	Scenedesmus sp.	30.41	0.0018
	Oocystis sp.	40.55	0.0203
	Cosmarium sp.	10.14	0.0051
	Planctonema sp.	91.23	0.0319
	Staurodesmus sp.	30.41	0.0456
	Elakatothrix sp3	20.27	0.0051
	Group total	263.56	0.1130
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	304.11	0.0015
	Anabaena circinalis	273.70	0.2463
	Oscillatoria limnetica	435.89	0.1526
	Oscillatoria agardhii	141.92	0.1064
	Aphanizomenon sp.	91.23	0.1368
	Microcystis sp.	30.41	0.0152
	Group total	1277.25	0.6589
	GRAND TOTAL	3294.48	0.9976

Lake: OKANAGAN **Station:** 7 **Depth:** 0-10M
Date: 13/09/99 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	20.27	0.0016
	Fragilaria crotonensis	131.78	0.0158
	Fragilaria acus var1	40.55	0.0041
	Fragilaria acus var2	10.14	0.0015
	Cyclotella stelligera var3	50.68	0.0076
	Cyclotella sp3	30.41	0.0015
	Cyclotella comta var2	20.27	0.0101
	Stephanodiscus sp.	20.27	0.0304
	Rhizosolenia sp.	30.41	0.0015
	Group total	354.79	0.0742
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	435.89	0.0087
	Chrysochromulina sp.	344.65	0.0258
	Chryptomonas sp4	40.55	0.0284
	Rhodomonas sp3	324.38	0.0324
	Chroomonas acuta var1	202.74	0.0304
	Kephyrion sp1	40.55	0.0020
	Dinobryon sp5	162.19	0.0324
	Small microflagellates	314.24	0.0031
	Group total	1865.18	0.1634
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp1	10.14	0.0101
	Group total	30.41	0.0172
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	40.55	0.0032
	Oocystis sp.	10.14	0.0051
	Staurastrum sp.	20.27	0.0203
	Cosmarium sp.	10.14	0.0051
	Staurodesmus sp.	20.27	0.0304
	Crucigenia sp.	50.68	0.0101
	Planctonema sp.	70.96	0.0248
	Group total	223.01	0.0990
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	557.53	0.0028
	Anabaena circinalis	60.82	0.0547
	Oscillatoria limnetica	405.47	0.1419
	Oscillatoria agardhii	253.42	0.1901
	Aphanothecae sp.	40.55	0.0041
	Aphanizomenon sp.	60.82	0.0912
	Microcystis sp.	111.51	0.0558
	Group total	1490.12	0.5405
	GRAND TOTAL	3963.52	0.8944

Lake: OKANAGAN **Station:** 7 **Depth:** 0-10M
Date: 15/10/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Fragilaria construens var2	30.41	0.0024
	Fragilaria crotonensis	50.68	0.0061
	Fragilaria acus var1	10.14	0.0010
	Fragilaria acus var2	30.41	0.0046
	Aulicoseira italica var1	10.14	0.0020
	Cyclotella stelligera var3	141.92	0.0213
	Cyclotella comta var2	30.41	0.0152
	Stephanodiscus sp.	10.14	0.0152
	Rhizosolenia sp.	30.41	0.0015
	Group total	344.65	0.0693
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	314.24	0.0063
	Chrysochromulina sp.	283.83	0.0213
	Chryptomonas sp4	70.96	0.0497
	Rhodomonas sp3	354.79	0.0355
	Chroomonas acuta var1	223.01	0.0335
	Mallomonas sp6	10.14	0.0076
	Dinobryon sp5	40.55	0.0081
	Small microflagellates	324.38	0.0032
	Group total	1621.90	0.1651
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp1	20.27	0.0203
	Group total	40.55	0.0274
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	40.55	0.0032
	Scenedesmus sp.	10.14	0.0006
	Oocystis sp.	10.14	0.0051
	Staurodesmus sp.	20.27	0.0304
	Cosmarium sp.	10.14	0.0051
	Crucigenia sp.	20.27	0.0041
	Planctonema sp.	162.19	0.0568
	Group total	273.70	0.1052
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	810.95	0.0041
	Anabaena circinalis	40.55	0.0365
	Oscillatoria limnetica	638.62	0.2235
	Oscillatoria agardhii	172.33	0.1292
	Aphanothecae sp.	50.68	0.0051
	Microcystis sp.	91.23	0.0456
	Aphanizomenon sp.	202.74	0.3041
	Group total	2007.10	0.7481
	GRAND TOTAL	4287.90	1.1152

Lake: OKANAGAN **Station:** 7 **Depth:** 0-10M
Date: 17/11/99 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Fragilaria acus var1	40.55	0.0041
	Aulicoseira italica var1	81.09	0.0162
	Aulicoseira distans var2	20.27	0.0071
	Cyclotella stelligera var3	20.27	0.0030
	Cyclotella sp3	50.68	0.0025
	Cyclotella comta var2	40.55	0.0203
	Stephanodiscus sp.	10.14	0.0152
	Navicula sp.	20.27	0.0101
	Group total	293.97	0.0794
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	283.83	0.0057
	Chrysochromulina sp.	111.51	0.0084
	Chryptomonas sp4	60.82	0.0426
	Rhodomonas sp3	91.23	0.0091
	Chroomonas acuta var1	30.41	0.0046
	Mallomonas sp6	30.41	0.0228
	Small microflagellates	293.97	0.0029
	Group total	902.18	0.0960
Dinophyceae (dinoflagellates)			
	Peridinium sp4	30.41	0.0106
	Gymnodinium sp2	20.27	0.0304
	Gymnodinium sp1	20.27	0.0203
	Group total	70.96	0.0613
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	111.51	0.0089
	Quadrigula	20.27	0.0051
	Oocystis sp.	10.14	0.0051
	Dichtyosphaerium	20.27	0.0182
	Staurastrum sp.	30.41	0.0304
	Elakatothrix sp3	20.27	0.0051
	Group total	212.87	0.0728
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2230.11	0.0112
	Anabaena circinalis	10.14	0.0091
	Oscillatoria sp2	354.79	0.0071
	Oscillatoria limnetica	506.84	0.1774
	Oscillatoria agardhii	70.96	0.0532
	Aphanothecae sp.	50.68	0.0051
	Aphanizomenon sp.	60.82	0.0912
	Group total	3284.35	0.3543
	GRAND TOTAL	4764.33	0.6638

Lake: OKANAGAN **Station:** 8 **Depth:** 0-10M
Date: 14/04/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	27.65	0.0022
	Asterionella formosa var1	152.05	0.0152
	Fragilaria construens var3	27.65	0.0041
	Fragilaria acus var1	41.47	0.0041
	Aulicoseira italica var1	677.33	0.1355
	Aulicoseira distans var2	27.65	0.0097
	Cyclotella stelligera var3	96.76	0.0145
	Cyclotella sp3	304.11	0.0152
	Cyclotella comta var2	13.82	0.0069
	Stephanodiscus sp.	41.47	0.0622
	Group total	1409.95	0.2697
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	456.16	0.0091
	Chrysochromulina sp.	193.52	0.0145
	Chryptomonas sp4	13.82	0.0097
	Rhodomonas sp3	262.64	0.0263
	Chroomonas acuta var1	179.70	0.0270
	Small microflagellates	718.80	0.0072
	Group total	1824.64	0.0937
Dinophyceae (dinoflagellates)			
	Peridinium sp4	13.82	0.0048
	Gymnodinium sp2	13.82	0.0207
	Gymnodinium sp1	55.29	0.0553
	Group total	82.94	0.0809
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	69.12	0.0055
	Cosmarium sp.	13.82	0.0069
	Group total	82.94	0.0124
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	1174.96	0.0059
	Oscillatoria limnetica	331.75	0.1161
	Lyngbya sp.	55.29	0.0276
	Aphanothecae sp.	110.58	0.0111
	Group total	1672.58	0.1607
	GRAND TOTAL	5073.04	0.6174

Lake: OKANAGAN **Station:** 8 **Depth:** 0-10M
Date: 18/05/99 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	45.62	0.0036
	Asterionella formosa var1	91.23	0.0091
	Fragilaria crotonensis	228.08	0.0274
	Fragilaria ulna	15.21	0.0152
	Fragilaria acus var1	410.54	0.0411
	Fragilaria acus var2	182.46	0.0274
	Aulicoseira italica var1	197.67	0.0395
	Cyclotella stelligera var3	197.67	0.0297
	Cyclotella sp3	15.21	0.0008
	Cyclotella comta var2	60.82	0.0304
	Stephanodiscus sp.	15.21	0.0228
	Cocconeis sp.	15.21	0.0030
	Group total	1474.91	0.2500
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	1474.91	0.0295
	Chrysochromulina sp.	197.67	0.0148
	Chryptomonas sp4	91.23	0.0639
	Rhodomonas sp3	471.36	0.0471
	Chroomonas acuta var1	182.46	0.0274
	Small microflagellates	1931.07	0.0193
	Group total	4348.72	0.2020
Dinophyceae (dinoflagellates)			
	Peridinium sp4	76.03	0.0266
	Gymnodinium sp2	15.21	0.0228
	Group total	91.23	0.0494
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	45.62	0.0036
	Cosmarium sp.	15.21	0.0076
	Elakatothrix sp3	30.41	0.0076
	Group total	91.23	0.0189
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2660.93	0.0133
	Oscillatoria limnetica	1216.42	0.4257
	Oscillatoria agardhii	106.44	0.0798
	Group total	3983.79	0.5189
	GRAND TOTAL	9989.89	1.0391

Lake: OKANAGAN **Station:** 8 **Depth:** 0-10M
Date: 9/6/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	33.79	0.0027
	Asterionella formosa var1	371.69	0.0372
	Fragilaria acus var1	50.68	0.0051
	Cyclotella stelligera var3	253.42	0.0380
	Cyclotella sp3	101.37	0.0051
	Cyclotella comta var2	33.79	0.0169
	Stephanodiscus sp.	33.79	0.0507
	Group total	878.53	0.1556
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	929.21	0.0186
	Chrysochromulina sp.	135.16	0.0101
	Chryptomonas sp4	33.79	0.0237
	Rhodomonas sp3	236.53	0.0237
	Chroomonas acuta var1	50.68	0.0076
	Dinobryon sp5	50.68	0.0101
	Small microflagellates	1013.69	0.0101
	Group total	2449.74	0.1039
Dinophyceae (dinoflagellates)			
	Peridinium sp4	50.68	0.0177
	Gymnodinium sp2	16.89	0.0253
	Gymnodinium sp1	16.89	0.0169
	Group total	84.47	0.0600
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	33.79	0.0027
	Group total	33.79	0.0027
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	5913.18	0.0296
	Anabaena circinalis	16.89	0.0152
	Oscillatoria limnetica	152.05	0.0532
	Oscillatoria agardhii	152.05	0.1140
	Aphanizomenon sp.	33.79	0.0507
	Aphanothecae sp.	33.79	0.0034
	Group total	6301.76	0.2661
	GRAND TOTAL	9748.29	0.5883

Lake: OKANAGAN **Station:** 8 **Depth:** 0-10M
Date: 19/07/99 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Fragilaria crotonensis	30.41	0.0036
	Fragilaria acus var1	20.27	0.0020
	Fragilaria acus var2	10.14	0.0015
	Aulicoseira italica var1	40.55	0.0081
	Cyclotella stelligera var3	20.27	0.0030
	Cyclotella comta var2	20.27	0.0101
	Stephanodiscus sp.	10.14	0.0152
	Tabellaria fenestrata	10.14	0.0051
	Cymbella sp1	10.14	0.0015
	Group total	182.46	0.0511
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	243.28	0.0049
	Chrysochromulina sp.	202.74	0.0152
	Chryptomonas sp4	40.55	0.0284
	Rhodomonas sp3	141.92	0.0142
	Chroomonas acuta var1	60.82	0.0091
	Dinobryon sp5	70.96	0.0142
	Small microflagellates	375.06	0.0038
	Group total	1135.33	0.0897
Dinophyceae (dinoflagellates)			
	Peridinium sp4	30.41	0.0106
	Gymnodinium sp1	30.41	0.0304
	Group total	60.82	0.0411
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	10.14	0.0008
	Scenedesmus sp.	10.14	0.0006
	Staurastrum sp.	10.14	0.0101
	Elakatothrix sp3	20.27	0.0051
	Planctonema sp.	30.41	0.0106
	Group total	81.09	0.0273
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	608.21	0.0030
	Anabaena circinalis	81.09	0.0730
	Oscillatoria limnetica	324.38	0.1135
	Oscillatoria agardhii	111.51	0.0836
	Aphanothecae sp.	10.14	0.0010
	Aphanizomenon sp.	60.82	0.0912
	Group total	1196.15	0.3654
	GRAND TOTAL	2655.86	0.5746

Lake: OKANAGAN **Station:** 8 **Depth:** 0-10M
Date: 9/8/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	20.27	0.0016
	Fragilaria crotonensis	60.82	0.0073
	Fragilaria construens var3	10.14	0.0015
	Cyclotella stelligera var3	30.41	0.0046
	Cyclotella sp3	10.14	0.0005
	Cyclotella comta var2	20.27	0.0101
	Stephanodiscus sp.	20.27	0.0304
	Cymbella sp1	10.14	0.0015
	Group total	182.46	0.0576
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	233.15	0.0047
	Chrysochromulina sp.	131.78	0.0099
	Chryptomonas sp4	40.55	0.0284
	Rhodomonas sp3	101.37	0.0101
	Chroomonas acuta var1	50.68	0.0076
	Dinobryon sp5	60.82	0.0122
	Small microflagellates	395.34	0.0040
	Group total	1013.69	0.0768
Dinophyceae (dinoflagellates)			
	Peridinium sp4	10.14	0.0035
	Gymnodinium sp2	20.27	0.0304
	Gymnodinium sp1	20.27	0.0203
	Group total	50.68	0.0542
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	10.14	0.0008
	Scenedesmus sp.	20.27	0.0012
	Staurodesmus sp.	20.27	0.0304
	Group total	50.68	0.0324
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	2027.37	0.0101
	Anabaena circinalis	405.47	0.3649
	Oscillatoria limnetica	233.15	0.0816
	Oscillatoria agardhii	162.19	0.1216
	Merismopedia sp.	20.27	0.0004
	Aphanothecae sp.	30.41	0.0030
	Aphanizomenon sp.	40.55	0.0608
	Group total	2919.42	0.6426
	GRAND TOTAL	4216.94	0.8636

Lake: OKANAGAN **Station:** 8 **Depth:** 0-10M
Date: 13/09/99 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Fragilaria crotonensis	50.68	0.0061
	Fragilaria acus var1	50.68	0.0051
	Cyclotella comta var2	10.14	0.0051
	Stephanodiscus sp.	10.14	0.0152
	Rhizosolenia sp.	10.14	0.0005
	Navicula sp.	10.14	0.0051
	Cymbella sp1	10.14	0.0015
	Group total	162.19	0.0393
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	334.52	0.0067
	Chrysochromulina sp.	223.01	0.0167
	Chryptomonas sp4	111.51	0.0781
	Rhodomonas sp3	314.24	0.0314
	Chroomonas acuta var1	202.74	0.0304
	Dinobryon sp5	10.14	0.0020
	Small microflagellates	395.34	0.0040
	Group total	1591.49	0.1693
Dinophyceae (dinoflagellates)			
	Peridinium sp4	20.27	0.0071
	Gymnodinium sp2	20.27	0.0304
	Gymnodinium sp1	20.27	0.0203
	Group total	60.82	0.0578
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	20.27	0.0016
	Staurodesmus sp.	30.41	0.0456
	Coelastrum sp.	20.27	0.0101
	Cosmarium sp.	10.14	0.0051
	Planctonema sp.	50.68	0.0177
	Group total	131.78	0.0802
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	1368.48	0.0068
	Anabaena circinalis	111.51	0.1004
	Oscillatoria limnetica	628.49	0.2200
	Oscillatoria agardhii	405.47	0.3041
	Aphanothecae sp.	50.68	0.0051
	Microcystis sp.	111.51	0.0558
	Aphanizomenon sp.	152.05	0.2281
	Group total	2828.19	0.9202
	GRAND TOTAL	4774.47	1.2668

Lake: OKANAGAN **Station:** 8 **Depth:** 0-10M
Date: 15/10/99 **Magnif:** 1560

Class	Species	No. Cells/mL	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	30.41	0.0024
	Fragilaria crotonensis	60.82	0.0073
	Fragilaria construens var3	10.14	0.0015
	Fragilaria acus var1	10.14	0.0010
	Aulicoseira italica var1	30.41	0.0061
	Cyclotella comta var2	30.41	0.0152
	Stephanodiscus sp.	10.14	0.0152
	Cymbella sp1	10.14	0.0015
	Group total	192.60	0.0503
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	496.71	0.0099
	Chrysochromulina sp.	283.83	0.0213
	Chryptomonas sp4	70.96	0.0497
	Rhodomonas sp3	243.28	0.0243
	Chroomonas acuta var1	131.78	0.0198
	Dinobryon sp5	131.78	0.0264
	Small microflagellates	456.16	0.0046
	Group total	1814.50	0.1559
Dinophyceae (dinoflagellates)			
	Peridinium sp4	30.41	0.0106
	Gymnodinium sp2	10.14	0.0152
	Gymnodinium sp1	20.27	0.0203
	Group total	60.82	0.0461
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	10.14	0.0008
	Oocystis sp.	10.14	0.0051
	Cosmarium sp.	10.14	0.0051
	Staurastrum sp.	10.14	0.0101
	Planctonema sp.	40.55	0.0142
	Coelastrum sp.	10.14	0.0051
	Group total	91.23	0.0403
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	1520.53	0.0076
	Anabaena circinalis	30.41	0.0274
	Oscillatoria limnetica	598.08	0.2093
	Oscillatoria agardhii	283.83	0.2129
	Aphanothecae sp.	20.27	0.0020
	Microcystis sp.	10.14	0.0051
	Aphanizomenon sp.	364.93	0.5474
	Group total	2828.19	1.0117
	GRAND TOTAL	4987.34	1.3043

Lake: OKANAGAN **Station:** 8 **Depth:** 0-10M
Date: 17/11/1999 **Magnif:** 1560

Class	Species	No. Cells/ml	BioV. mm3/L
Bacillariophyceae (diatoms)			
	Achnanthes sp2	10.14	0.0008
	Asterionella formosa var1	20.27	0.0020
	Fragilaria acus var1	10.14	0.0010
	Aulicoseira italica var1	70.96	0.0142
	Cyclotella stelligera var3	20.27	0.0030
	Cyclotella sp3	30.41	0.0015
	Cyclotella comta var2	50.68	0.0253
	Rhizosolenia sp.	10.14	0.0005
	Navicula sp.	30.41	0.0152
	Suriella	10.14	0.0051
	Group total	263.56	0.0687
Chryso- & Cryptophyceae (flagellates)			
	Chromulina sp1	314.24	0.0063
	Chrysochromulina sp.	162.19	0.0122
	Chryptomonas sp4	111.51	0.0781
	Rhodomonas sp3	152.05	0.0152
	Chroomonas acuta var1	60.82	0.0091
	Mallomonas sp6	20.27	0.0152
	Small microflagellates	364.93	0.0036
	Group total	1186.01	0.1397
Dinophyceae (dinoflagellates)			
	Peridinium sp4	70.96	0.0248
	Gymnodinium sp2	20.27	0.0304
	Gymnodinium sp1	40.55	0.0405
	Group total	131.78	0.0958
Chlorophyceae (coccoid greens, desmids, etc.)			
	Ankistrodesmus sp3	70.96	0.0057
	Crucigenia sp.	20.27	0.0041
	Dichtyosphaerium	20.27	0.0182
	Oocystis sp.	10.14	0.0051
	Staurastrum sp.	10.14	0.0101
	Group total	131.78	0.0432
Cyanophyceae (blue-greens)			
	Synechococcus sp. (<2 um)	1571.22	0.0079
	Oscillatoria sp2	456.16	0.0091
	Oscillatoria limnetica	273.70	0.0958
	Oscillatoria agardhii	233.15	0.1749
	Aphanizomenon sp.	70.96	0.1064
	Group total	2605.18	0.3941
	GRAND TOTAL	4318.31	0.7415

MACROZOOPLANKTON POPULATION ABUNDANCE AND COMPOSITION TRENDS IN OKANAGAN LAKE, WITH EMPHASIS ON 1996-1999 DATA

by

Greg Wilson[1]

INTRODUCTION

The water quality and kokanee populations of Okanagan Lake have been influenced by a variety of activities in the last 50 years and, as a result, the kokanee populations have declined to unprecedented low numbers. Several previous studies have identified problems and some attempted solutions to varying degrees of success (Okanagan Basin Agreement 1974; Shepherd 1990). In response to the significant kokanee decline during the 1990s, a technical workshop was held in 1995 where existing data on Okanagan Lake was reviewed, and hypotheses for the decline in fish populations evaluated (Ashley and Shepherd 1996). The Okanagan Lake Action Plan (OLAP) evolved from the workshop with a focus on practical research activities aimed at better understanding the biological dynamics of Okanagan Lake. Kokanee population restoration is the principal goal of the OLAP.

The primary findings of the workshop, supported by the first three years of OLAP research activities, have indicated that decline in kokanee may be partially due to reduced productive capacity of the lake (Ashley et al. 1999). The decline has probably been exacerbated by the introduction of the freshwater opossum shrimp (*Mysis relicta*) in 1966 (Shepherd 1990). These macrozooplanktors compete with kokanee for preferred zooplankton prey, as has been documented in other large BC lakes (Ashley et al. 1997). The study of zooplankton and *mysis* distribution and their abundance are therefore, an integral part of the OLAP. This report summarizes past zooplankton and *mysis* data, with emphasis on data collected since 1996.

METHODS

Zooplankton

Analysis of Okanagan Lake pelagic macrozooplankton data in conjunction with the OLAP has been conducted since August 1996. Samples have been collected from up to 8 stations (Map 2), with additional samples collected from Kalamalka Lake (Ashley et al. 1998 and 1999). Samples were taken monthly in 1996 (August to October), 1997 (February to December), 1998 (February to December) and 1999 (April to November) using a vertically hauled Wisconsin net (0.5 m diameter mouth, 153 µm mesh). The net was lowered then retrieved from a depth of 45 m, with samples preserved in 70% ethanol for later analysis. Duplicate hauls were taken from the deepest part of a transect across the lake at each site from August 1996 to May 1997. This procedure was changed in June 1997 to account for possible patchy distribution of zooplankton due to Lagmuir spirals (see McEachern *in* Ashley et al. 1999). Three vertical hauls were taken at

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each site, one sample at mid-lake, and single samples 500 m to the east and west of the mid-lake sample.

Table 1. Okanagan Lake Action Plan zooplankton sample sites, 1996-1999.

Site[a] Designation	**Site Number**	**Site Name**	**Year**			
			1996[b]	**1997[c]**	**1998**	**1999**
KA1	0500246	Kalamalka Lake South End	x	x		
KA2	0500847	Kalamalka Lake Deep Basin	x	x		
OK1	0500454	Okanagan Lake South Prairie Creek	x	x	x	x
OK2	0500729	Okanagan Lake South Squally Point	x	x		
OK3	E223295	Okanagan Lake Opposite Rattlesnake Island	x	x	x	x
OK4	0500236	Okanagan Lake DNS Kelowna STP	x	x	x[d]	x[e]
OK5	0500456	Okanagan Lake UPS Kelowna STP	x	x		
OK6	0500730	Okanagan Lake North Okanagan Centre	x	x	x	x
OK7	E206611	Okanagan Lake at Vernon Outfall	x	x	x	x
OK8	0500239	Okanagan Lake Central Armstrong Arm	x	x	x	x

[a] See Map 1.
[b] OK7, OK6 and OK5 were the only sites sampled in November 1996.
[c] Several stations not sampled in February and March due to ice cover.
[d] Only sampled in February, March, August and December.
[e] Only sampled in May, August and November.

L. McEachern (see Ashley et al. 1999) analyzed samples collected in 1996-1998 at the Penticton Office of the Ministry of Environment, Lands and Parks (MELP) lab. Samples were split using a two-chambered Folsom plankton wheel and counted in a square gridded dish under the microscope at 10X magnification. Cladocerans were identified to genus and copepods to suborder (Calanoida or Cyclopoida). Commencing in June 1997, copepods were identified to genus.

L. Vidmanic analyzed samples collected as of April 1999 at the UBC Fisheries Center. Samples were re-suspended in tap water and filtered through a 74 µm mesh and sub-sampled using a four chambered Folsom-type plankton splitter. Splits were placed in gridded plastic petri dishes and stained with Rose Bengal to facilitate viewing with a Wild M3B dissecting microscope. For each replicate, organisms were identified to species level and counted until up to 200 organisms of the predominant species were recorded. If 150 organisms were counted by the end of a split, a new split was not started. Lengths of 30 organisms of the most common cladocerans and copepods were measured, for use in biomass calculations, using a mouse cursor on a live television image. Lengths were converted to biomass (µg dry weight) using empirical length-weight regressions from McCauley (1984). The reproductive stage of females, the number of eggs carried by gravid females, and the number of eggs loose in the sample were recorded for use in fecundity estimations.

Density estimates from the MELP lab in Penticton and the UBC Zoology lab were compared and found to be fairly similar, with no consistent trend for estimates from one lab to be higher than the other (Thompson and Kuzyk *in* Ashley et al. 1998).

Mysids

Sampling for *Mysis relicta* in Okanagan Lake has been conducted monthly in 1996 (August to November), 1997 (February to December), 1998 (January to October), and 1999 (April to December), as part of the OLAP (Ashley et al. 1998; 1999). Mysid sampling always occurred during the period of the new moon (moonless nights) using a vertically hauled net (1 m^2 mouth; 1,000 µm mesh size net; 210 µm mesh in the terminal cone and 438 µm in the collecting bucket) at several stations along the length of the lake (Map 1; Table 2). Duplicate hauls were taken from the deepest part of a transect across the lake at that site, and duplicate shallow (~ 40 m) hauls were taken from a near-shore area either east or west of the deep haul, from August to October 1996. In November 1996, the procedure was changed to duplicate hauls taken from the deepest part of a transect across the lake at each site, and single shallow (~ 40 m) hauls from near shore areas to the east and west of the deep hauls. Nets were raised with a hydraulic winch at 0.33 m sec^{-1}, and samples were preserved with 100% denatured alcohol (85% ethanol, 15% methanol) until analysis. Samples collected from 1996-1998 were analyzed by Dr. D. Lasenby at Trent University in Peterborough, Ontario, where mysids were counted using a low power dissecting scope. Life history analysis was performed on select samples from stations OK1, OK3 and OK6 and station KA2 in Kalamalka Lake, with methods and results reported by Whall and Lasenby (*in* Ashley et al. 1999)

Table 2. Okanagan Lake Action Plan *Mysis relicta* sample sites, 1996-1999.

Site[a] Designation	**Site Number**	**Site Name**	**Deep Haul ~ Sample Depth (m)**	**Year**			
				1996	**1997**	**1998**	**1999**
KA1	0500246	Kalamalka Lake South End		x	x	x[d]	
KA2	0500847	Kalamalka Lake Deep Basin		x	x	x[d]	
KA3		Kalamalka			x[b]	x[e]	
OK1	0500454	Okanagan Lake South Prairie Creek	80	x	x	x	
OK2	0500729	Okanagan Lake South Squally Point	110	x	x	x[f]	x
OK3	E223295	Okanagan Lake Opp. Rattlesnake Island	140	x	x	x	x
OK4	0500236	Okanagan Lake DNS Kelowna STP	80	x	x	x[g]	x
OK5	0500456	Okanagan Lake UPS Kelowna STP	140	x	x	x	x
OK6	0500730	Okanagan Lake N. Ok. Centre	220	x	x	x	x
OK7	E206611	Okanagan Lake at Vernon Outfall	80	x	x	x	x
OK8	0500239	Okanagan Lake Central Armstrong Arm	50	x	x[c]	x[h]	x

[a] See Map 1.
[b] OK8 not sampled in Feb, Mar, or Apr. due to ice cover.
[c] Sampled only July-December.
[d] Not sampled January, July-September.
[e] Only sampled February-May.
[f] Only sampled Jan-April.
[g] Only sampled April-October.
[h] Only sampled March-October.

L. Vidmanic analyzed samples collected in 1999 at the UBC Fisheries Center. The entire sample was examined for mysids using a low power dissecting scope. The reproductive stage of males and females were recorded for use in fecundity estimations. Sex was determined by the presence of the antennal peduncle in males or absence of in females, or by the formation of oostegites in females and genitalia in males. Juveniles did not exhibit any of the above sexual characteristics. Maturity of females was confirmed by the presence of complete overlap of the brood pouch and presence of chromatophores on the pouch. Brooding females were identified by the presence of developing eggs or embryos in the brood pouch. Spent females were those that had recently released their brood as indicated by an open brood pouch. Mature males were distinguished by the extension of the fourth pleopod beyond the base of the telson. Lengths of 30 organisms of each sex at each stage were measured, for use in biomass calculations, using a mouse cursor on a live television image. Total body length was determined from the tip of the rostrum to the edge of the last segment prior to the base telson. Lengths were converted to biomass (mg dry weight) using length-weight regressions developed from mysis samples taken from Okanagan Lake in 1996 (Whall and Lasenby *in* Ashley et al. 1998). The equipment and techniques used are the same as that employed on Kootenay Lake (Ashley et al. 1997) and Arrow Reservoir (Pieters et al. 1998), therefore, allowing direct comparison of results between these large systems.

Mysis samples collected from 1989 through 1995 were also taken with vertically hauled net but with a 0.96 diameter mouth opening and equipped with a net of variable mesh sizes ranging from 1,000 µm to < 500 µm. These samples were collected only once per year, in late-September or early-October around the period of the new moon. Five of the sites sampled correspond spatially to OLAP sites (OK1, OK3, OK4, OK6, and OK7) and are therefore, used for historical comparison. A side-by-side comparison of the two nets was conducted in 1997 by McEachern (*in* Ashley et al. 1999) to determine the comparability of data collected by the nets. It was determined that the 'new' net captured 1.43 times as many *mysis* · m^{-2} as the 'old' net, and this number was used to convert density values from 1989-1995 (original data on file, MELP, Penticton, #40.3902), to values comparable with 1996-1999 data.

RESULTS

Zooplankton

The following analysis concentrates on data collected from five stations in Okanagan Lake (OK1, OK3, OK6, OK7, and OK8) and monitored annually as part of the OLAP since 1996.

1996-1999 General Trends

The seasonal (May to October) pelagic macrozooplankton community in Okanagan Lake has fluctuated during OLAP monitoring with a range of densities from 19 L^{-1} in 1997, 7.6 L^{-1} in 1998, to a high of 24 L^{-1} in 1999 (Table 3). However, the population composition appears to have remained constant in both the main lake (stations OK1-7) and limnologically different Armstrong Arm (OK8) (see McEachern *in* Ashley et al. 1999). The population density has been dominated by copepods (calanoid and cyclopoid) which averaged near 100% of the early summer populations and 94% of the August to October populations from 1997-1999. The cladoceran populations usually peaked at 7-12% of the total density in late-summer (Fig. 1).

The seasonal copepod populations were equally split between calanoid and cyclopoids, and the composition of cladoceran genera has averaged 39% (*Diaphanosoma*), 32% (B*osmina*) and 29% (*Daphnia*) over the same years. Population densities also generally increased from the southern stations (OK1 and OK3) to the northern stations (OK6 and OK7), with maximum populations usually found in Armstrong Arm (OK8). In 1999 for example, copepod density averaged 14-17 L^{-1} at the southern stations (OK1 and OK3), 22-26 L^{-1} at the northern stations (OK6 and OK7), with a maximum of 32 L^{-1} in Armstrong Arm (OK8) (Table 4).

Table 3. Seasonal (May to October) average abundance (#·L^{-1}) of zooplankton species in Okanagan Lake, 1997-1999.

	SPECIES	**YEAR**		
		1997	**1998**	**1999**
Cladocera	*Daphnia galeata mendotae*	0.21	0.11	0.67
	Diaphanosoma leuchten	0.16	0.12	0.55
	Bosmina longirostris	*0.23*	*0.05*	*0.56*
	Leptodora kindti	n/d	n/d	<0.001
	Chydor sp.	n/d	n/d	0.006
Total Cladocera		**0.61**	**0.29**	**1.79**
Copepoda (Calanoida)		6.66	3.57	10.25
	Diaptomus ashlandi	n/d	3.50	10.05
	Epischura nevadensis	n/d	0.05	0.21
Copepoda (Cyclopoida)		11.9	3.7	10.7
	Cyclops bicuspidatus	n/d	3.7	10.7
Total Copepoda		**18.5**	**7.3**	**22.2**
Total Density		**19.1**	**7.6**	**24.0**

<u>1996-1999 Population Composition</u>

In 1999, copepods numerically dominated the zooplankton communities at each station with mean seasonal densities ranging from 14.3 L^{-1} at OK1 to 32 L^{-1} at OK8 (Table 4). Individuals were captured on all sampling dates, with populations at most stations peaking in July at 22 L^{-1} in the southern stations, 35 L^{-1} at the northern stations, and a maximum of 55 L^{-1} in Armstrong Arm (Fig. 2). Copepod seasonal (May to October, 1999 only) biomass generally ranged from 10-30 µg·L^{-1} in April, to peaks values of 100 µg·L^{-1} in late summer at stations OK1-OK7, and 300 µg·L^{-1} at OK8 (Fig. 3). Despite their numerical dominance throughout the summer, copepods comprised only 50% of total zooplankton biomass when cladoceran populations were at their peak densities, reflecting their small size relative to cladocerans.

The copepods were generally comprised of equal numbers of calanoids and cyclopoids, with calanoids dominating the spring populations and cyclopoids more numerous in mid-to-late summer. Calanoid copepods densities were at their lowest in March, then quickly increased to peak populations in June, concurrent with spring phytoplankton maxima (see Stockner, in this

OLAP report) as they are primarily herbivorous, with populations slowly decreasing during the summer/fall (Fig. 4). Peak densities in 1999 ranged from 7· L^{-1} at OK1 to 34· L^{-1} at OK7. Commencing in mid-1997, analysis of copepods was conducted to the species level with *Diaptomus ashlandi* and *Epischura nevadensis* the only calanoids identified. *Diaptomus* has been the dominant calanoid with *Epischura* densities remaining low <1· L^{-1} (Table 3, Fig. 5). Enumeration of copepod nauplii began in 1999, with peak populations of 3· L^{-1} found in April and May (when sampling began) at the three southern stations (OK1, OK3, and OK6) and 7· L^{-1} at OK7 and OK8 (Fig. 5).

The cyclopoid copepods reached peak densities in late-June, early July, with values ranging from 13· L^{-1} at OK1 to 28· L^{-1} at OK8 (Fig. 4). Seasonal densities averaged 11.9, 3.7 and 10.7· L^{-1} from 1997 to 1999, respectively (Table 3). Starting in mid-1997, analysis of copepods has been conducted to the species level and *Cyclops bicuspidatus* has been the only cyclopoid identified.

Table 4. Seasonal (May to October) abundance (#·L^{-1}) of cladoceran and copepod zooplankton at 5 sample sites in Okanagan Lake, 1997-1999.

		Site					
Species	**Year**	**OK 1**	**OK 3**	**OK 6**	**OK 7**	**OK 8**	**Whole Lake**
Cladocera	1997	0.62	0.53	0.42	0.43	1.02	0.61
	1998	0.08	0.14	0.26	0.34	0.58	0.29
	1999	1.36	0.94	1.44	1.51	3.72	1.79
Copepoda	1997	11.0	13.7	15.6	16.0	36.4	18.5
	1998	5.2	6.2	7.2	7.5	10.6	7.3
	1999	14.3	16.5	22.2	25.9	32.0	22.2

Cladoceran density in Okanagan Lake has fluctuated with average seasonal abundances of 0.61, 0.29 and 1.78· L^{-1} from 1997-1999, respectively (Table 3). Densities have generally increased from the south (OK1) to maximum values at the north end (OK8) of the lake (Table 4, Fig. 6). Cladocerans are generally found between June and October in Okanagan Lake, with maximum densities of 3 to 4· L^{-1} found in July 1999 (Fig. 6). They represent approximately 5% of the total zooplankton population density. However, as a result of their larger individual size compared to copepods, they account for an average 30% of the summer macrozooplankton biomass with values peaking at 40-60 µg·L^{-1} in the main lake (stations OK1-7), and 200 µg·L^{-1} in Armstrong Arm (Fig. 3).

Five species of cladocerans have been identified in Okanagan Lake with *Daphnia galeata mendotae*, *Diaphanosoma leuchten*, and *Bosmina longirostris* the most numerous (Table 3). *Daphnia* numbers increased from the south to the north end of the lake, with densities peaking at <1· L^{-1} at the southern stations (OK1 and OK3), 2· L^{-1} at the northern stations (OK6 and OK7), and the highest number of 6· L^{-1} found in Armstrong Arm (OK8) (Fig. 6). *Diaphanosoma* peaked around 2· L^{-1} in September to October at most stations. *Bosmina* were usually the first cladoceran to appear in spring, with peak populations of 2· L^{-1} found in June-July, and were one of the few species with similar densities at all the stations monitored (Fig. 6). *Leptodora kindti* and

Chydor sp. (only examined in 1999) were occasionally captured, but at densities too low for accurate enumeration. *Leptodora* were noted in mid-summer and appeared to be most numerous in Armstrong Arm (OK8), except in 1998 when none were collected. *Chydor* sp. were present in the spring and only in the Armstrong Arm.

Historical Zooplankton Populations

Okanagan Lake has been sampled for zooplankton periodically over the last 20 years. They have been routinely sampled from 1996-1999 as part of the OLAP. They have been periodically sampled by MELP (McEachern *in* Ashley et al. 1999) since the 1980s as well as by Truscott and Kelso (1979) in 1978 and in 1971 by Patalas and Salki (1973). Seasonal comparisons cannot be made as sampling was often conducted in early spring or late fall. However, general abundance trends can be analyzed by comparing populations in August of each year, the most common month sampled when both cladocerans and copepods were present (McEachern *in* Ashley et al. 1999).

Both cladoceran and copepod densities appear to quite be consistent over the last 20 years. This is somewhat surprising considering the limited data set for comparison, the range of analysists and variable counting and collection methods used. The percent of cladocerans in the total population has ranged from 4-10% in the main body of Okanagan Lake (mean of stations OK1-7), with densities usually 1-2· L^{-1}, but with no distinct trend over time (Fig. 7). In Armstrong Arm (OK8), the percent of cladocerans has had a similar range, 1-8%, with densities ranging from <1· L^{-1}, to highs of 4· L^{-1} in both 1980 and 1999. Copepod populations have ranged from 7-40 L^{-1} in the main body of the lake (stations OK1-7), and from 8-50 L^{-1} in Armstrong Arm, also with no distinct trend evident (Fig. 7).

Zooplankton Fecundity

Fecundity data was collected from the two most common copepods (*Diaptomus* and *Cyclops*) and cladocerans (*Daphnia* and *Bosmina*) in 1999. Gravid copepods comprised a substantial proportion of the female population in April when sampling began and in August (Fig. 8) with similar proportions found at each station. Gravid *Cyclops bicuspidatus* usually comprised 20-40% of the female population in spring and carried an average 15-20 eggs per gravid female (Fig. 9). The gravid female population in fall was usually slightly less and carried only 10-15 eggs, with the exception of the OK7 and OK8 sites where gravid females carried 20-25 eggs per female, which is more than in the spring. Gravid *Diaptomus* females were also found in spring and late summer and carried a maximum of 10 eggs per gravid female (Fig. 9).

Gravid cladoceran females represented a smaller proportion of the female population at the southern stations (OK1, OK3 and OK6) and were found earlier in the summer than at OK7 and OK8. Gravid *Bosmina* and *Daphnia* were found in June to July at the three southern stations, with the proportion of gravid Bosmina below 0.2, while only a few gravid *Daphnia* were found at OK1 (Fig. 10). At OK7 and OK8 gravid *Bosmina* comprised 50-80% of the females, while *Daphnia* reached a high of 50% at OK7 in June and at OK8 in April to May (Fig. 10). There was less variation in the number of eggs carried by gravid cladoceran females. Gravid *Daphnia* carried 1-2 eggs and *Bosmina* carried 3-4 eggs in early summer and at most 1 egg in late summer (Fig. 11).

Mysids

Sampling for *Mysis relicta* in Okanagan Lake has been conducted monthly since August 1996 from up to 8 stations, as well as some additional samples collected in Kalamalka and Woods Lake (Ashley et al. 1998; 1999). The following analysis concentrates on data collected from the seven stations in Okanagan Lake (OK1, OK3-OK8) monitored annually.

1996-1999 Mysid Abundance

The seasonal abundance of mysids in Okanagan Lake decreased to 212 m^{-2} in 1999, down from 333 and 403 m^{-2} estimated in 1997 and 1998 respectively, (Table 5). The lowest densities (<300 m^{-2}) have generally been at stations OK1 to OK4, with the highest at the north end stations (OK7 and OK8). Peak values were found in July to August at all stations, with the highest values of ~ 1,000 m^{-2} recorded at OK7 in 1997 and 1998 (Fig. 12). Biomass values followed density trends, with values at each station generally increasing from 1,000-2000 mg m^{-2} at OK1 and OK4-6, and 14,000 mg m^{-2} at OK7 (Fig. 13). Biomass at OK3 peaked at 4,800 mg m^{-2} in September probably because of a somewhat larger proportion of females in the population that are slightly larger than males (Fig. 14).

The highest densities were consistently captured in the deep hauls that varied from 90-220 m^{-2} depending on the station (Table 5). At each station, the densities from the deeper hauls were usually 2 to 4-fold higher than the shallow (40 m) hauls. The OK7 station was the exception where the catch in the deepwater haul averaged 6-fold higher than the shallow water haul (Fig. 12), suggesting that fewer mysids make the vertical migration at this site compared to the other stations.

The mysid density in Armstrong Arm declined to near zero in October of 1999 (Fig. 12). This is consistent with other years noted by McEachern (*in* Ashley et al. 1999) who suggested they horizontally migrate out of this area due to a combination of hypolimnetic oxygen depletion and warm epilimnetic water.

Table 5. Seasonal (May to October) abundance ($\# \cdot m^{-2}$) of *Mysis relicta* taken in the deep hauls at 7 sample sites in Okanagan Lake, 1997-1999.

Year	**Station**							**Whole Lake Average**
	OK 1	**OK 3**	**OK 4**	**OK 5**	**OK 6**	**OK 7**	**OK 8**	
1997	232	459	207	271	294	419	447	333
1998	330	328	232	349	374	947	262	403
1999	157	181	98	117	139	650	142	212

Mysis State of Maturity

Mysid fecundity, in terms of the proportion of gravid females (female:gravid female) and life stage were recorded for the first time as part of regular OLAP monitoring in 1999. The mysid population was generally comprised of an equal proportion of males and females. Juvenile stages, usually lower in numbers, were found when sampling began in April, until August (Fig. 13). Other work on Okanagan Lake has shown juveniles are released by brooding females starting in November, and usually continue until July/August, with the majority of releases occurring in March to May (Whall and Lasenby *in* Ashley et al. 1999).

Gravid females were found at all stations during the summer, with the proportion fluctuating but generally ranging from 40-80%, and averaging about 65% at all stations (Fig. 15). In November and December the proportion of gravid females at all stations approached 90%.

Historical *Mysis* Analysis

Mysid densities recorded in the fall have been on the decline in Okanagan Lake for the period of record 1989-1999. Values averaged 300-450 m^2 from 1989-1992 and have averaged 200-300 m^2 since 1993, with 226 m^2 estimated in 1999 (Fig. 15). There was a slight increase in 1997 and 1998 noted in both the seasonal abundance (Table 5) and September to October values (Fig. 16).

DISCUSSION

There is a trophic gradient in Okanagan Lake from the mesotrophic Armstrong Arm (OK8) at the north end to more oligotrophic conditions in the south. This gradient is reflected in both the zooplankton densities and phytoplankton populations (see Stockner, in this OLAP report) which increase from the south to north end of the lake. The zooplankton data set, while limited, suggests high inter-year variability but no large changes over the past 25 years. It is possible that annual variability may be related to inflow and spring total dissolved phosphorus (TDP) concentrations. In 1996 and 1997, inflow volumes to the lake were among the highest for the period of record 1922-1997 (Ward and Yassien *in* Ashley et al. 1999). Spring TDP concentrations were also relatively high in 1996 and 1997, with a decrease in 1998 (Jensen *in* Ashley et al. 1999). Zooplankton densities were comparatively high in 1997 and 1998 (Fig. 2).

Fall chlorophyll *a* concentrations and summer phytoplankton densities have been increasing through the late-1990s, including 1998 (Jensen *in* Ashley et al. 1999). Several more years of data collection will be required to test this relationship, including an investigation into the role of nitrogen and phosphorus as limiting nutrients. Surface concentrations of soluble nitrogen approach non-detection limits and soluble nitrogen to phosphorus ratios (by weight) drop below 15 in Okanagan Lake during summer (Jensen *in* Ashley et al. 1999; Kirk in this OLAP report), accompanied by a significant increase of nitrogen fixing blue-green algae (Stockner, in this report).

Mysid densities have been declining since 1989 (extent of currently available data) with a slight increase in 1997-1998. This increase may have been due to the relatively high zooplankton densities in 1996 and 1997 (Table 3, Fig. 2), and with the mysid two year life cycle there would have been some carryover into 1998. However, in 1999, high zooplankton densities were also recorded, but the spring TDP was comparatively low, as were mysid densities (212 · m^{-2}), one of the lowest densities on record. Clearly, a closer examination of zooplankton, mysid densities and nutrient loadings to the lake is required.

Compared to Kootenay and Arrow reservoirs, Okanagan Lake has a moderate zooplankton density with a lower proportion of cladocerans (Table 6). The May to October average zooplankton density in Okanagan from 1997-1999 was 17 · L^{-1} (range 7-24), , considerably more than the Arrow Reservoir density of 7 · L^{-1} (Pieters et al. 1998) but slightly less than Kootenay Lakes' average which has fluctuated between 17-23 · L^{-1} from 1992-1997 (Ashley et al. 1999b). Okanagan and Kootenay lakes are at the more productive end of the oligotrophic trophic level. In contrast, total zooplankton density in Alouette Reservoir, a coastal reservoir bordering on ultra-oligotrophic productive condition, is < 2 · L^{-1} (Wilson et al. 1999).

Okanagan Lake has a very small percentage of cladocerans (including *Daphnia*) compared to Kootenay Lake or Arrow Reservoir. Cladocerans averaged 5 % of summer zooplankton densities in Okanagan, 9 % in Kootenay and 20 % in Arrow (Table 6). The current percent of cladocerans in Okanagan Lake are close to values of pre-fertilized Kootenay Lake, where cladocerans comprised < 5 % of zooplankton populations from 1972-1990 (Ashley et al. 1999b). This difference can be partially explained by the higher mysid density of 212-403 · m^{-2} in Okanagan Lake compared to 48 · m^{-2} in Arrow Reservoir, and 131 · m^{-2} in Kootenay Lake (1997 data). Significantly, Kootenay Lake did have a mysid density closer to 400 · m^{-2} prior to 1992 (pre-fertilization) when the kokanee population was severely depressed. No doubt there are other factors involved in the zooplankton and mysid population dynamics of Okanagan Lake (such as hydrology nutrient loadings, fish populations) requiring further analysis.

Table 6. Comparison of seasonal (~ May to October) total density of zooplankton, cladocerans and *Daphnia* as percent of total zooplankton, and mysid abundance (deep hauls) in Okanagan Lake and four other BC lakes/reservoirs (see text for sources).

Lake/Reservoir (Year)	**Seasonal Total Density (# · L^{-1})**	**% Cladocerans**	**% *Daphnia***	**Mysid Density (# · M^{-2})^{A}**
Kootenay (1992-96)	17-23	9 %	7 %	131
Okanagan (1997-99)	7-24	5 %	1.5 %	212
Arrow (1998)	7	21 %	9 %	48
Kalamalka (1997-98)	1-2	6 %	12 %	400
Alouette (1998)	< 2	20 %	< 1 %	0

[a] Kootenay Lake in 1996, Okanagan in 1999, average of upper and lower Arrow in 1998, Kalamalka in 1998.

REFERENCES

Ashley, K.I. and B.G. Shepherd. 1996. Okanagan Lake Workshop Report and Action Plan. Fisheries Project Report No. RD 45. Province of BC, Ministry of Environment, Lands and Parks. Fisheries Branch.

Ashley, K., L. Thompson, D. Lasenby, L. McEachern, K. Smokorowski and D. Sebastian. 1997. Restoration of an Interior Lake Ecosystem: the Kootenay Lake Fertilization Experiment. Water Qual. Res. J. Canada. 32:295-323.

Ashley, K., B. Shepherd, D. Sebastian, L. Thompson, L. Vidmanic, Dr. P. Ward, H.A. Yassien, L. McEachern, R. Nordin, Dr. D. Lasenby, J. Quirt, J.D. Whall, Dr. P. Dill, Dr. E. Taylor, S. Pollard, C. Wong, J. den Dulk, G. Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Ashley, K.I., Thompson, L.C., Warburton, P., Yang, Jing-Rong, Pick, F.R., Hamilton, P.B., Lasenby, D.C., Smokorowski, K.E., McEachern, L., Sebastian, D., and G. Scholten. 1999b. Kootenay Lake Fertilization Experiment – Year 4 (1995/96) Report. British Columbia Ministry of Environment, Lands and Parks, Fisheries Project Report No. RD 58.

Ashley, K., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H.A. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J.D. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, G. Scholten, M. Zimmerman, P. Epp, V. Jensen and R. Finnegan. 1999. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. RD 78. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples. *In*: Downing, J.D. and F. H. Rigler (eds). 1984. A Manual on Methods for the Assessment of Secondary Productivity in Fresh Waters – 2nd ed. Blackwell Scientific Publications.

Okanagan Basin Agreement. 1974. Summary Report, including the Comprehensive Framework Plan: Canada British Columbia Okanagan Basin Agreement, March 1974, 42pp.

Patalas, K. and A. Salki. 1973. Crustacean plankton and the eutrophication of lakes in the Okanagan Valley, British Columbia. J. Fish. Res. Board Can. 30:519-542.

Pieters, R., L. Thompson, L. Vidmanic, S. Pond, J. Stockner, P. Hamblin, M. Yound, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian, G. Scholten, and D. Lombard. 1998. Arrow Reservoir limnology and trophic status – year 1 (1997/98) Report. Report RD 67. Fisheries Branch. Ministry of Environment, Lands and Parks. Victoria, B.C.

Shepherd, B.G. 1990. Okanagan Lake Management Plan, 1990-95. BC Ministry of Environment, Lands and Parks, Recreational Fisheries Program, Penticton, BC.

Truscott, S.J. and B.W. Keslo. 1979. Trophic changes in lakes Okanagan, Skaha and Osoyoos, B.C., following implementation of tertiary municipal waste treatment. Canada – British Columbia Okanagan Basin Implementation Agreement. 159pp.

Wilson, G.A., Land, R.W., Ashley, A., Standen, E., Berkhout, T., Scholten, G., and D. Sebastian. 1999. The Alouette Reservoir Fertilization Experiment: Per-Fertilization (1998) Report. British Columbia Ministry of Fisheries Project Report No. RD 79.

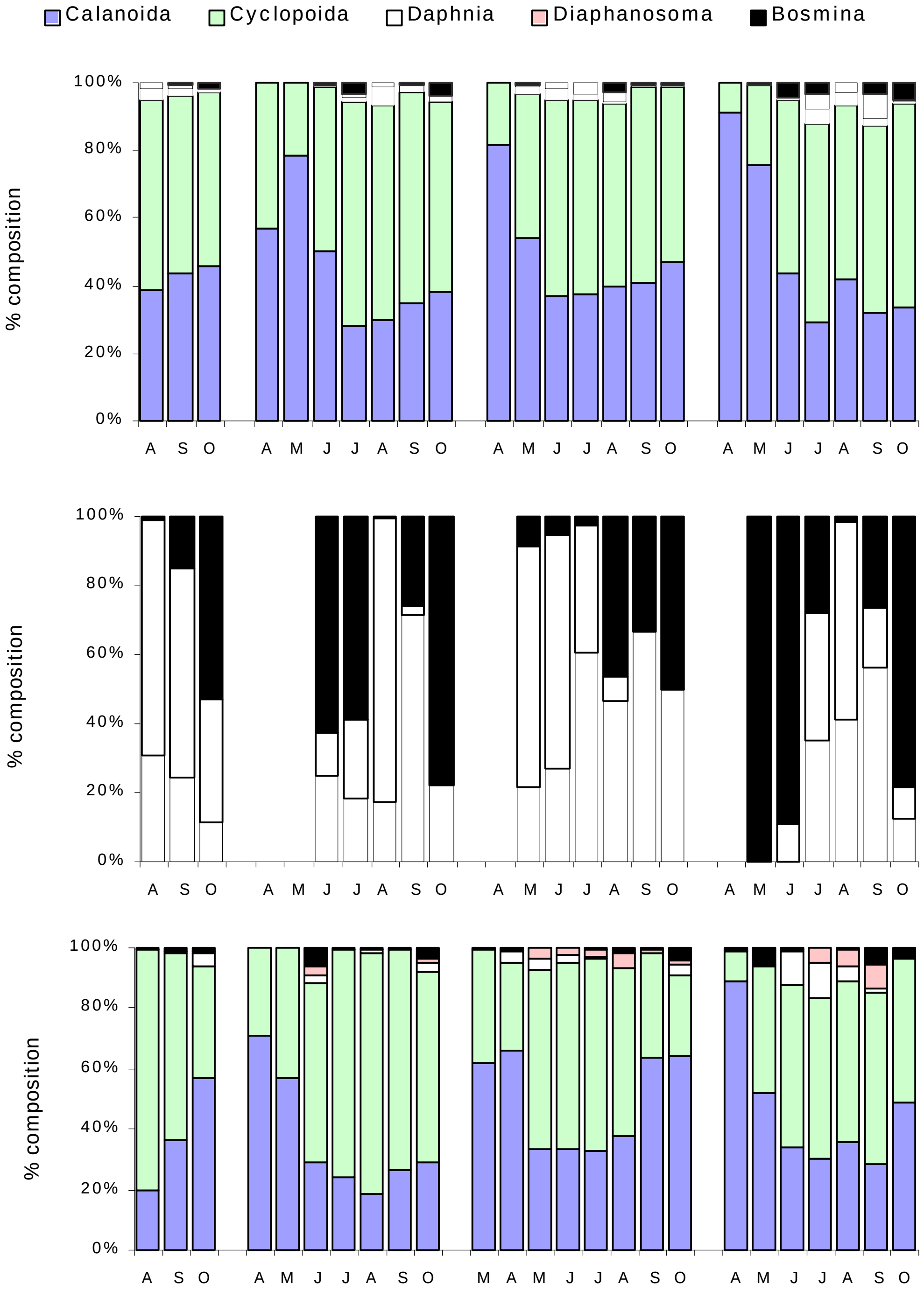

Figure 1. Percent composition of major zooplankton groups in Okanagan Lake, April to October of 1996-1999. Average of stations OK1-7 (top), Armstrong Arm only (middle), and copepods only in station OK1-7 (bottom).

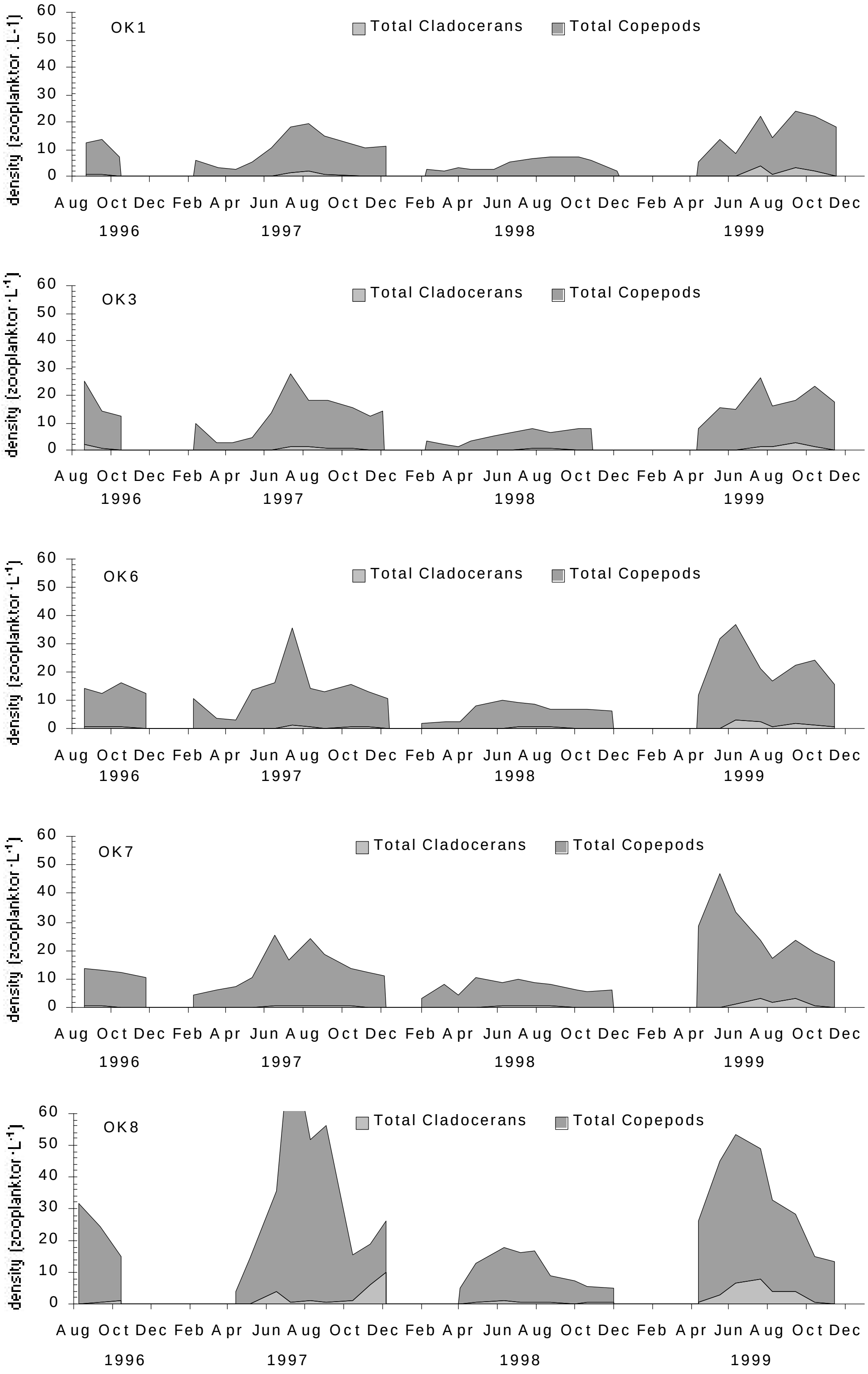

Figure 2. Density of cladoceran and copepod zooplankton in Okanagan Lake, 1996-1999.

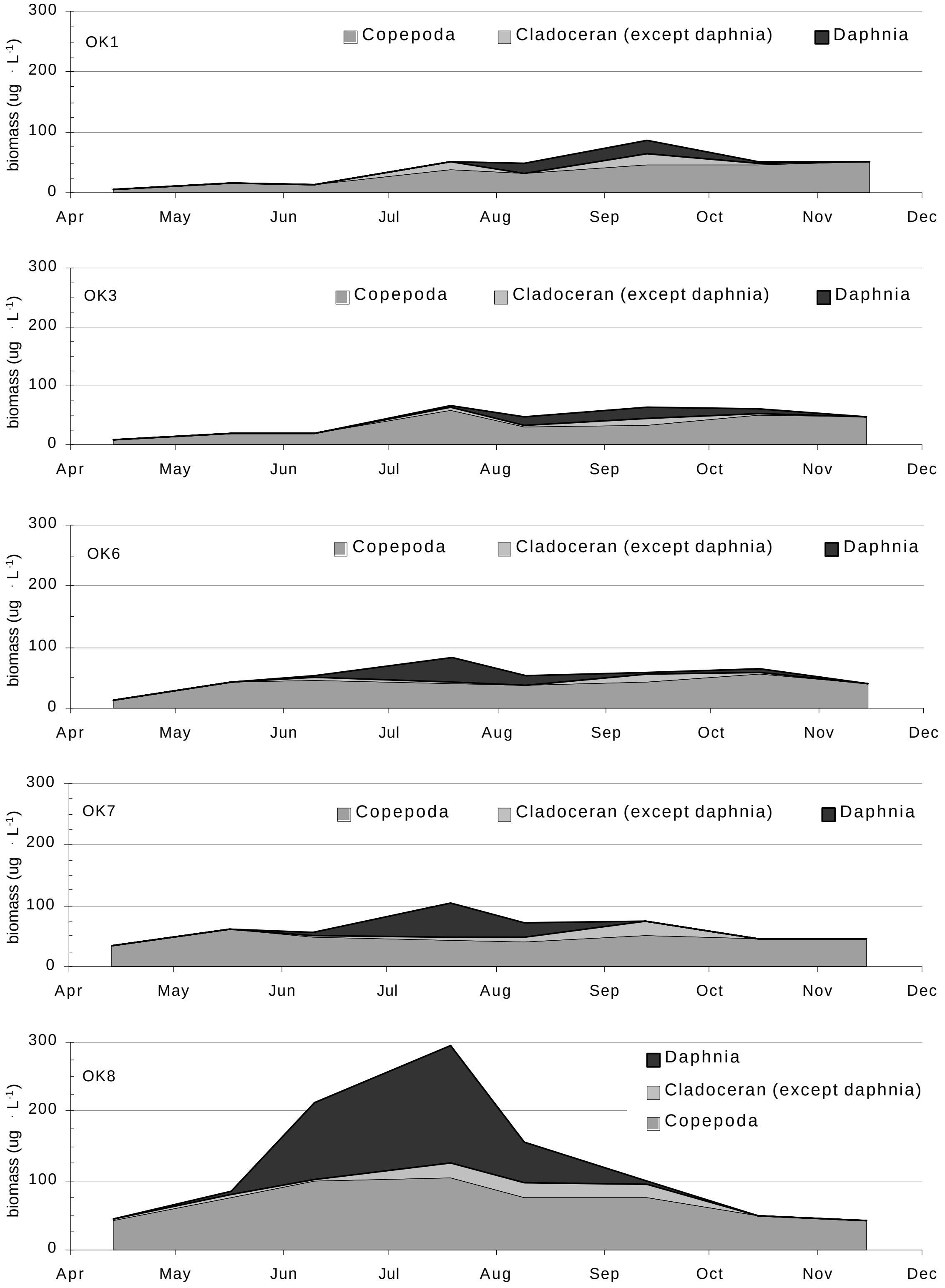

Figure 3. Biomass of cladoceran and copepod zooplankton in Okanagan Lake, April to November 1999.

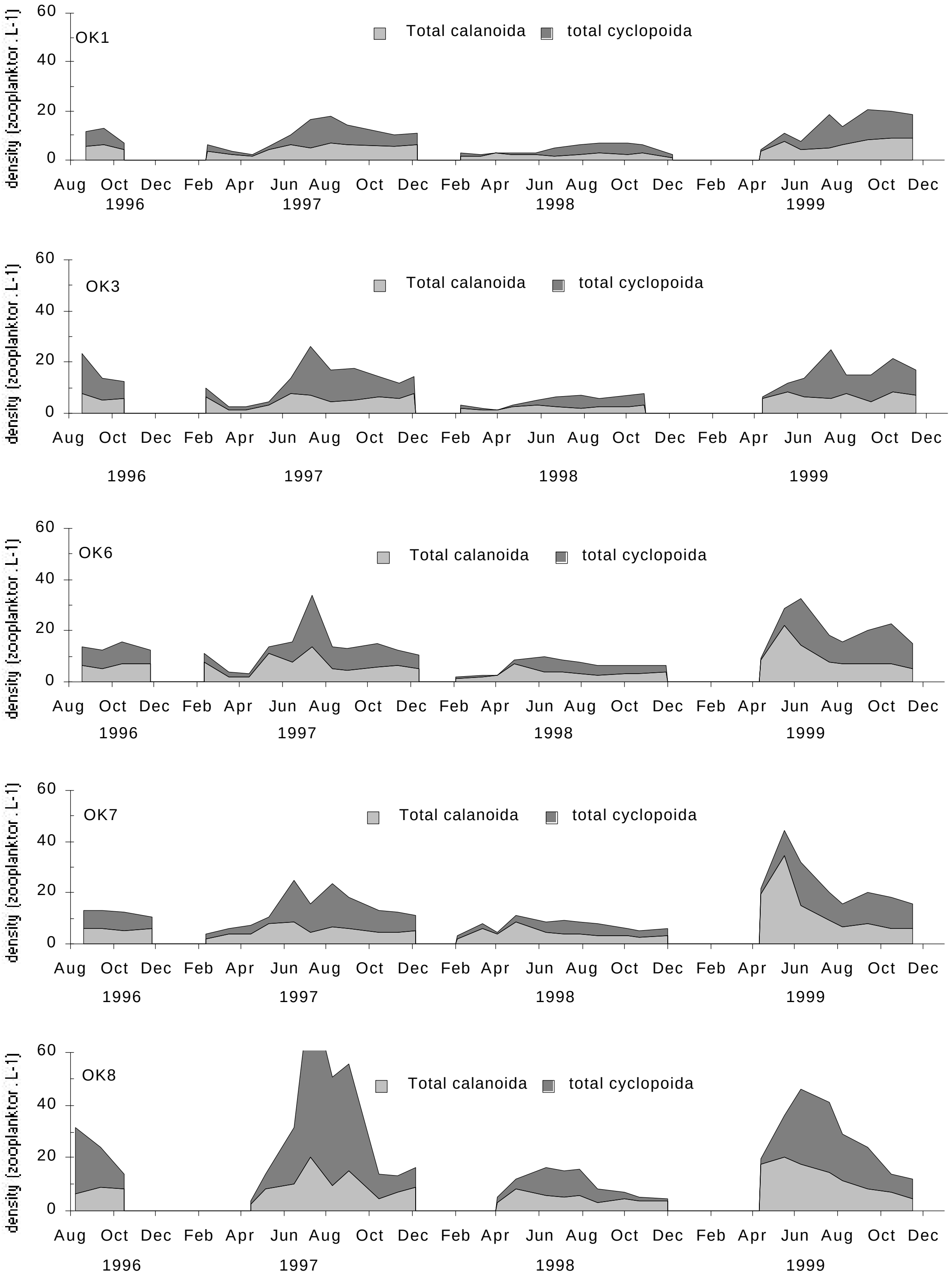

Figure 4. Density of calanoid and cyclopoid copepods in Okanagan Lake, 1996-1999.

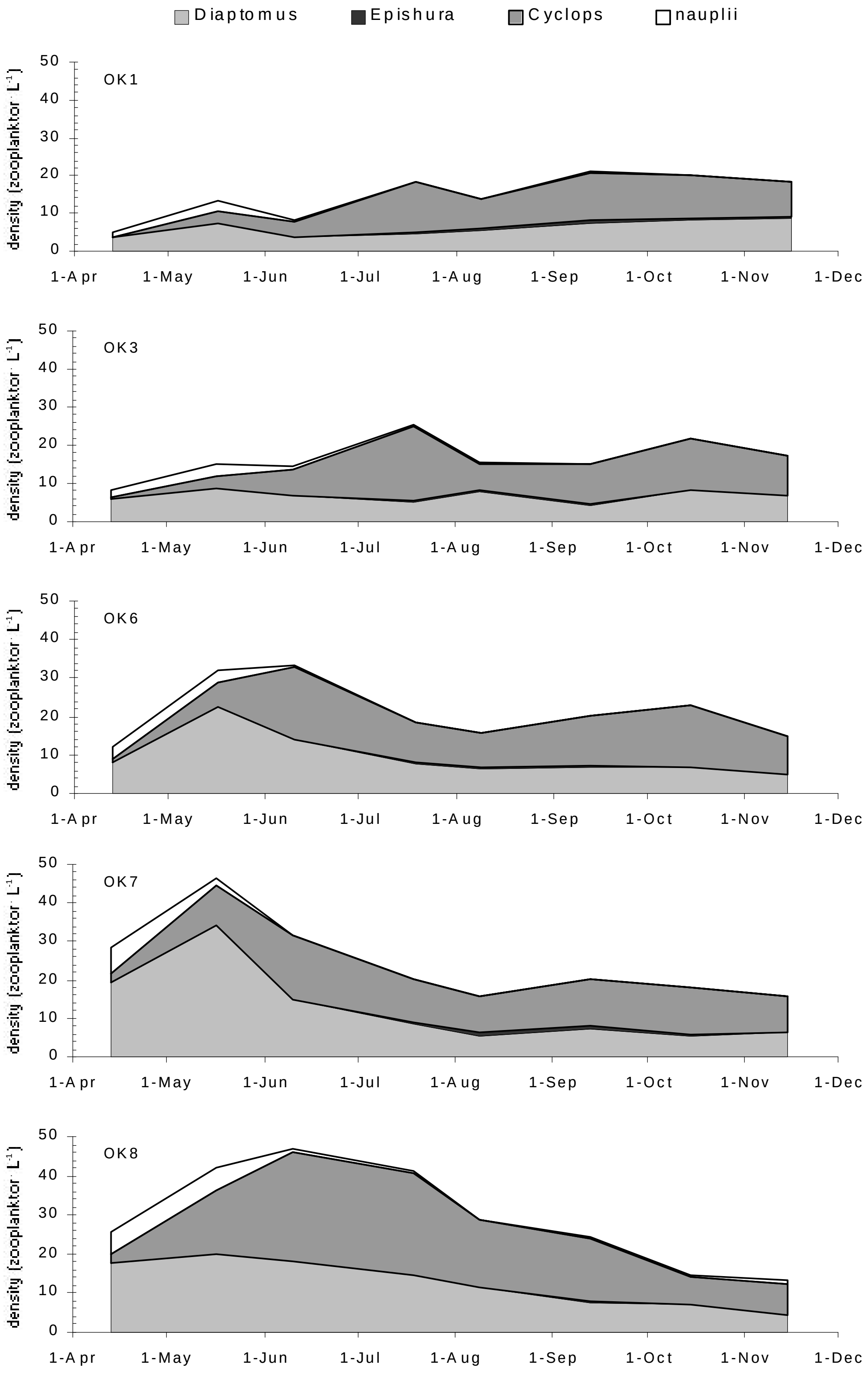

Figure 5. Density of copepod species in Okanagan Lake, April to November 1999.

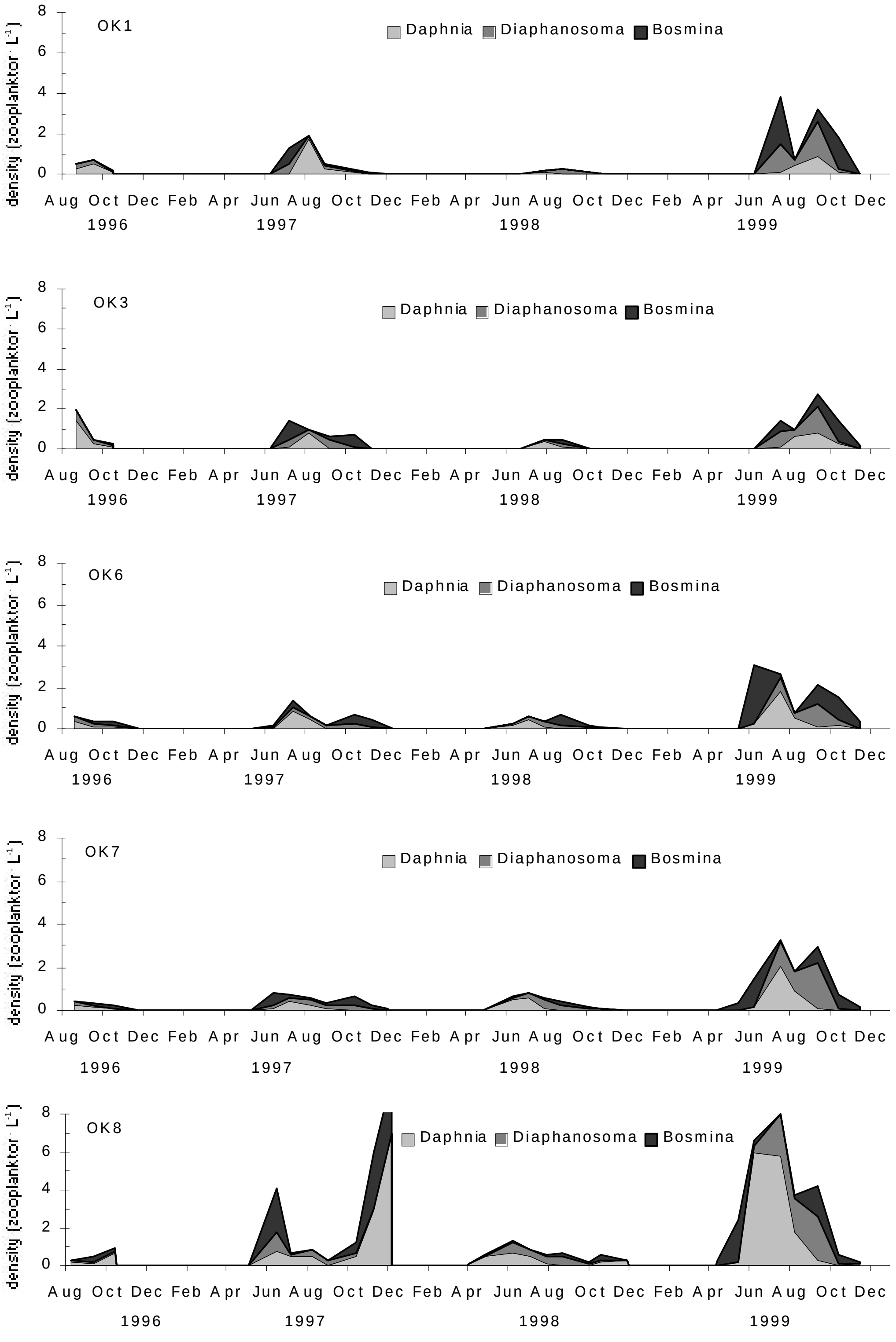

Figure 6. Density of cladoceran species in Okanagan Lake, 1996-1999.

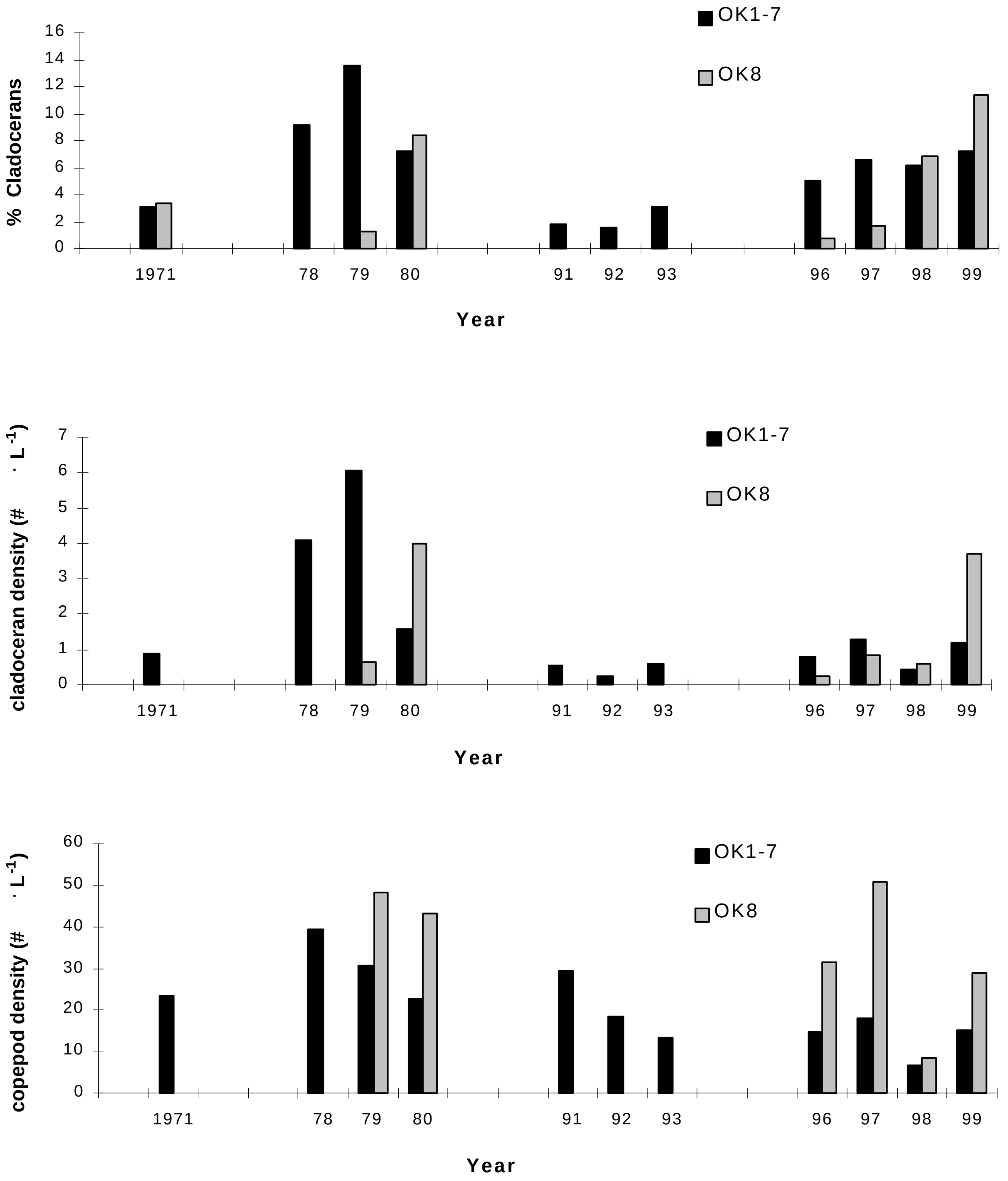

Figure 7. Historical comparison of cladoceran and copepod zooplankton in the main body of Okanagan Lake (stations OK1-7) and in the Armstrong Arm (OK8), during August 1971-1999; Cladocerans as percent of total zooplankton (top), density of copepods middle, and density of cladocerans (bottom).

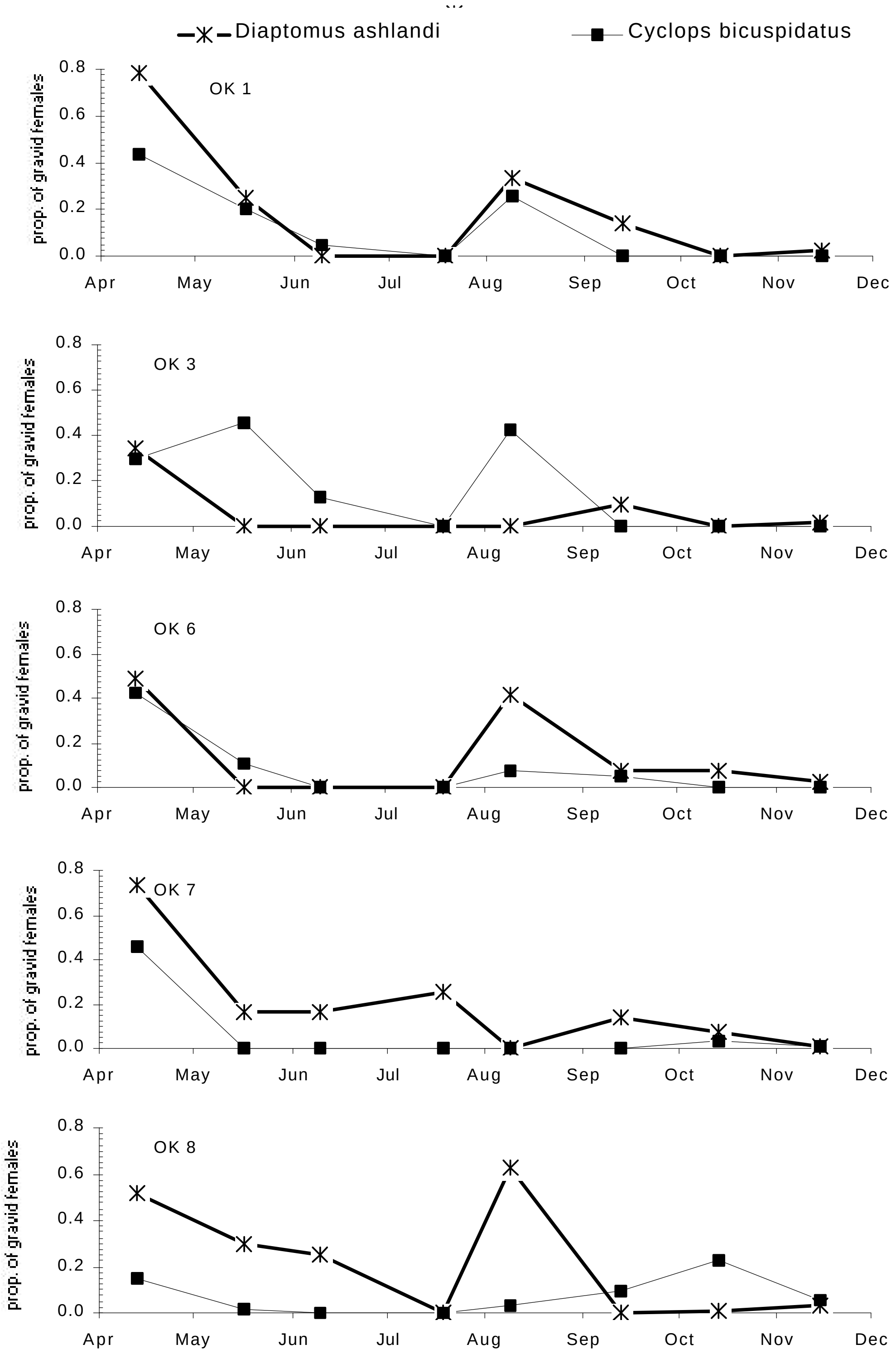

Figure 8. Proportion of gravid females in two genera of copepods found in Okanagan Lake, April to November 1999.

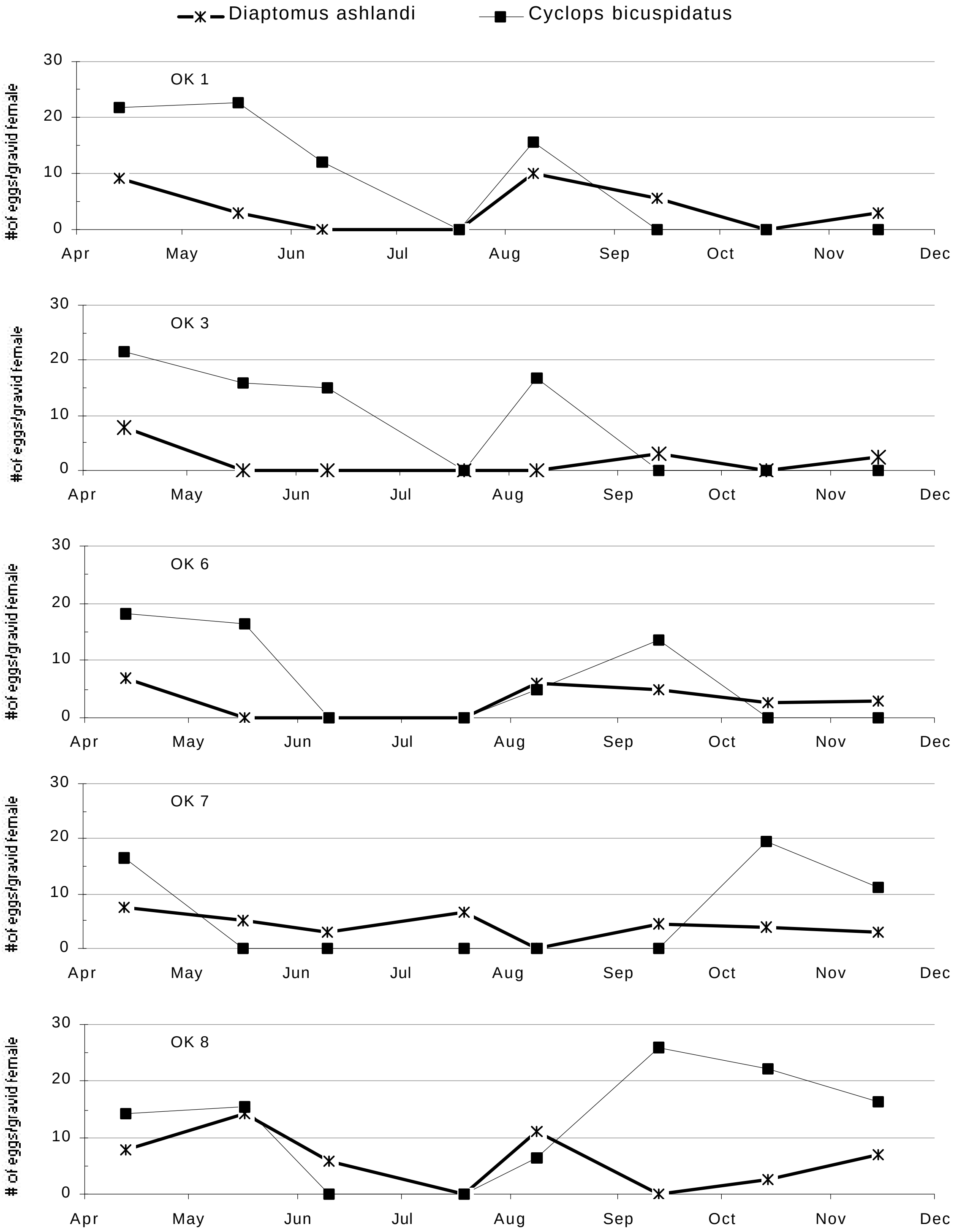

Figure 9. Number of eggs per gravid female in two genera of copepods found in Okanagan Lake, April to November 1999.

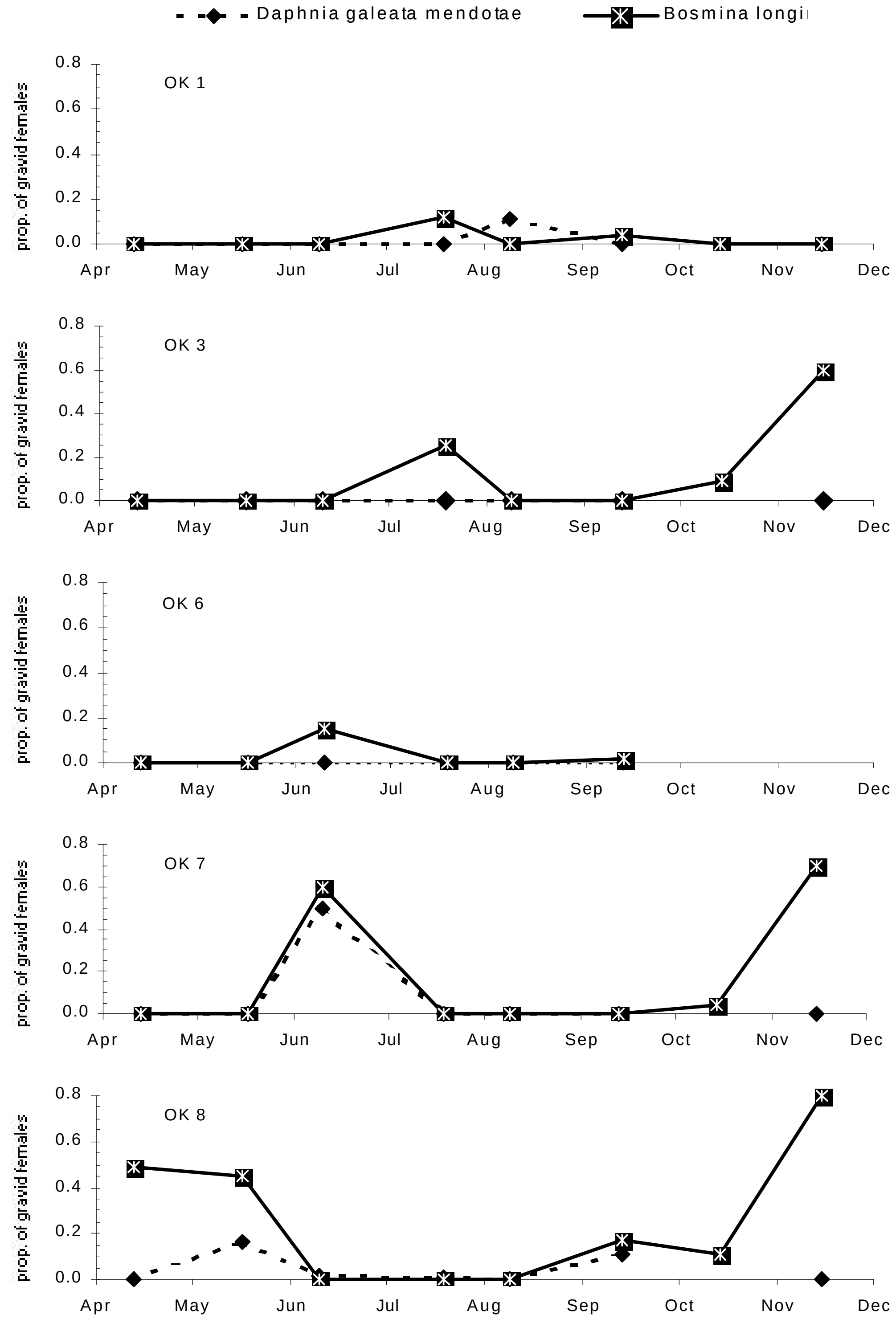

Figure 10. Proportion of gravid females in two genera of cladocerans found in Okanagan Lake, April to November 1999.

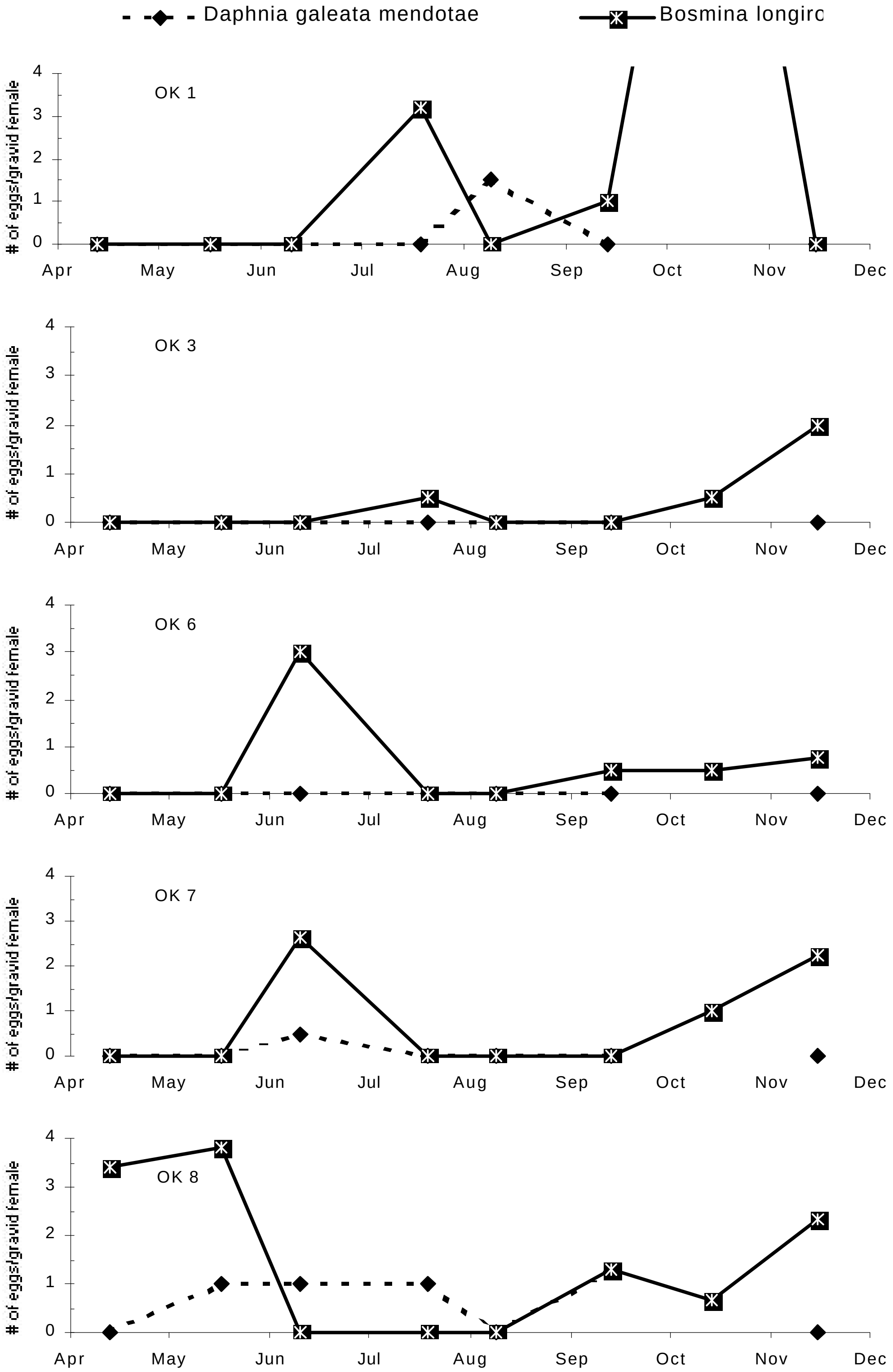

Figure 11. Number of eggs per gravid female in two genera of cladocerans found in Okanagan Lake, April to November 1999.

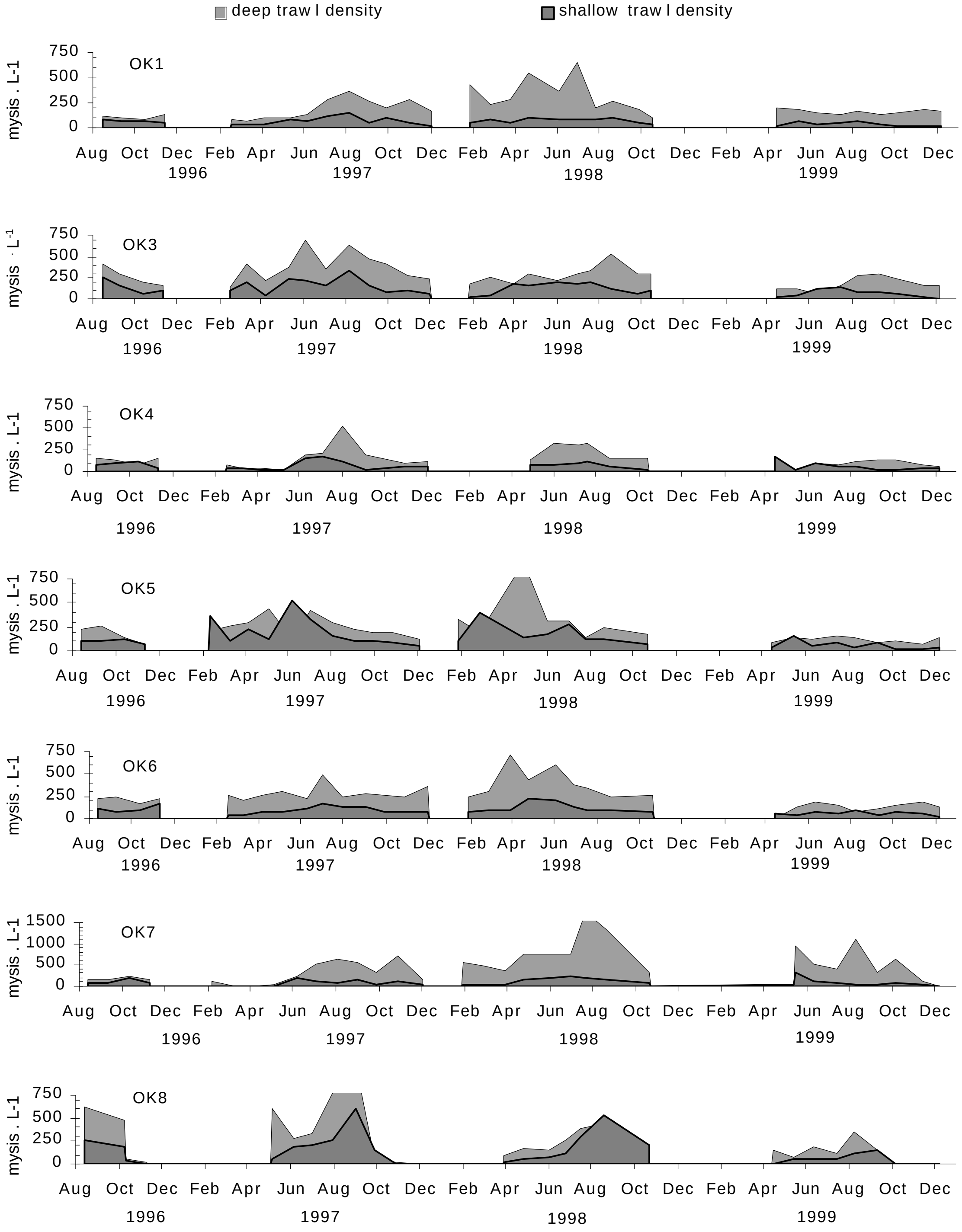

Figure 12. Density of *Mysis relicta* in the deep and shallow hauls of Okanagan Lake, August 1996 to December 1999. **Note:** OK7 graph on different scale.

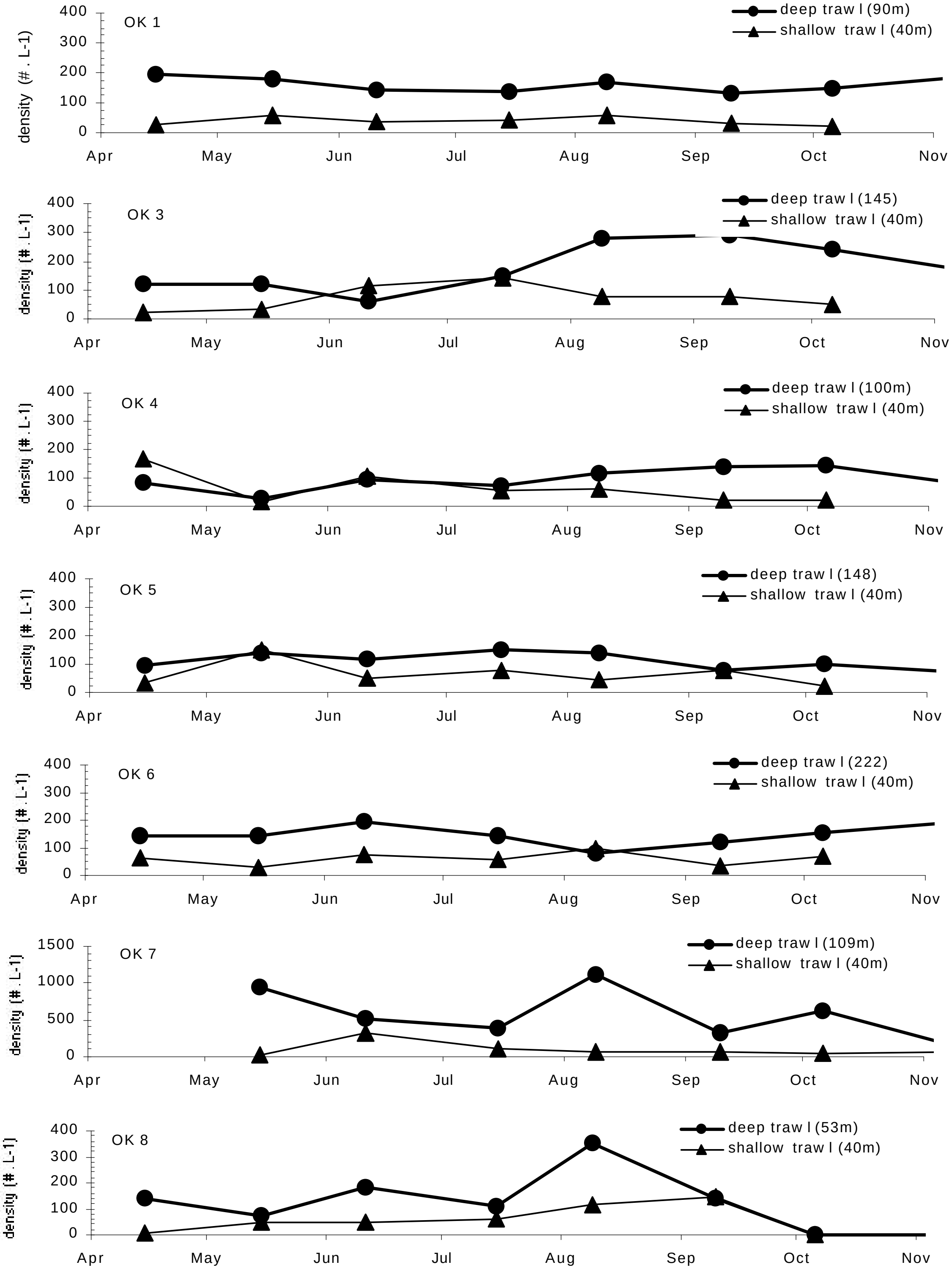

Figure 13. Biomass of male, female and juvenile *Mysis relicta* in the deep trawls (50-229 m) of Okanagan Lake, April - December of 1999. **Note:** OK7 graph on different scale.

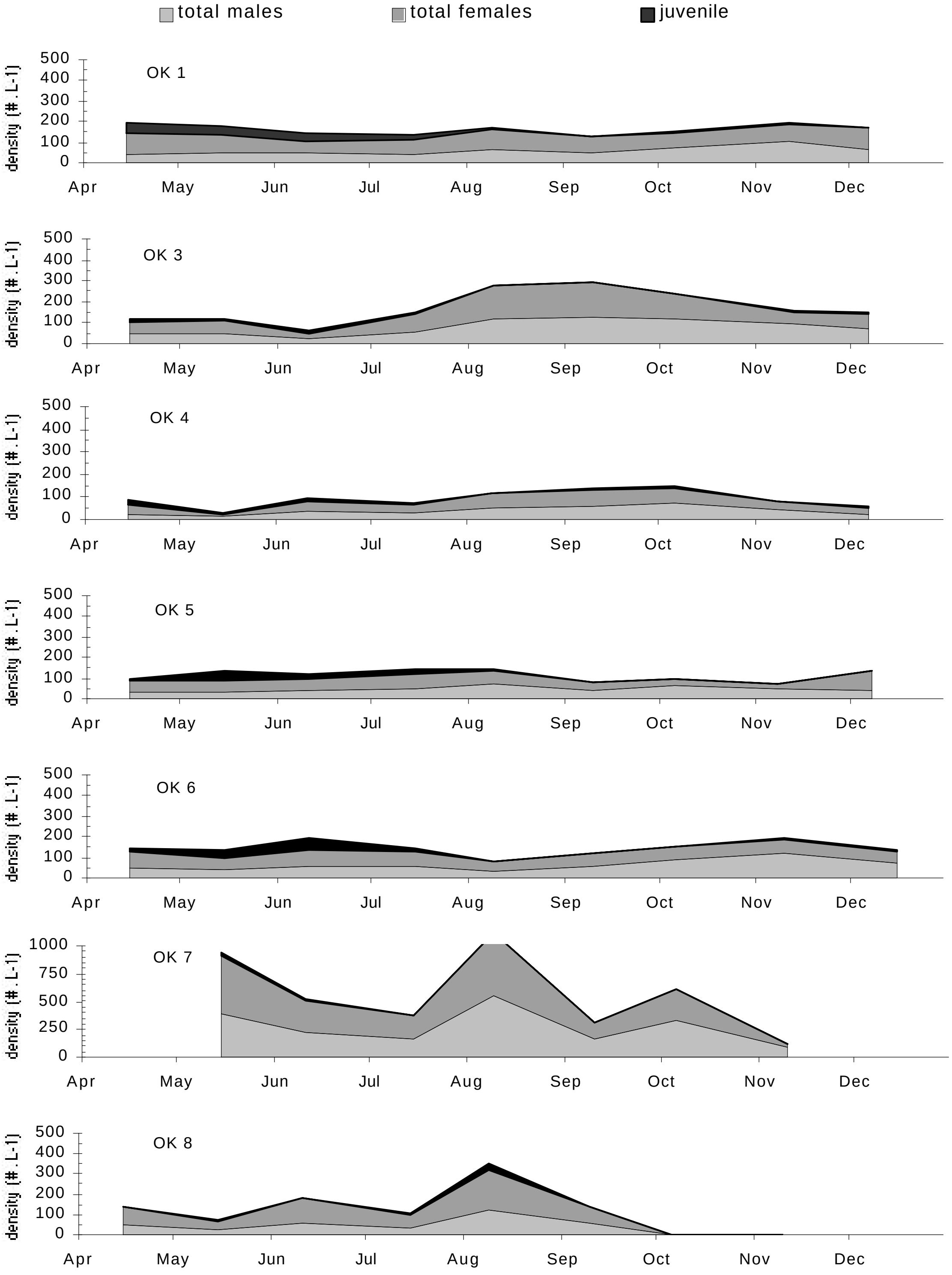

Figure 14. Density of male, female and juvenile *Mysis relicta* in the deep trawls (50-229 m) of Okanagan Lake, April - December of 1999. **Note:** OK7 graph on different scale.

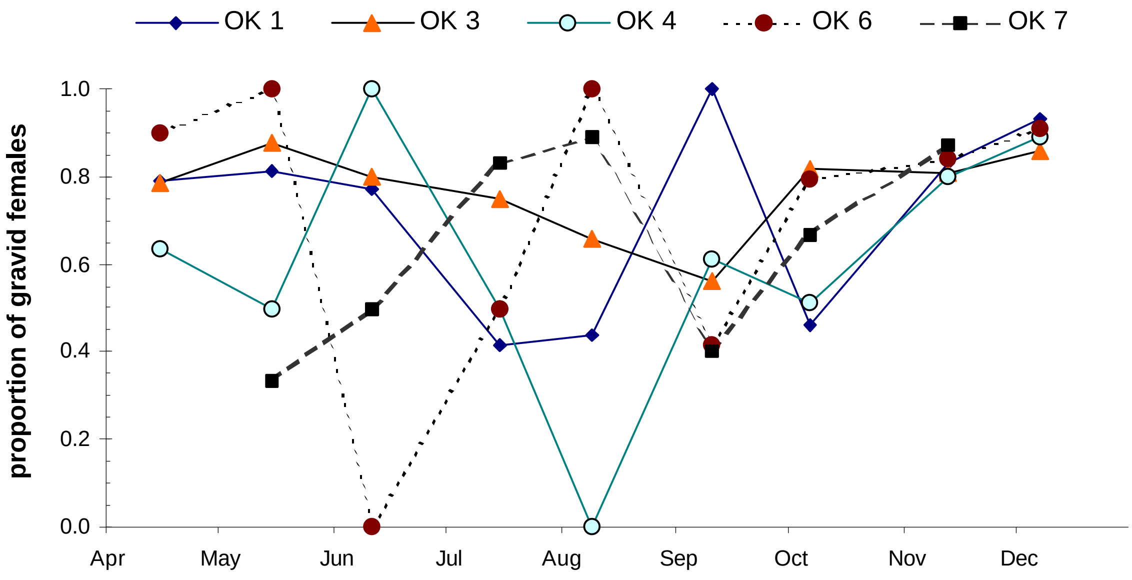

Figure 15. Proportion of gravid female (female:gravid female) *Mysis relicta* from several sample stations in Okanagan Lake, April to December 1999.

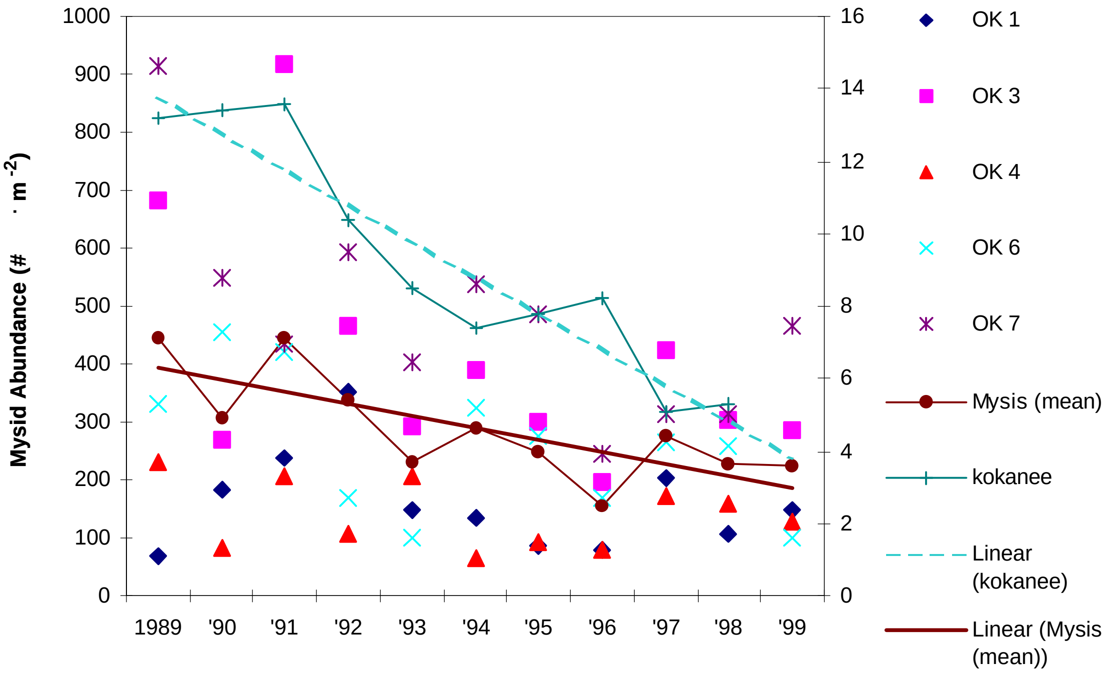

Figure 16. Abundance of *Mysis relicta* and kokanee in Okanagan Lake from 1989-1999. Mysid values are average of September and October deep hauls only. Kokanee abundance based on fall acoustic surveys (from Sebastian and Scholten 1999 *in* Ashley et al. 1999)

OKANAGAN LAKE KOKANEE ABUNDANCE, SIZE AND AGE STRUCTURE BASED ON TRAWL AND ACOUSTIC SURVEYS

1988 to 1999

by

D. C. Sebastian[1] and G. Scholten[1]

INTRODUCTION

Okanagan Lake is a large lake (351 km^2) located in southern BC, which supports a sizeable kokanee (*Oncorhynchus nerka*) population that recently has undergone a significant decline. In response to the decline a monitoring program was initiated in 1988 to determine the status of the population. Hydroacoustic and trawl net surveys have been conducted annually in the fall months since 1988. Establishment of a continuous data set over a period of time is invaluable for determining trends in the population. Calculations of in-lake abundance indices from the trawl and hydroacoustic data should complement annual shore and stream spawner counts and provide greater insight into stock status. This report provides an update of Sebastian et al. (1995, MS) and Sebastian and Scholten (*in* Ashley et al.1998; 1999). This report summarizes acoustic and trawl data collected during 1996 to 1999 under the Okanagan Action Plan and makes comparisons with data collected since 1988.

METHODS

Hydroacoustic Sampling

A complete night time survey of the limnetic habitat in Okanagan Lake was conducted during October 8-10, 1996, October 1-4, 1997, September 20-21, 1998 and September 6-8, 1999, concurrent with the annual trawl surveys. Acoustic surveys each consisted of 18 transects evenly spaced from the south to the north end of Okanagan Lake (see Map 2) using the standard survey design in Sebastian et al. (1995, MS). The 1997 survey also included 6 transects on Kalamalka Lake.

All surveys were conducted using a Simrad model EY200P operating at 70 kHz. The transducer was towed on a planer along side the boat at a depth of 1.5 m and data was collected continuously along survey lines at 1 to 2 pings$\cdot$s^{-1} while cruising at 2 m$\cdot$s^{-1}. The data was converted to digital format and stored both on a PC computer and backed-up on Sony Digital Audio Tape (DAT). Navigation was by radar and a 1:50,000 Canadian Hydrographic Services chart. The sounder was field calibrated at depths of 15 to 40 m using a standard -39.1 dB copper calibration sphere.

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The Simrad survey data were digitized and then analyzed using the Hydroacoustic Data Acquisition System (HADAS) program version 3.98 by Lindem (1991). The HADAS statistical analysis performed a function similar to manual counting to determine the number of targets per unit area by depth stratum. In addition, the HADAS estimated the fish size distribution using a statistical de-convolution algorithm based on Craig and Forbes (1969). The resulting bimodal acoustic size distribution was used to proportion the fish population into two size classes representing age 0 fish and age 1 to 3 fish, respectively.

Fork lengths of trawl caught fish were converted to the same acoustic scale using Love's (1977) empirical relation and compared to acoustic size distributions in order to verify the age cut-off for the two size groups. Since it was not possible to distinguish between age 1 to 3 fish using acoustic data, the proportions of these age groups were based on trawl catches. Kokanee abundance estimates and age 0 proportions were derived from acoustic data while abundance estimates of age 1 and age 2 fish relied on both trawl and acoustic results. Age proportions were less in reliable in 1999 compared with previous years as a result of small sample sizes of trawl caught fish.

Trawl Sampling

Trawl gear consisted of a 5 x 5 m beam trawl, holding a 15 m long net of graduated mesh size (0.6-10.0 cm stretched), towed at 0.65-0.95 $m^{\cdot}s^{-1}$. The cable angle and the length of cable deployed estimated net depth. In addition, a Global Positioning System (GPS) has been used since 1997 to verify the distances traveled by the trawl net, and to correct sample volume estimates.

A standard trawl survey of the limnetic habitat (>20 depth) in Okanagan Lake was completed during October 6-9, 1996, October 2-11, 1997, September 15-22, 1998, and September 5-8, 1999. The survey design and sampling techniques were consistent with the kokanee stock monitoring that has been conducted annually on Okanagan Lake since 1988 (Sebastian et al. 1995, MS). The survey consisted of 24 standardized trawls with 3 replicates at each of 8 evenly spaced stations from the south to the north end of the lake (Map 2). Stepped-oblique trawls ensured a representative sample of fish was attained from each depth strata where fish were observed on the echosounder. The net was typically fished for 8 minutes at each consecutive 5 m depth layer covering fish from 10-45 m depth. Captured fish were kept on ice until processed the following morning. The species, fork length, weight, distinguishing marks (e.g., fin clips), scale code and stage of maturity were recorded and samples were then preserved in 10% formalin for long-term storage. Scales were taken from fish >75 mm for aging, and otoliths (n=30) were taken as a second method of age determination in 1999. A small amount of flesh was also collected for stock identification through genetic analysis.

Trawl surveys provide the following information: species verification for the acoustic survey, an indices of kokanee abundance, age structure, size-at-age and the proportion of mature fish in the catch. Abundance indices were calculated based on a standardized volume of water filtered, representing the upper 55 m of the water column, which produced estimates of density in numbers per million litres or megalitres (ML) of water filtered. The sample volumes in 1999 ranged from

98.5 to 125 ML per trawl depending on the boat speed, and fish densities were calculated accordingly. Fish lengths were adjusted to a standardized survey date of October 1 to enable growth comparisons with previous fall surveys (Sebastian et al. 1995, MS). The 1999 survey was the earliest on record, so required the largest adjustment in fish size to October 1 (i.e. 22-26 days growth).

RESULTS AND DISCUSSION

Fish Distribution

Trawl catches during standard fall surveys indicated that the large majority (98-100%) of fish that are occupying the limnetic habitat below the thermocline at night were kokanee. The number of kokanee caught per survey ranged from 57 (1999) to 1,014 (1988) and number of trawls per survey ranged from 21 to 26 (Table 1). The average distribution of fish by age for the eight trawl stations based on twelve years of data (1988 to 1999) showed the greatest abundance of age 0 fish at Cameron Point (station 8) followed by Squally Point (station 3), Gelately (station 4) and Trout Creek (station 1) (Fig. 1). Largest numbers of age 1 fish often occurred at the same locations as the largest numbers of fry, indicating a similarity in their preference for local habitat conditions. Age 2 fish tended to be more uniformly distributed over the lake except at the end(s) of the lake (e.g., Cameron Point and Trout Creek), where their numbers were typically low.

Table 1. Summary of kokanee catches in Okanagan Lake standard trawl surveys, 1988 to 1999.

Survey	Survey	No. of	No. of	Number of Kokanee Caught					
Year	Period	Stations	Trawls	Age 0	Age 1	Age 2	Age 3	Mature	Total
1988	Oct 6-18	8	23	754	206	54	0	3	1,014
1989	Sep 28 - Oct 5	8	24	362	111	69	0	6	542
1990	Oct 16-20	7	21	395	117	62	0	1	574
1991	Oct 4 - 8	8	24	258	110	170	21	29	559
1992	Sep 27 - Oct 1	8	24	349	118	130	1	21	598
1993	Oct 13-19	8	24	191	108	54	6	11	359
1994	Oct 4-8	8	24	167	69	79	1	18	316
1995	Sep 22-28	9	26	331	109	161	21	57	622
1996	Oct 8 - 11	8	23	441	49	31	14	13	535
1997	Oct 2 - 11	8	24	293	97	41	6	13	437
1998	Sep 15-22	8	24	104	86	30	2	11	222
1999	Sep 8-11	8	24	26	9	11	11	12	57

In 1997, the trawl age distribution and abundance was fairly similar to the (then) 10 year average at all stations except stations 1 and 2 (Trout Creek and Summerland) where catches of all ages were low. In 1998, there was an obvious lack of age 0 fish at stations 3, 4, 5 and 8, which typically supported high numbers (Fig. 2). When compared to acoustic survey results, it appears that some age 0 fish in 1998 were missed by the trawl sampling, either as a result of the depth of sampling (slightly too deep to catch the top of the fish layer) or placement of trawls at the sample stations. To reduce the potential for a near shore bias, there was a deliberate emphasis in 1998 on sampling 3 replicates at each of the trawl stations toward the center of the lake. After sampling was completed, the GPS coordinates indicated that some of the replicates were done toward the low density side of the lake, and would therefore have underestimate the true numbers of fish present. In retrospect, spreading the trawls out across the lake as done in previous years did tend to produce a more reliable index of overall fish abundance, particularly for age 0 fish. It is recommended that replicates be spread out across the lake and GPS “way points” be selected for trawling starting locations.

A further decline in age 0 fish catches in the trawl was observed in 1999 (Fig. 3). Since 1997, the numbers of fry captured by standard trawling methods have declined by 91%. A 90% decline in the numbers of age 1 kokanee captured in 1999 compared with 1998 supports the notion that the 1997-1998 decline in fry numbers was real, and not just an artifact of sampling. Based on trawl results in isolation of other sampling techniques, one would conclude that Okanagan Lake kokanee numbers are currently experiencing a severe rate of decline. However, when compared with acoustic results, it appears that 1999 kokanee densities have declined below a threshold level where trawling is no longer a reliable indicator of their abundance. It appears the threshold for trawling in Okanagan Lake may be approximately 200 fish$\cdot$ ha^{-1}. A similar decline in trawl catches was noted in Arrow Reservoir when acoustic densities dropped below 100 fish$\cdot$ ha^{-1} (Pieters et al. 1999). The trawl efficiency for kokanee may vary from basin to basin depending on their nighttime vertical distribution (i.e., how concentrated or dispersed the layer is?)

Abundance

Estimates of kokanee abundance in the limnetic zone of Okanagan Lake have ranged from 4 to 14 million fish over the last twelve years. Abundance was estimated at 8.2 million fish in 1996, 5.1 million in 1997, 5.3 million in 1998 and 4.1 million in 1999. The total number of fish declined by 45% from 1991 to 1994, increased slightly in 1996, and then declined a further 24% to 4.1 million in 1999 (Fig. 4). The 95% confidence limits on these estimates suggest that declines observed during 1991 to 1994 and again in 1997 were statistically significant. According to acoustic size distributions, the proportions of fall fry (age 0 fish) in Okanagan Lake has ranged from 46 to 71% of the total population with 1999 the lowest proportion. The lowest proportion estimated was that in 1999. Fry abundance has declined 79% from 9.0 to 1.9 million between 1990 and 1999 (i.e., spawning years 1989 to 1998). The large decrease in fry abundance in 1997 followed a low shore spawner estimate in 1996 and an extreme lake drawdown during the spring of 1997. Fry numbers increased slightly in 1998 but remained fairly low. Further decline in fry numbers observed in 1999 were anticipated following the lowest shore spawner count on record (Sebastian and Scholten *in* Ashley et al. 1999).

From 1990 to 1999 estimates of age 1 fish have declined by 80% from 3.0 to 0.6 million although the most recent and lowest estimate is based on a very small sample size (Fig. 5). Trends in age 2 fish abundance were generally more variable but also showed an overall decline of about 75% between 1991 to 1999 survey years, corresponding to the 1988 to 1996 spawning years (assuming age 3+ at maturity).

Age Structure and Sampling Techniques

A combination of trawl and acoustic results was used to estimate the age structure of kokanee in the lake (Fig. 5). Acoustic results were preferred over trawling results for estimating total abundance and proportion of age 0 fish, since the sample coverage was greater and the variability in estimates was lower (i.e., more stable). The tendency for fry to congregate in high densities immediately below the thermocline makes them somewhat difficult to sample quantitatively using a stepped oblique trawl method, since the depth of the "fry layer" and the thermocline can vary along the lake as well as along the length of a trawl. These variations in fish depth do not present a problem for acoustic counting, which analyzes each 5 m depth layer separately. Unfortunately, the ability to distinguish size differences using the single beam de-convolution method is limited to large size differences, so this technique is not suitable for separating age 1, 2 and 3 fish into different size groups. The proportions of age 1, 2 and 3 fish from the trawl were applied to the total acoustic abundance of age 1 to 3 fish to proportion the population into these age groups (Fig. 5).

Similarity, in estimated numbers of age 1 and 2 fish for the same spawning years indicates there may be some problems in using the trawl proportions for estimating age 1 abundance. Three potential sources of error associated with trawl netting are: 1) location and intensity of sampling relative to where the fish are; 2) estimating the volume of water sampled in each trawl; and 3) relative efficiency of the net for capturing different sized fish as a result of the mesh size and tow speed.

The confidence intervals on age 1 trawl catches were similar or tighter than on age 2 catches, indicating that patchiness of age 1 fish or insufficient number of sample sites were not likely to be the cause of low age 1 catches. The GPS coordinates of trawl start and end points recorded in 1997 and 1998 indicated that average boat speed was 15% less than previously estimated. However, this error would likely apply similar bias to all age groups, and should have minimal effect on age proportions in the catch. Field observations from the Kootenay Lake fertilization study suggest that there is a greater loss of age 1 than age 2 fish through the large mesh at the head end of the trawl net (D. Miller, contractor Nelson BC pers comm., 1996). It was concluded that relative catch efficiency due to large head-end mesh size was the most likely reason that numbers of age 1 fish remain relatively low and similar in numbers to age 2 fish in the trawl. With this problem in mind, trends in abundance within a specific age group should still be valid. Size (age) specific expansion factors for age 0 and 1 fish would have to be developed in order to estimate and track survivals of cohort groups through the population using current sampling methods.

The abundance of age 1 fish originating from the 1996 spawning year was expected to decline as a result of a 50% reduction in the 1997 fry population compared to the previous year. However, a slight increase in age 1 numbers suggests that fry-to-yearling survival may have improved in 1998. A decline in age 1 fish did occur the following year, after a second year of low fry recruitment (i.e., the 1997 spawning year). Caution should be used in relying on trawl proportions for tracking age structure, particularly during the last two survey years when trawl catches (i.e. sample sizes) were low. This problem is all too evident from the 1999 trawl data when the age 3 fish originating from the 1995 spawning year outnumbered the age 2 fish from the same spawning year.

Mature Fish and Shore Spawner Distribution

Trawl surveys during 1988 to 1997 occurred between September 22nd and October 20th and was after the peak of stream spawning activity and before the peak of shore spawning. During this period the number of mature fish caught in the trawl ranged from 1 to 57 fish. It was anticipated that distribution and abundance of mature fish caught in the trawl would be useful in predicting distribution and relative abundance of shore spawners 2 to 3 weeks later. Numbers in the trawl were too low to predict abundance but there appeared to be a reasonable correlation between the distribution of mature fish from trawls and the location of observed shore spawning. The largest numbers of mature fish were caught in the vicinity of Squally Point and Okanagan Resort, two areas known to have high spawner concentrations (Map 2). Lower numbers at Cameron Point, Gelately and Whiskey Island also correlate to fewer numbers of observed spawners (Fig. 6). The 1996 trawl suggested that Squally Point would be the most important area with less spawning near Okanagan Resort and Whiskey Island. This data agreed with the observed distribution in 1996, although the numbers of mature fish did not reflect the apparent low abundance of spawners suggested by the shoreline counts. The 1997 trawl results suggested higher than average numbers of potential spawners just south of Kelowna, and little if any spawning activity for Squally Point and southward (Fig. 6). These results again agreed with shore spawner count distributions if it is assumed that fish caught off Mission Creek (where there is no suitable shore spawning habitat) moved immediately north of Kelowna to spawn where highest numbers were observed. Lack of shore spawning activity at Squally Point parallels the trawl results.

Trawl surveys during 1998 and 1999 were conducted earlier in September, and there is a likelihood that mature fish could have been either stream or shore ecotypes. Unlike previous years, neither the 1998 nor 1999 mature fish distributions correlated with the observed distribution of shore spawning 6-8 weeks later. In 1999, the majority of mature fish were caught at the south end of the lake (Trout Creek) where there is no known shore spawning in the vicinity. In October 1999, the highest concentration of shore spawners were observed by Smith (in this OLAP report) in the Squally Reach, followed by the north east quadrant (the Okanagan Center to Cameron Point area).

Growth

The early sampling date in 1999 required fish length corrections of up to 7% for age 0, 5% for age 1 and 1-2% for age 2 and 3 fish in order to account for growth that would have occurred between the time of sampling and October 1. Although this correction is a potential source of error in mean size at age estimates for 1999, it is relatively insignificant compare to observed differences in fish size between the various survey years.

Kokanee mean size-at-age during 1985 to 1996 were 59 ± 2 mm for age 0, 131 ± 6 mm for age 1, 214 ± 2 mm for age 2 and 237 ± 4 mm for age 3 fish adjusted to an October 1 standard (Fig. 7). The mean size of all age groups had declined notably by 1997 and 1998. The mean size-at-age in 1998 was 55 ± 2 mm for age 0, 114 ± 3 mm for age 1, 189 ± 4 mm for age 2 and 207 ± 35 mm for age 3 fish. The decline in size from 1996 to 1998 was most noticeable in the age 2 and 3 fish, with age 2 size statistically the lowest on record for its age group. The low numbers of age 3 fish resulted in wide confidence limits on the means. Except for age 3 fish, it appears that there has been a gradual downward trend in size of Okanagan Lake kokanee since about 1990. This downward trend in size is remarkably similar to what occurred to Kootenay Lake kokanee in the late 1980s (Ashley et al. 1997). Initial indication of a reversal in the downward trend of size-at-age in Okanagan Lake was observed in 1999 (Fig. 7).

Trends in kokanee length-at-age showed no evidence of density dependence. In fact, simultaneous declines in both size and density of kokanee support the current theory of declining lake capacity. From a preliminary trawl survey in 1997, mean size-at-age of kokanee in nearby Kalamalka Lake appeared to be smaller than in Okanagan Lake (Fig. 7).

Mature fish caught by trawl-net averaged 233 ± 5 mm from 1988 to 1996. This was consistent with the mean size of 237 ± 2 mm for a sample of 104 shore spawners collected at Squally Point and Okanagan Lake Resort during 1994 (Pollard and Taylor, 1997). Pollard and Taylor (1997) reported that all their samples were age 2+. A small sample of mature fish from the 1996 trawl (n=13) suggested that 70% of the fish were age 3+, with a mean size of 247 ± 4 mm. A similar size sample in 1997 suggested 70% were age 2+ with a mean length of only 205 mm. Mature fish in 1998 also appeared to be mainly age 2+ with a mean length of about 200 mm. However, Andrusak and Sebastian (in this OLAP report) conducted length frequency analysis of trawl caught fish and spawners to conclude that most mature fish are 3+. Clearly, there is a need to clarify the age at maturation for these fish. An otolith and scale analysis comparison is currently in progress in yet another attempt to confirm age at maturity.

Spawner Abundance and Fry Recruitment

Okanagan Lake kokanee stock assessment work continues to be problematic due to the inability to determine actual number of shore spawners compared to number of stream spawners. For this reason some effort has been made to determine a correlation between known in-lake fry abundance and total number of spawning fish that produced those fry.

An initial comparison of spawner estimates to in-lake fry abundance estimates the following year was made using data from the 1987 to 1998 spawning years (Fig. 8). Separate correlations of stream and shore spawners to the number of fry in the lake suggested that the shore component had the largest influence over fry abundance. In order to combine the indices of stream and shore spawner abundance, they were each adjusted to represent the total numbers of spawners. The stream peak count was expanded by 1.5 times as suggested in Andrusak (1999) and has been revised downward from the 2.3 factor used previously for Okanagan stream spawners (Ashley et al. 1998). There are considerable uncertainties associated with enumerating shore spawners (e.g., less coloration, wave action, and depth of spawning) with a shorter residence time and lower frequency of shore surveys(Thomson in Ashley et al. 1998). For these reasons it is believed that the expansion factor for shore spawners would have to be > 1.5 used for stream spawners.

After much analysis using an expansion factor of 3.5 resulted in a reasonably good correlation between the total combined spawner estimates and the resulting fry population in 11 of the 12 years of record (Fig. 8). Figure 8 also suggests that the downward trend in numbers of spawners and late summer fry has been relatively consistent and parallel over the past decade i.e., highly correlated. This is surprising, in light of evidence that proportions of stream to shore spawning fish appears to have been highly variable.

The use of the 3.5 conversion factor provides one method of estimating numbers of shore spawners. Use of genetic markers to differentiate between stream and shore spawning stocks from trawl caught samples has been described by Taylor et al. (*in* Ashley et al. 1999) and by Pollard (in this OLAP report). Annual determination of the ratio of stream versus shore origin fish by year class will provide a second means of estimating numbers of shore spawning fish, since stream spawner numbers are estimated annually.

The extremely low shore counts reported in October 1998 suggested that there would be a sharp decline in the numbers of kokanee fry in Okanagan Lake during fall 1999. Both acoustic and trawl surveys confirmed that fry numbers were low in 1999. Based on the 1999 spawner counts, a substantial increase in fry numbers are predicted for 2000. If the model holds true, an acoustic fry estimate of 5-7 million fry is expected in October 2000.

RECOMMENDATIONS

1. Trawl sampling should be scheduled as close to October 1 as possible in order to minimize length corrections. If the intent is to capture mature shore but not stream spawners, trawling must be scheduled between Sept 25 and Oct 20. If the intent is to capture mature fish from both groups, then a second trawl survey should be done in August
2. GPS coordinates for trawl starting locations should be defined in order to minimize further bias associated with site selection between surveys.
3. Continue to collect scales from trawl caught fish >130 mm and use for age verification.
4. Collect tissue samples and preserve in 95% ethanol for genetic analysis to estimate the proportions of shore spawning stock to total fish. It is important to keep tissue samples from different age groups separate, as proportions appear to change from year to year. The majority of trawl caught fish can be aged reliably based on their length. However, if age is uncertain, the samples should be stored in separate vials and labeled with scale codes until the age can be determined through scale analysis.
5. In view of declining trawl catches, consider collecting additional tissue samples for stock identification from kokanee by-catch captured in mysis harvesting trials.

ACKNOWLEDGEMENTS

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REFERENCES

Andrusak, H. 1999. MS. Performance Evaluation of Six Kokanee Spawning Channels in British Columbia. Unpubl. MS. Ministry of Fisheries, Province of British Columbia. Victoria, BC.

Ashley, Ken, Lisa, C. Thompson, Peter Warburton, Ying-Rong Yang, Francis R. Pick, Paul B. Hamilton, David C. Lasenby, Karen E. Smokorowski, Laurie McEachern, Dale Sebastian and George Scholten. 1997. Kootenay Lake Fertilization Experiment – Year 4 (1995/96) Report. Fisheries Project Report No. RD 58, Fisheries Br., Ministry of Environment, Lands and Parks, Victoria, BC. 181 p.

Ashley, K., B. Shepherd, D. Sebastian, L. Thompson, L. Vidmanic, Dr. P. Ward, H. Yassien, L. McEachern, R. Nordin, Dr. D. Lasenby, J. Quirt, J.D. Whall, Dr. P. Dill, Dr. E. Taylor, S. Pollard, C. Wong, J. den Dulk and G. Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Fisheries Management Branch, Ministry of Fisheries, Victoria, BC. 396p.

Ashley, K. I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, G. Scholten, M. Zimmerman, P. Epp, V. Jensen and R. Finnegan. 1999. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. RD 78, Fisheries Management Branch, Ministry of Fisheries, Victoria, BC. 338p.

Craig, R. E., and S. T. Forbes. 1969. Design of a sonar for fish counting. Fisheridirektoratets Shrifter. Series Havundersokelser 15: 210-219.

Lindem, T. 1991. Hydroacoustic Data Acquisition System HADAS. Instruction Manual. Lindem Data Acquisition, Lda, Oslo, Norway.

Love, R. H. 1977. Target Strength of an Individual Fish at any Aspect. J. Acoust. Soc. Am. 62(6): 1397-1403.

Pieters, R., L.C. Thompson, L. Vidmanic, S. Pond, J. Stockner, P. Hamblin, M. Young, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian, G. Scholten and D.L. Lombard. 1998. Arrow Reservoir Limnology and Trophic Status - Year 1 (1997/98) Report. Fisheries Project Report No. RD 67. Ministry of Environment, Lands and Parks, Province of British Columbia.

Pollard, S. and R. Taylor. 1997. Genetic and Phenotypic Variation Between two Spawning Ecotypes of Kokanee (*Oncorhynchus nerka*) in Okanagan Lake. B.C. Ministry of Environment, Lands and Parks, Fisheries Management Report No. 106 (in prep), Victoria, BC. 29 p.

Sebastian, D., G. Scholten, D. Addison and D. Green. 1995. Results of the 1985-94 Acoustic and Trawl Surveys on Okanagan Lake. Unpublished MS, Stock Management Unit Report No. 2. Fisheries Branch, Ministry of Environment, Lands and Parks, Victoria, BC, 54p.

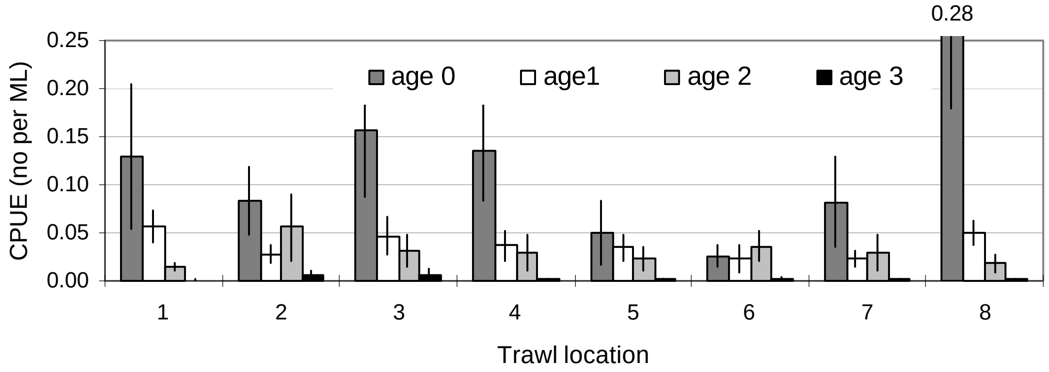

Figure 1. Kokanee distribution by age in Okanagan Lake based on trawl surveys, 1988 to 1997. Error bars denote 95% confidence limits on means.

Figure 2. Kokanee distribution by age during fall 1998 based on trawl survey.

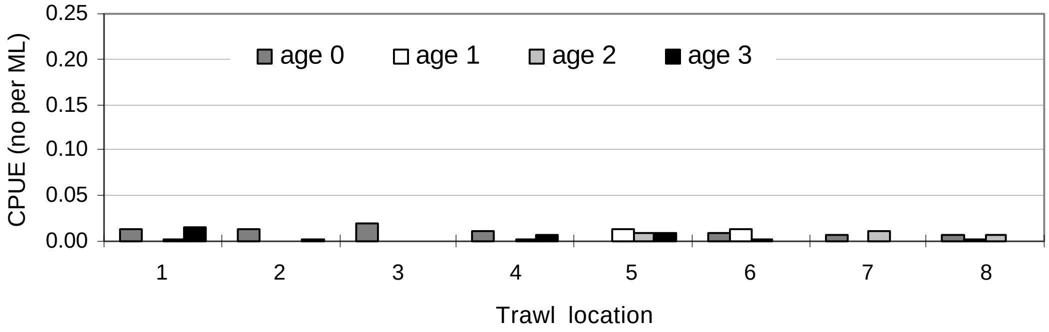

Figure 3. Kokanee distribution by age during fall 1999 based on trawl survey.

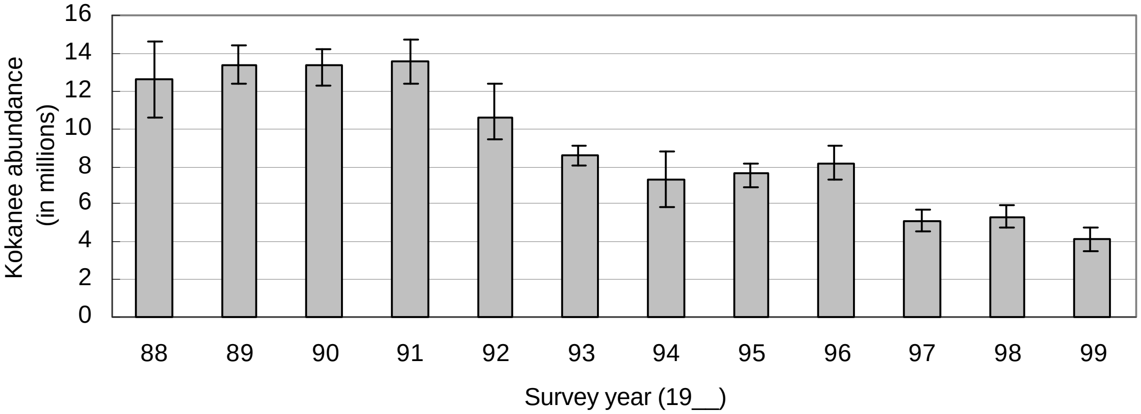

Figure 4. Kokanee abundance in Okanagan Lake based on fall acoustic surveys, 1988 to 1999. Error bars represent 95% confidence limits.

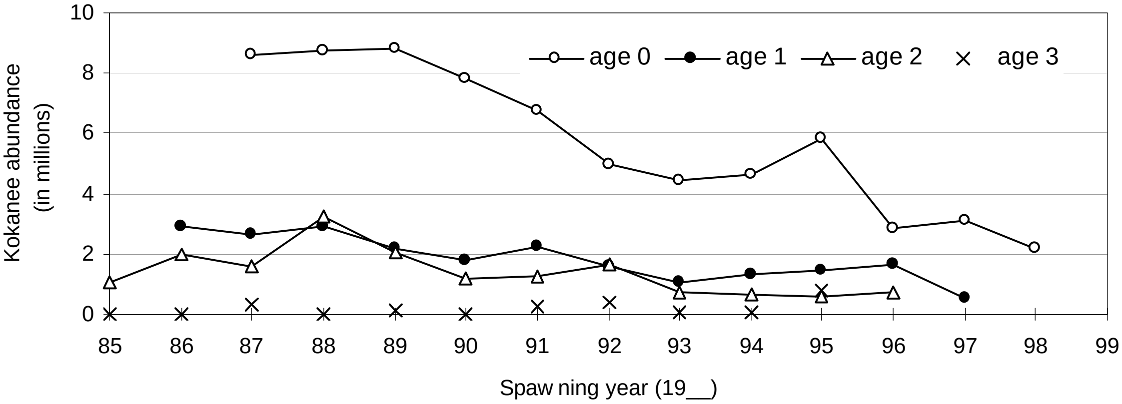

Figure 5. Trends in kokanee abundance by age and spawning year based on acoustic and trawl surveys conducted in 1988 to 1999. Note: data presented by spawning years.

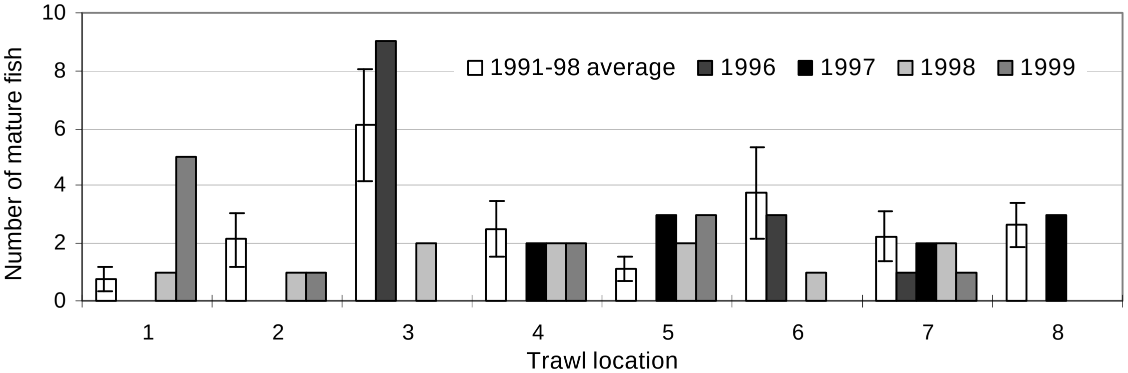

Figure 6. Distribution of mature fish in Okanagan Lake prior to shore spawning in 1996 to 1999 compared with the last eight years.

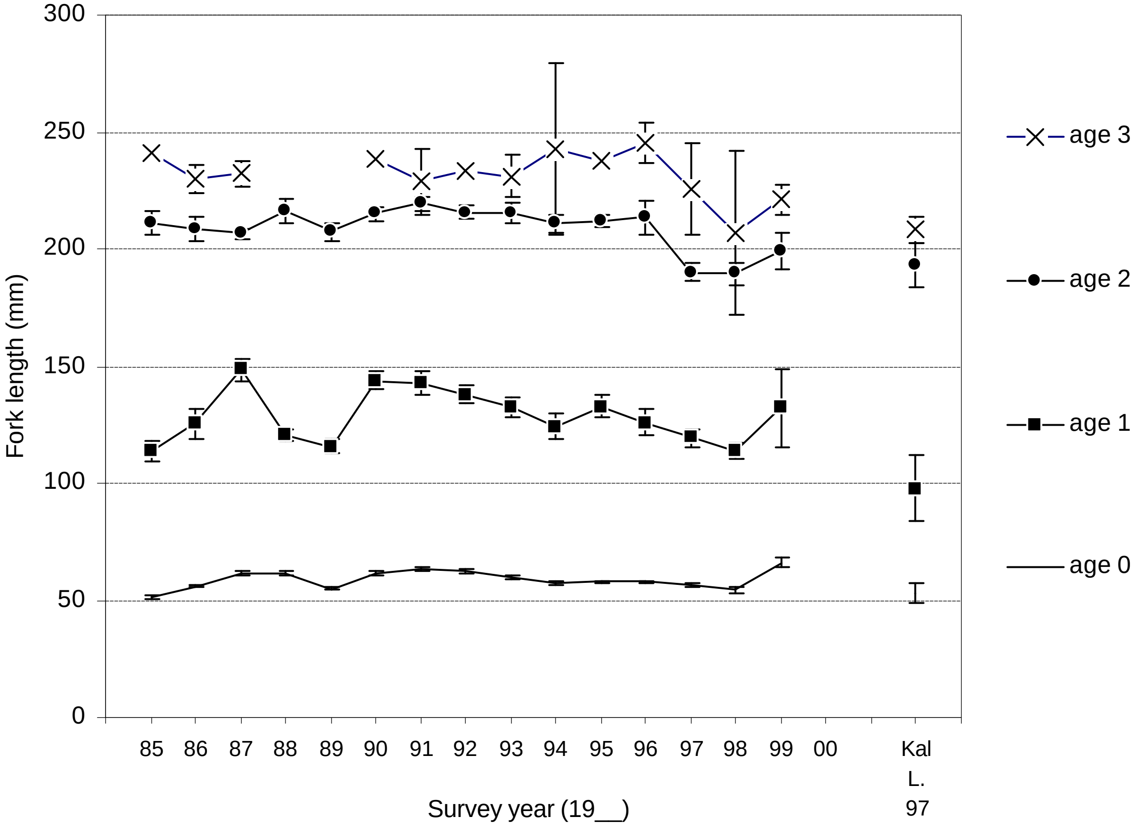

Figure 7. Kokanee mean fork length-at-age for Okanagan Lake adjusted to October 1 based on trawl sampling, 1985 to 1999. Note: limited length-at-age results for Kalamalka Lake in 1997 are included.

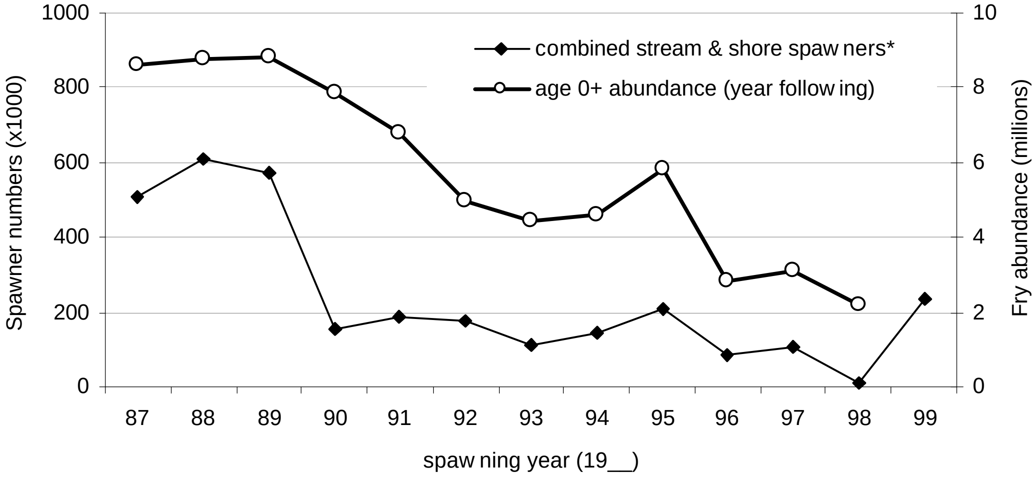

Figure 8. Trends in spawner returns and following year fry populations in Okanagan Lake based on spawner counts and acoustic surveys, 1987 to 1999.

OKANAGAN LAKE KOKANEE BIOLOGY

by

H. Andrusak[1] and D. Sebastian[2]

INTRODUCTION

Over the last fifty years there have been a number of problems associated with Okanagan Lake and its fish populations. In an area that has a very dry climate, 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 have constantly been threatened. Anglers and fisheries biologists have observed a gradual decline of Okanagan Lake fish population size since the 1960s. Most of the observations have been made on kokanee since this species is not only an important sport fish but also a key food source for several other species of fish.

Clemens et al. (1939) conducted the first scientific survey of fish in the Okanagan area. During this pioneer work the question of mysid introduction into Okanagan Lake was raised to improve lake whitefish (*Coregonus clupeaformis*) growth. In the mid 1950s Northcote and Larkin (1956) described the limnology of Okanagan Lake. After this initial work there was little effort directed toward Okanagan Lake kokanee until the late 1960s. In the meantime, a better understanding of British Columbia kokanee biology had been gained through some classic work by Vernon (1957) on Kootenay Lake kokanee; Lorz and Northcote (1965) on Nicola Lake; the early work on *Mysis relicta* and kokanee interactions on Kootenay Lake by Zyblut (1967); and Northcote (1973).

In terms of quantitative information useful to Okanagan Lake fisheries managers, kokanee investigations and subsequent literature increased dramatically with the advent of the *Canada - British Columbia Okanagan Basin Agreement* in 1969. In accordance with that agreement, a series of studies (Anon 1973; and Marr et al. 1974) were undertaken to plan the integrated development and management of water resources in the Okanagan Basin. Fisheries studies conducted during this initiative were the foundation on which future fisheries-oriented activities were based. For example, routine monitoring of kokanee annual spawning escapements began in the early 1970s as part of the Okanagan Basin Studies. Fortunately, in the early 1970s, Northcote et al. (1972) and Smith (1978) collated some of the early data on Okanagan Lake kokanee.

OBJECTIVES OF REPORT

A considerable amount of information is available in various forms in government files and published literature on Okanagan Lake kokanee. There is however, no one single document available that summarizes key biological data important to their management. This report

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attempts to describe the methods and summarize key, relevant kokanee data. By no means has all the data been summarized, but it is believed that the most pertinent data has been included in this report.

The purpose of this report is to:

a) summarize available, reliable, and relevant data on Okanagan Lake kokanee; and
b) provide a summary table of key data to serve as biostandards for Okanagan Lake kokanee for a future stock assessment report.

BACKGROUND

Early fisheries work (1950s and 1960s) on Okanagan Lake focussed on rainbow trout and to a lesser extent on kokanee. The work of Northcote et al. (1972) initially set the stage for a more comprehensive examination of kokanee because lack of quality spawning habitat was identified as being problematic. In the late 1970s, funds were provided to implement some recommendations of the Okanagan Basin Study Program. By this time, it was apparent that kokanee abundance might be in decline, although the extent was not clear nor the reason(s) why. This funding allowed fisheries staff to test enhancement initiatives such as releases of kokanee from the Skaha Hatchery and rainbow trout from a semi-natural rearing pond on Mission Creek. Some of the attempts to enhance kokanee inadvertently led to the conclusions as to why Okanagan Lake fish are in such peril today.

During the early 1980s, the federal-provincial Salmonid Enhancement Program (SEP) raised public interest and involvement in enhancement projects including some on Okanagan Lake. With such an expansion in activities, an improved database was required to store the increasing volume of data. The need for planning also became evident in order to make best use of limited budgetary resources. A five-year (1980-1985) fisheries management plan was drafted for the Okanagan main valley lakes (Anon 1980), followed by a kokanee management plan for the main valley lakes (Harper 1985). A management plan specific to Okanagan Lake kokanee for the 1988-1995 period was drafted by Bull (1987) and revised by Shepherd (1990) for the 1990-1995 period.

Data collection efforts have focused on Okanagan Lake due to some milestone events including the following:

- In 1966, the provincial Water Resources Service proposed a diversion of water for agricultural purposes from the Middle Shuswap River into the North Arm of Okanagan Lake; both provincial and federal fisheries agencies had strong concerns regarding such a project (Anon 1969).

- Public concern over pesticides and mercury (leading to a partial ban on human consumption of trout) in the late 1960s.

- Additional federal attention was captured with the occurrence of algal blooms in Okanagan Lake in the late 1960s, which probably spurred signing of the *Canada - British Columbia Basin Agreement* and resulted in study focus on Okanagan Lake.

- Following completion of the Okanagan Basin Studies, a regional fisheries management statement was prepared that addressed increasing angling pressure and concluded that the large lakes offered "...the only hope for absorbing large increases in effort" (Bull 1987). Okanagan Lake, being by far the largest lake in the basin, was seen to have the greatest potential and thus remained the focus of large-lake fisheries studies.

- In the early 1990s, the provincial Fisheries Program priorities shifted from meeting angler demand to conserving and protecting wild fish stocks and their habitats. Due to the very rapid growth in human population in the Okanagan Valley habitat protection had already become the priority and, once again, effort focused on Okanagan Lake and its tributaries because of the concentration of human development pressures along these waterways.

- From data analyses in the most recent management plan (Shepherd 1990) and creel census report (Shepherd 1994) it was concluded that Okanagan Lake kokanee production was in serious decline.

- Initiation and creation of the Okanagan Lake Action Plan (OLAP) in 1996.

Formation of the OLAP occurred as a result of public and government concern for the conservation of Okanagan Lake kokanee. A workshop held in 1995 between fisheries experts, public representatives, engineers and limnologists resulted in the comprehensive, long-term plan initially described by Ashley and Shepherd (1996) to address all the fish related problems in Okanagan Lake. The workshop reviewed changes to the lakes' water quality, nutrients, plankton, kokanee and rainbow populations. A key finding was that most of the decline in kokanee numbers could be attributed to a reduction in nutrients, spawning habitat and or competition from mysids (Ashley et al. 1999).

This report is written to assist meeting the long-term objective of the OLAP of rebuilding and maintaining the biodiversity of the wild kokanee stocks in Okanagan Lake.

SITE DESCRIPTION

Dominating the Okanagan Valley is Okanagan Lake located in the southern interior of BC near the 49th parallel positioned in a north-south axis between the Monashee and Cascade mountain ranges. The lake is located entirely within the warm, dry southern interior and receives an average annual precipitation annually of only 315 mm (Ward et al. *in* Ashley et al. 1999). The lake is approximately 135 km long, but only 4-5 km wide with a surface area of about 35,112 hectares. Despite this size the lake has a maximum depth of 242 m and a mean depth of only 76 m. Figure 1 illustrates the longitudinal profile of the lake that is divided into three basins created by underwater sills located at Squally Point and at the site of the Kelowna Bridge.

The lake is not fed by a major river system with inflow coming from very few tributary streams of any size. The Okanagan River flows out of the south end of the lake near Penticton, British Columbia into Skaha Lake, then south through Osoyoos Lake and eventually joins the Columbia River in northern Washington. At the outlet located near Penticton is a small dam that effectively regulates the lake between elevations 341 m to 342.5 m (Ward et al. *in* Ashley et al. 1999 for more detail). The average throughflow of water is relatively small because of the arid climate of the Okanagan Valley hence low annual runoff. Lake residence time has been calculated at 52 years (Shepherd 1990).

Several authors in Ashley et al. (1999) have described the lakes' physical and chemical attributes. The lake is oligotrophic although the extreme north end is considered mesotrophic (Bryan 1990). Key limnological attributes (Northcote and Larkin 1956; also McEachern (*in* Ashley et al. 1999) relative to understanding kokanee distribution and abundance include:

- productivity index (TDS) of about 165;
- thermal stratification is well established by July with surface temperatures often exceeding 20º C and the thermocline usually @ 15-20 m;
- dissolved oxygen profiles are typical of oligotrophic lakes with hypolimnion water well oxygenated;
- Armstrong Arm located at the north end of the lake is very different limnologically from the remainder of the lake. This basin is shallow (maximum depth of 54 m) with the hypolimnetic waters having oxygen concentrations of <1 mg L^{-1} in the fall months (McEachern *in* Ashley et al. 1999);
- secchi disk transparency readings range from 2-10 m with the lowest recordings in Armstrong Arm; and
- very low flushing rate with lake residence time ~52 years.

Stocking History

Historical stocking records of kokanee date back to the late 1920s and early 1930s when fry and eyed egg plants were initiated into Okanagan Lake at Summerland and Eneas Creek (Appendix 1). These fish came from the Nelson hatchery and the egg source was from the West Arm of Kootenay Lake. In the 1940s and 1950s, Meadow Creek stock (North Arm stock, Kootenay Lake) was used extensively for eyed egg plants directly into Okanagan Lake and in several Okanagan Lake tributaries. In the 1970s and early 1980s, fry of Meadow Creek origin were planted in large numbers in Mission and Penticton creeks. In the late 1980s and early 1990s, fed fry from Mission Creek stock were planted in Mission and Penticton creeks. The impacts of these introductions are unknown.

Impacts on Kokanee Habitat

There are several important factors that have affected kokanee numbers in Okanagan Lake and these have been summarized in numerous papers including Shepherd (1994, and Ashley et al. (1998). No attempt is made in this report to describe all the impacts. At this point in time, the most important factor has probably been the introduction of *Mysis relicta* into Okanagan Lake in 1966. The result of this introduction has negatively impacted on kokanee due to competition for preferred zooplankton between mysids and kokanee juveniles (Ashley et al. 1998). However, this single event does not diminish the significant degradation of stream habitat due to urbanization and agriculture that clearly has negatively impacted kokanee stream production. Total removal of all water from some spawning streams, extremely low flows in others, and or complete channelization of most of the lower reaches has rendered the majority of the tributaries today virtually unusable by spawning kokanee. The timing of lake drawdown during winter and early spring has negatively impacted shore spawning success. More detail on impacts to stream and shore habitat can be found in Ashley et al. (1998; 1999).

METHODS

Data on Okanagan Lake fish can be found in numerous files in the Penticton office, but it was generally collected in an ad hoc fashion and much of it is of limited value for comparison purposes. Northcote et al. (1972) organized the best historic data on Okanagan Lake kokanee and a more systematic approach to data collection followed thereafter. In the late 1980s, Okanagan fish and fisheries information were consolidated into computer databases on boat counts (BOATSP.dbf), catch success (OKCREELP.dbf), fish samples (OKFISHP.dbf), and enumeration of stream and shore spawning kokanee runs (KO_ENUMP.dbf and KO_SHORE.dbf, respectively). These databases are now updated annually and are the primary source of Okanagan Lake fisheries management data. For example, by the end of 1998 the OKFISH database had some 14,474 entries on lengths of Okanagan Lake kokanee (Appendix 2). Most of these databases were used extensively in the preparation of this report. Good summaries of the sport fishery and kokanee management plans can be found in Shepherd (1990; 1994).

Stream Escapement Estimates

Over the past thirty years, stream escapement estimates have been refined into a routine enumeration program usually conducted by an experienced two person field crew. Estimates before the 1980s are less reliable since single counts were often conducted and the peak of spawning was probably missed. Commencing in the second week of September and continuing to the end of October, stream reaches known in past years to support significant numbers of kokanee spawners were walked every 10 days (reducing to 5 days when close to the peak of spawning), to count live and dead spawners. The survey route was broken into stream groupings on the basis of: run timing, geographic, and access logistics. An example from the 1997 survey methods detail the stream groupings, timing, and amount of habitat surveyed (Table 1).

The enumeration schedule used in the 1990s was further modified in 1999 to provide more intensive coverage of the higher use tributaries and reduced coverage on the lower use streams. More specifically, Mission, Powers, Peachland, Penticton, Trepanier and Kelowna creeks have been counted every three days during the spawning period. Previously, counts were conducted on 5 day intervals, but concerns were raised that the peak escapement count may be missed. Counts during the lower use spawning periods (early and late in migration) were not conducted since the data is not necessary for determining spawner numbers provided the peak count is obtained. The remaining tributaries, which support less than 5% of the total escapement, were counted only once, at the predicted peak based on run timing in adjacent tributaries.

Table 1. Kokanee stream spawner survey plan (1997) and accessible stream length for Okanagan Lake tributaries.

Grp.	Stream	Initial Survey Date	Subsequent Dates	Site Descriptions for annual surveys sections (accessible length if diff.)	Length Surveyed (km)	Number of Reaches	Accessible Length (km)
1	Mission	Sept 9	Sept 19, 24, 29; Oct 9	Lake to Hollywood Road (to Gallagher falls)	12.0	7	18.9
	Spawning channel			Spawning channel	0.9	1	0.9
	Kelowna	Sept 9	Sept 19, 24, 29 Oct 9	Lake to Spall Road[1]	5.0	6	5.0
2	Peachland	Sept 10	Sept 20, 25, 30 Oct 5, 10	Lake to Hardy Falls	1.2	1	1.2
	Trepanier			Lake to Falls	1.3	1	1.3
	Powers			Lake to Falls	2.6	6	2.6
	Lambly			Lake to Falls	1.2	2	1.2
3	Naramata	Sept 11	Sept 21, 26; Oct 1, 11	Lake – Highway culvert	2.4	1	2.4
	Penticton			Lake to Wade Ave. Bridge[2]	1.0	2-3	3.0
	Eneas			Lake to upper access limit	0.6	1	0.6
	Prairie Valley			Lake to upper access limit first culvert	0.1	1	0.1
4	Middle Vernon Cr.	Oct 3	Oct 11	Lake to Beaver Lake Road (Wood Lake to Duck Lake)	4.0	3	5.5
	Winfield			Wood Lake to upper access limit	1.0	1	1.0
	Vernon			Okanagan Lake to Kalamalka Lake	8.0	5	8.0
	Coldstream			Kalamalka Lake to Coldstream Ranch	5.0	2	5.0
	Shorts			Lake to upper access limit	1.2	1	1.2
	15 streams			Total surveyed	47.5		57.9
	Equesis	NS[3]		Lake to barrier			4.8
	Whiteman	NS[3]		Lake to irrigation structure			0.8
	Nashwito	NS[3]		Lake to irrigation structure			2.6
				Total not surveyed			8.2
Total	18 streams						66.1

1. Kelowna (Mill) Creek has no definite barriers. It may be accessible for up to 16km (near airport), but not used as a result of poor habitat quality and low numbers of fish (Wightman 1978).
2. The only spawning habitat in Penticton Creek has been created at upper end of the 'accessible' section, however, it is not known if kokanee can access this habitat without man's intervention.
3. First Nations Reserve land streams were not surveyed annually; accessibility based on Tredger (1976).

Where multiple reaches are involved, the two-person survey crew splits up along the reaches thus each reach is surveyed by one crew member only. On each survey date, the numbers of live and dead kokanee spawners are counted, and the water temperature taken at reach ends with a pocket thermometer (± 0.5°C).

Numerous sources of error exist for stream escapement estimates. Certainly, weather, flow and water clarity conditions are highly variable. Obtaining the peak count of spawning numbers can be difficult unless the stream is monitored at least weekly and preferably more frequently; small numbers of fish are probably easier to count compared to very large numbers. The expansion factor described below also assumes a normal distribution. Despite these possible short comings stream escapement data can, at the very least, be used as an index of abundance for trend analysis.

There are a number of other streams known to support kokanee spawning that have not been included in the routine annual surveys for the following reasons:

(1) Insignificant counts - small streams such as Thompson Brook, and Bellevue, Fascieux, and Brandt creeks are often reported by the public to have kokanee spawners in them, but the numbers are normally quite low (less than a few hundred fish in total). The additional effort to survey these systems has been deemed to be cost-ineffective.

(2) Chronic low flows and associated habitat problems - Trout Creek, although a much larger watershed than the systems mentioned in (1), suffers from chronic low flows and high water temperatures due to major water withdrawals. As a consequence, only a few kokanee have been observed, and only in years when flows are higher than usual thus routine survey of Trout Creek has also been discontinued.

(3) Access limitations - larger streams located on First Nations Reserve lands (Equesis, Nashwito and Whiteman creeks on the west side of the North Arm of Okanagan Lake have been surveyed only periodically due to difficulties in obtaining access permission from the Bands. Two years of spawner surveys conducted on the North Arm streams in 1995 and 1996 suggests inclusion of these creeks in the annual counts would increase the total stream spawning run estimates for Okanagan Lake by about 5-6%.

The upper reaches of Mission Creek are now routinely checked only once (at the approximate peak of spawning) during the annual surveys. This reduction in effort was due to consistently low utilization by spawners over a considerable distance. In some years, stream bank counts were either augmented or replaced with counts from aircraft that were basically to verify continued low usage.

The expansion factor used to adjust the peak count to an estimate of total number has recently been reanalyzed because of previous use of a range of conversion rates. Data from Mission, Hill, Bridge and Redfish creeks was used (Appendix 3) to ascertain the appropriate conversion rate (Redfish Consulting Ltd. 1999). A regression of peak counts (cumulative count to single day peak count) on known total counts produced a conversion factor of 1.5 ($r^2 = 0.90$; $n = 25$). All Okanagan stream counts have been readjusted from original peak count in the database to reflect the 1.5 conversion factor (Table 2).

Table 2. Okanagan Lake kokanee stream spawner count estimates (Note: adjusted by a factor of 1.5)

Stream	1971*	1974	1975	1976	1977	1978	1979	1980	1981	1983	1984	1985	1986
Mission Creek	312,000												
Mission Creek Ch.													
Total Mission Cr.	**312,000**	**136,304**	**40,435**	**31,956**	**33,913**	**90,652**	**117,391**	**78,261**	**61,957**	**37,500**	**76,220**	**98,625**	**84,000**
Powers	7,943			1,741	2,935	5,869	9,783	9,783	7,826	3,390	14,543	22,109	8,152
Peachland	22,650	3,000	3,495	430	978	1,300	3,913	4,565	3,300	1,826	3,930	7,957	4,557
Penticton											75	1,260	1,500
Trepanier	8,700			1,300	0	1,956	600	3,913	600	1,857	4,845	4,943	1,826
Lambly											1,730	1,740	1,239
Naramata													
Mill											2,376	3,140	3,678
Total	**351,293**	**139,304**	**43,930**	**35,427**	**37,826**	**99,777**	**131,687**	**96,522**	**73,683**	**44,573**	**103,719**	**139,783**	**104,952**
Shore Index	520,000	730,000			543,000	55,000	110,000	180,000	215,000	57,000	5,000	30,000	20,000

Stream	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Mission Creek			13,044	16,304	61,500	41,153	20870	12,783	7,043	14,804	8,283		
Mission Creek Ch.			4,565	3,913	14,022	23,478	9,783	3,783	3,261	7,826	3,653		
Total Mission Cr.	**16,200**	**21,525**	**17,609**	**20,217**	**75,522**	**64,631**	**30,653**	**16,566**	**10,304**	**22,630**	**11,936**	**1,735**	**1,613**
Powers	12,653	6,913	4,630	8,543	11,674	13,500	8,478	8,807	6,000	4,304	2,739	722	611
Peachland	6,315	6,360	4,065	5,283	5,087	11,413	7,826	5,283	3,703	3,261	2,087	1,587	1,658
Penticton	2,019	345	6,285	8,413	2,935	1,696	1,304	7,761	7,826	4,239	2,217	2,661	1,554
Trepanier	477	2,609	1,701	652	1,043	1,630	2,609	261	652	1,957	1,043	26	455
Lambly	1,043	848	261	261	913	65	0	1,500	65	65	65	5	8
Naramata			3,913	705	864	399	1,304	522	848	783	587	18	138
Mill	3,068	1,712	1,959	3,087	0	1,103	0	1,826	717	783	527	435	246
Total	**41,775**	**40,312**	**40,423**	**47,161**	**98,038**	**94,437**	**52,174**	**41,806**	**30,115**	**38,022**	**21,201**	**7,189**	**6,283**
Shore Index	155,000	190,000	176.000	36,000	30,000	25,000	20,000	35,000	59,000	16,000	19,000	1,000	77,000

* From Northcote et al (1972)
All other data from ko_enum except 1997-1999(hard copy from Penticton office)

Water temperatures were recorded for all streams at the time of each count using a pocket thermometer (± 0.5° C). Commencing in 1999, continuous temperature recorders were placed in most of the important spawning streams to record temperature throughout the spawning and incubation period (see Kirk in this OLAP). Up to 50 fresh carcasses or moribund fish (where available) were collected from Mission, Powers, Penticton and Peachland creeks and analyzed for nose fork length, sex, age (otolith), fecundity and egg retention. Data collected in all years has been entered to the fisheries OKFISHP database (on file, Penticton Office).

Shore Spawning Escapement Estimates

Counts of kokanee spawning along the shoreline of Okanagan Lake have been made from various provincial government fisheries boats since 1971. The standard method has been to run a boat parallel to the shoreline at 800-1200 RPM along the 3-4 m depth contour. The numbers of spawners inshore of this point were estimated visually by MELP Fisheries staff with previous survey experience. Estimates were made separately for reaches designated by landmarks on aerial photographs, and then, summed by quadrant as outlined in Table 3.

Table 3. Shoreline habitat reach descriptions. Note: reach numbering runs counterclockwise, beginning in the SE quadrant.

Quadrant Name	Quadrant (Reach) Boundaries	Reach No's[1]
SE (southeast)	Penticton to Kelowna Bridge (Commando Bay to Lebanon Cr)	1 - 22a
NE (northeast)	Kelowna to Armstrong Arm (Alder Pt to opp. Nashwito Cr)	23 - 49b
NW (northwest)	Armstrong Arm to Kelowna Bridge (Whiteman Cr to Trader's Cove)	50 – 77
SW (southwest)	Kelowna Bridge to Penticton (Gellatly to Peachland)	78

[1] Details of location of reach numbers can be found in Wong (*in* Ashley et al. 1998) and Figure 1 of Thompson (*in* Ashley et al. 1998).

Reaches were only given numbers if kokanee spawning had been observed there during the Okanagan Basin studies in the 1970s (see details in Northcote et al. 1972). Numbered reaches not known to support shore spawners prior to 1988 were at most spot-checked in subsequent years; for example, only a small section of the SW Quadrant (Kelowna Bridge - Penticton) was checked, and only in 1997. Local residents within this quadrant continue to report the presence of shore spawning kokanee, but the small numbers involved do not warrant annual enumeration.

Surface water temperatures were measured to the nearest 0.5^0C (±) at the ends of reaches using a bucket and pocket thermometer, except in 1996, when a hull mounted thermistor measured surface water temperatures to the nearest 1.0^0C. The time at which the reaches were sampled was recorded, along with comments on weather, wave and visibility conditions.

In most years, counts routinely began in the SE Quadrant (Squally Point - Bertram Creek area) in the third week of October. Prior to the first count, reach 22 (Squally Point area consistently has high numbers of kokanee) was checked either by boat or aircraft until spawners were sighted. In recent years, waterfront residents and Okanagan University College (OUC) researchers also advised MELP staff when kokanee were first observed at Bertram Creek Park near Kelowna. Annual enumeration began shortly following the first kokanee sighting and continued each week until it was obvious that numbers had peaked and were declining, usually by early November.

Shoreline enumerations by boat in most years have been supported by visual observations made by experienced MELP Fisheries observers using fixed-wing aircraft. These flights were used to verify general spawner distributions throughout the lake, confirm low or nil numbers in stretches not surveyed by boat, and also to direct subsequent boat surveys to the areas utilized by spawners.

An exception to this standard procedure occurred in 1997 due to a rapid onset and completion of spawning in the SE Quadrant. Spawning was complete before boat counts could be conducted. An estimate was developed using the peak count recorded by the OUC researchers at Bertram Creek Park on October 16, expanded by the proportions of fish observed during a fixed-wing survey of the Bertram Creek site as well as the rest of the SE Quadrant on October 17. In this year, greater use was made of fixed-wing flights concurrent with the boat counts, in order to maximize the amount of boat time spent surveying reaches that actually contained spawners. Consequently, the SE Quadrant was surveyed by boat only twice, the NE and NW Quadrants were surveyed four times (but a complete survey of each quadrant was done only once), and the SW Quadrant was not surveyed at all by boat.

Peak estimates determined for each quadrant were summed to produce a total peak estimate for the year. Sources of error in estimating shore spawners are even greater than those described for stream spawner estimates. Over the years of record, temporal and spatial coverage as well as the quality of shore counts have been significantly affected by weather conditions, especially wave action. In some years, quadrant counts were incomplete for all reaches at the estimated peak date, and were adjusted using the proportions observed between reaches on the closest days that complete counts were made. Thompson (*in* Ashley et al. 1998) reviewed the methods employed over the years and discusses the biases inherent in the methods. The value of the shore counts is currently as an index of abundance and not an estimate of total spawner numbers.

Sebastian and Scholten (*in* Ashley et al., 1999) have attempted to estimate total number of shore spawning kokanee using the shore spawning index. A number of iterations were applied using different expansion factors to the shore counts then compared to the <u>combined</u> stream and shore spawner estimates and resultant fry estimates determined from ten years of hydroacoustics data (see Sebastian and Scholten (*in* Ashley et al., 1999). Using an expansion factor of 3.5 results in a good correlation between total combined spawner estimates and the resulting fry population estimate in 9 of 10 years of record (data on file Ministry of Fisheries, Victoria BC). This expansion factor will be useful for estimating total kokanee population size in Okanagan Lake.

Biological Data Collection

Fish lengths

Nearly 15,000 Okanagan Lake kokanee lengths have been recorded between 1943-1998 (Appendix 2). Some of this data has been collected from creel census but most was collected approximately one week following the peak of live stream counts, and coincident with the peak of die-off for each stream. A minimum of 50 fresh carcasses and/or moribund spawners was sampled by using dipnets, seines, or carcass fences (Table 3). In some locations and years, dead pitch samples were augmented with live spawners captured by seine or fence trap. Nose-fork lengths (hereto referred to as "lengths") were measured (±1 mm), and fish were then sexed and checked for hatchery marks.

Methods most commonly used to collect spawners were deadpitch (retrieval of fresh carcasses or moribund spawners), dipnetting or seining of live fish and trapping of incoming migrants below spawning areas. The most consistently recorded data is from Mission Creek summarized by method of capture in Table 4.

Table 4. Number of kokanee lengths sampled by method for Mission Creek and channel 1986-1999.

Year	Dipnet	Deadpitch	Seine	Trap	Total
1986			100		100
1987			201		201
1988			100		100
1989			50	47	97
1990		369	50	168	587
1991		483	113		594
1992		921			921
1993		398			398
1994		508	137		645
1995		284			284
1996		235			235
1997		327			327
1998	17	32			49
1999		70			70
Total	**17**	**3,627**	**751**	**215**	**4,610**

In most years since 1987 approximately 50 shore spawners per year have been sampled by beach seine for biological characteristics. Usually seining was done at Squally Point, but additional samples were taken at Carr's Landing in 1989 to determine if biological characteristics varied with location. Low spawner numbers in the late 1990s resulted in fewer samples being taken but were collected by Taylor and Pollard (*in* Ashley et al. 1999) as part of the genetics work. These fish were also seined.

Table 5. Number of Okanagan Lake shore spawners sampled and method.

Year	Deadpitch	Seine	Trapped	Total
1987		100		100
1988		100		100
1989	39[1]	100		139
1990		241		241
1991		50		50
1992		49		49
1993		53		53
1994		104		104
1995			49[2]	49
1997		79		79
1998		0		0
1999		?		0
Total	**39**	**876**	**49**	**964**

[1] Suspected to be stream spawners due to large size.
[2] From Dill (*in* Ashley et al 1998).

It should be noted that during the course of data analysis it was found that size of deadpitched spawners was significantly larger than seined or dip netted fish in five of seven cases (B. Shepherd, DFO, Prince Rupert, pers comm.). Size of trapped fish was also larger than the seined fish. Fish measured from deadpitch and live trap samples have been the standard method used to measure stream spawners except for the 1986-1989 period. Only 754 of 14,492 measurements were recorded from seined fish therefore this is not considered a major problem when analyzing length frequency data trends over time. This is problematic only when attempting to compare shore and stream spawner size since the majority of beach spawners have been captured by seine net (Table 5) while virtually all stream spawners have been measured from dying (dead) fish and or trapped fish through fence operations.

Fecundity

Egg counts of Okanagan Lake kokanee have been made from individual mature females for many years. If the female was partially spawned prior to death, the number of eggs was counted to determine egg retention. If it was judged that the female had died without spawning (usually indicated by the eggs still remaining in skeins), then the egg counts were used to determine fecundity. All such data has been entered into the database. One weakness of the Okanagan Lake data is the surprisingly few egg counts from mature females that had not begun to spawn, i.e., egg counts from female fish with eggs still in the skein are limited to 104 of the ~7000 females sampled.

Age determination

Until 1995, the method of choice for age determination was through scale samples. Slime was cleaned from the "preferred area" 2-3 scale rows above the lateral line, and between the posterior insertion of the dorsal fin and the anterior insertion of the anal fin. A scale patch was then removed by scraping 2-3 scale rows within this area. Scale samples were placed into envelopes, dried and read using a microfiche reader-printer. Scale sampling was discontinued in 1996 because of uncertainty in reading older (spawners) fish scales. Commencing in 1997, otoliths have been taken and used for age determination.

Over the last ten years, age determination using scales from trawl caught kokanee has been conducted by several contractors (D. Sebastian, Ministry of Fisheries, Victoria, BC, pers comm.). Otoliths were taken from all age groups of the trawl samples in 1997 and 1999 in an attempt to resolve the age of mature fish. A catalogue of otolith images is currently being developed which will show the full range of otolith features of Okanagan Lake kokanee for each age group from 0+ to spawners. This should ensure consistent (future) interpretation of age at spawning.

In-lake kokanee sampling

Since 1988, a routine monitoring program has been conducted on Okanagan Lake involving a combination of hydroacoustic and trawl net surveys. This work has been summarized and reported by Sebastian and Scholten (*in* Ashley et al. 1999) and the best overall data on Okanagan Lake kokanee abundance, numbers, growth and age structure can be found in this report. This present report on Okanagan Lake kokanee biology relies extensively on data interpretation from the trawl results particularly for age and growth information.

DATA ANALYSIS AND DISCUSSION

Stream Spawning Timing

Generally, spawning kokanee initially appear in the streams in late August with the peak of spawning occurring in the last week of September or first week of October. The more intensive daily surveys conducted on the Mission Creek spawning channel (Andrusak *in* Ashley et al. 1999) agrees well with the general run timing data. The channel data indicates the average peak count date for eight years falls on September 26 (range September 18 to October 06). The average date of first entry of fish into the channel has been September 3rd (range August 31 to September 11), and live fish were still present at the end of October and extending past mid-November in one year. Okanagan Lake kokanee run timing is similar to those observed in tributaries to Arrow Reservoir and the main part of Kootenay Lake. For example, the peak of spawning at Hill and Meadow spawning channels is usually the third week of September.

There appears to be a trend towards later peaks for those tributaries in the northern part of the Okanagan system (Table 6). The reason for such a trend is not obvious, but may be related to water temperature regimes even though Lorz and Northcote (1965) felt stream temperature was not a factor in onshore movement of spawning kokanee in Nicola Lake. Burger et al. (1995, 1997) examined run timings of sockeye populations that spawned in lakes, outlet rivers and tributary streams found that tributary stocks generally spawned earlier than lake and outlet spawning stocks. This suggests the timing differences were largely the result of moderated temperature regimes in both lakes and lake outlets. Similar to Okanagan Lake, kokanee enter streams in the southern basins of Kootenay Lake and Arrow Reservoir at least a week earlier than the northern basins. It is believed decreasing temperatures must be a trigger for movement of spawners into streams. For Okanagan Lake tributaries the question of temperature vs. timing will likely be answered since continuous temperature data recording on key streams commenced in 1999 (see Kirk in this OLAP report).

Table 6. Dates of peak live counts of kokanee spawners in Okanagan streams.

Name of Stream	Years on Record	Average Peak Date	Earliest - Latest Peak Dates (Year)
Powers	15	Sep 27	Sep 22 (91) - Oct 06 (83)
Penticton	14	Sep 27	Sep 23 (91, 92) - Oct 05 (87)
Mission	15	Sep 29	Sep 21 (89, 91)- Oct 09 (94)
Peachland	15	Sep 30	Sep 20 (92) - Oct 09 (84)
Trout	02	Oct 01	Sep 26 (84) - Oct 06 (83)
Lambly	13	Oct 02	Sep 24 (92) - Oct 20 (87)
Naramata	09	Oct 02	Sep 25 (90) - Oct 11 (94, 95)
Eneas	13	Oct 03	Sep 20 (92) - Oct 20 (87)
Vernon	13	Oct 03	Sep 23 (87) - Oct 13 (93)
Whiteman	02	Oct 03	Sep 29 (92) - Oct 10 (85)
Prairie Valley	08	Oct 04	Sep 11 (95) - Oct 15 (86)
Kelowna/Mill	11	Oct 05	Sep 24 (92) - Oct 15 (86)
Trepanier	15	Oct 05	Sep 25 (92) - Oct 19 (94)
Equisis	02	Oct 07	Oct 04 (92) - Oct 10 (85)
Shorts	08	Oct 08	Sep 27 (97) - Oct 18 (95)
Nashwito	01	Oct 09	(92)

Stream Escapements

As previously mentioned, there are very few streams that have year round flows into Okanagan Lake and all of them have been adversely impacted by agriculture, urban development and or linear development. The number of streams that support spawning kokanee are less than twenty and only twelve support annual escapements >500. These streams are relatively small and in total there is less than 70 km of suitable spawning habitat (Table1). The most important stream is Mission Creek followed by Powers, Peachland, Penticton, and Trepanier creeks.

Results of stream counts prior to 1983 are somewhat questionable since a systematic method of counting was not employed and the database often indicates the peak of spawning had occurred prior to single counts. The exception to this was the work by Northcote et al. (1972) when a total count from a fish fence was made on Mission Creek and visual peak count estimates were determined on other streams using the methods previously described. Peak stream estimates for 1971 (Appendix 3, *in* Northcote et al. 1972) have been converted using the 1.5 factor for comparative purposes, as have all other years when counts were made (Table 2). Clearly, stream escapements have been trending downward over the three decades when estimates have been made (Fig. 2). Until the late 1990s Mission Creek supported the largest number of spawners. In 1998 and again in 1999 the estimated number of kokanee in Mission creek fell to dangerously low levels (<2,000) with smaller Peachland and Penticton creek escapements actually slightly higher.

Anecdotal information in file reports and from Shepherd (1990) suggest that stream escapements were probably considerably < one million prior to the 1970s. This "guestimate" is only about half of estimates made for similar sized Arrow Reservoir (Sebastian et al. 1999) and Kootenay Lake (Andrusak and Brown 1987) where shore spawning is negligible. The comparatively lower Okanagan Lake stream spawners estimate is perhaps quite reasonable. It is most likely that shore spawners were always the dominant group given the paucity of any large streams that flow into the lake. As noted earlier, preliminary analysis by Sebastian and Scholten (in Ashley et al 1999) indicates actual number of shore spawners may be at least 3.5 times larger than the peak counts determined from the boat survey counts. If this holds true with the addition of more data then the shore spawning component probably was always been 3-4 times larger than stream spawning numbers. The conservative estimate of 0.5M shore spawners by Northcote et al. (1972) adjusted by a factor of 3.5 places the possible range of shore spawning numbers at ~1.7 M. This number combined with an estimated <1M stream spawners, compares with Arrow and Kootenay lake estimates.

Total escapements for Okanagan Lake in the 1970s appear to have ranged from ~300,000-850,000 and then declined in the 1980s to less than ~100,000 and in the 1990s the numbers have further declined from ~100,000 to less than 20,000 with the notable exception of 1999.

Shore Spawning Timing

A unique feature of Okanagan Lake kokanee is that a large component of them spawn on certain preferred beach sites. Taylor et al. (*in* Ashley et al. 1999) have reported on genetic differences between the shore and stream spawners in Okanagan Lake and their techniques are now being used to differentiate the two stocks from trawl caught fish. Using this technique, Pollard (in this OLAP report) found the 1998 trawl sample to be predominately shore spawning fish but the 1999 sample was primarily of stream origin. Small sample size was problematic for Pollard's initial testing of this technique and therefore further work is warranted.

Beach spawning usually begins in early October with peak of activity occurring in the third week and completion by the first week of November. This is nearly a month later than the stream spawners and suggests some racial separation between the two spawning populations. However, Taylor et al. (in Ashley et al., 1999) studied in laboratory conditions egg developmental rates of stream and shore spawning ecotypes and found no difference in time to hatching. Egg development of later spawning beach spawners simply accumulated more heat units over the winter months compared to eggs deposited in streams with much colder water over the winter months.

Dill and Taylor and Dill (*in* Ashley et al. 1998) have studied shore spawning behavior in some detail and their observations confirm the general period of peak spawning occurs in the latter part of October. Dill and Taylor (*in* Ashley et al. 1998) suggest the spawners prefer water depths of only 0.25-0.5 m along the shoreline. Kokanee in Coeur d'Alene Lake spawn on 3 km of beach in depths up to 20 m while those in nearby Lake Pend Oreille spawn in a narrow depth zone of about 1-1.5 m (N. Horner Idaho Fish and Game biologist, pers comm.). Beach spawning kokanee in these two Idaho lakes spawn very late (mid November through to early January), compared to Okanagan Lake shore spawners.

Shore Spawning Estimates

As noted earlier it has not possible to determine total numbers of shore spawning kokanee from visual counts. The recent work of Sebastian and Scholten (*in* Ashley et al 1999) suggests an expansion factor of 3.5 should applied to the total peak count in order to obtain an estimate of shore spawner abundance. The value of the shore peak counts is as an index of abundance as shown in Figure 3. The trend for shore spawners is similar to that of the stream spawners (Fig. 2). That is, large numbers (~200,000-700,000) were observed in the 1970s such as the Northcote et al. (1972) estimate of 0.5M in 1971 but rapidly declined to <200,000 in the 1980s and <50,000 in the 1990s.

After ten years of estimates <50,000 in the 1990s (except 1995) it is interesting to note that the 1999 estimate was nearly 76,000. This increase could be attributed to variation in observation conditions as discussed by Thompson (*in* Ashley et al. 1998). The widely held view and work of Matthews and Bull (1981), Dill (*in* Ashley et al. 1998) and Shepherd and Sebastian (*in* Ashley et al. 1998) suggests that beach spawning only occurs in a narrow, shallow band (<1m) along the shoreline. Contrary to the results of these studies it is possible that considerable spawning occurs at depths >1 m, i.e., it is quite conceivable spawners cannot be visually observed at depths >4-5 m. It seems unlikely that a species survival strategy would rely and utilize such a narrow band of habitat. Perhaps the majority of fish do spawn in water <1 m but variation in beach substrate over the entire shoreline surely must provide some opportunity for spawning at depths > 1 m. This hypothesis should be tested by designing a study involving a series of observations at various spawning sites.

Length- stream spawners

The Okanagan Lake database (OKFish) has thousands of entries of kokanee data. Unfortunately, much of the data cannot be used because of different sampling methods, incomplete record of location of capture or often because sampling was conducted opportunistically on a system in one year but not consistently sampled thereafter. The best data set is from Mission Creek although reasonably consistent data also exists for Penticton, Powers and Peachland creeks. There are virtually no data prior to the 1970s and only that collected by Northcote et al. (1972) is sufficiently useful for comparison with recent (1980s and 1990s) data.

Size of stream spawning kokanee has varied considerably over the last three decades (Fig. 4) with average size ranging from about 27 cm (1971) to an exceptionally large 39 cm in Peachland and Penticton creeks in 1998 (Table 7). Length frequency plots for Peachland (1992) and Penticton (1994) creeks indicate that the majority of spawning fish are found in the 23-26 cm mode but a few large individuals exceeding 30 cm are evident (Fig. 5). Exceptionally large sized spawners were observed in Peachland and Penticton creeks in 1998 (Fig. 5c). Comparison with the previous data (Figs. 5a,b) suggests the extreme shift in size in 1998 must be related to a shift in age at maturity. Trawl caught kokanee mean size-at-age in 1998 show no change thus lending support to the hypothesis of a shift in age. Regardless of year or stream, average size of Okanagan Lake stream spawners (~ 27 cm) has been much larger than those from Arrow Reservoir (~23 cm) or the main part of Kootenay Lake (~ 22 cm).

Table 7. Mean length (cm) of kokanee spawners from Mission Creek, Mission Creek spawning channel, Peachland, Penticton and Powers creeks.

Year	Mission Creek	Mission Channel	Peachland Creek	Penticton Creek	Powers Creek
1971	26.0		25.8		25.9
1986	26.5				
1987	35.2			32.4	
1988	27.0				
1989	28.5		28.1	26.7	28.2
1990	28.7	30.0	29.0	32.5	26.5
1991	27.0	28.9	26.5	30.5	25.8
1992	25.5	26.1	27.0	32.8	26.5
1993		25.5		20.2	
1994	27.0	26.6	31.3	25.6	25.9
1995	28.4	29.5	30.4	28.0	25.8
1996	29.9	30.1	31.5	35.1	29.7
1997	27.0	26.8	27.6	33.9	25.9
1998	38.9	38.9	39.3	38.3	35.8
1999	29.5				
Mean	**28.9**	**27.6**	**29.7**	**30.0**	**27.3**

The majority of Mission Creek kokanee are about 29 cm but some individual fish have been measured up to 60 cm (Fig. 6a). Males tend to be slightly larger than females (Fig. 6b) with some of the largest fish recorded in 1998 (sample size in 1998 was only 49). In some years, (e.g., 1991, 1995, and 1996) the length frequency distribution reflects multiple year classes.

The frequency distribution of spawners in 1998-1999 is worth noting. Small sample sizes for both years necessitated combining the two years to illustrate (Fig. 7b) the wide divergence in the size distribution pattern compared to the previous ten years of data (Figs. 7a,b). This information is consistent with that from the three other streams where fish were measured in 1998, i.e., very large fish were noted in Peachland, Penticton and Powers creeks (Fig. 5; Table 7). These sizes probably reflect a density response of kokanee within the lake where Sebastian and Scholten (*in* Ashley et al. 1999) have observed a substantial decline in total numbers over the last decade.

Length- shore spawners

Kokanee shore spawning data is available since 1987 (Table 8) but the sample size for any particular year is relatively small. Nonetheless, the data does indicate mean size has been surprisingly consistent with a single mode varying between 22-25 cm with no fish >30 cm (Fig. 8). Mean size in recent years has decreased slightly as shown in Figure 8, but unfortunately, no samples were taken in 1998 or 1999 when a large increase in stream spawner size was noted. If the increase in stream spawner size is a density response the shore spawner size should also have increased. Lack of any shore spawning fish >30 cm as well as differences in time of spawning has been the subject of considerable discussion and speculation since stream spawners have a great deal more variation in size. This difference is illustrated in Figure 9 where no shore spawning fish exceed 30 cm whereas stream spawners are characterized by sizes ranging up to 60 cm. There is however, little difference in the dominant mode of the two types of spawners that fall between 23-26 cm (Fig. 9) therefore they are assumed to be the same age.

There has been some thought that using a seine net for sampling beach spawning kokanee may be biased by under representation of the larger fish. It is difficult to imagine why two populations of kokanee inhabiting the same environment have such a size difference. This observed difference is worthy of further study since these two populations presumably inhabit the same habitat in the lake yet display such different sizes at maturity.

Table 8. Number of shore spawner length samples by method and mean lengths by method.

	Capture Method			Sample	Mean Length of Shore Spawners			
Year	**DP[1]**	**SN[2]**	**TP[3]**	**Size**	**DP**	**SN**	**TP**	**Mean (cm)**
1987		100		100		25.0		25.0
1988		100		100		23.3		23.3
1989	39	100		139	27.7	24.8		25.6
1990		241		241		24.3		24.3
1991		50		50		24.4		24.4
1992		49		49		22.8		22.8
1993		53		53		22.9		22.9
1994		104		104		23.7		23.7
1995			49	49			24.0	24.0
1997		79		79		22.9		22.9
Total	**39**	**876**	**49**		**27.7**	**24.0**	**24.0**	**24.1**

[1] Dead pitch
[2] Seine
[3] Trapped

Length- trawl caught kokanee

Sebastian and Scholten (*in* Ashley et al. 1999) have reported the mean lengths of trawl caught fish from 1985-1998. Figure 10 illustrates the length frequency distribution for all fish caught by trawl net from 1988-1997. Three modes are evident which correspond to age O+, 1+ and 2+ fish. There are small numbers of mature fish ~25 cm or larger that are likely age 3+. The age of these fish is discussed below.

Length- sport caught kokanee

The kokanee sport fishery on Okanagan Lake at one time was one of the largest in the province. Shepherd (1994) reported catch ranged from ~178,000 in the early 1970s but declining to ~37,000 by the early 1990s. The fishery has been closed to fishing since 1995. Examination of earlier data suggests the typical size of sport caught kokanee was usually only 23-25 cm (Fig. 11a, b). There were also a few fish caught that exceeded 30 cm and this larger size made them quite attractive to the angler. Further analysis of the size of sport caught fish is warranted since it may be possible to determine ratio of shore to stream fish within the catch from known size of stream spawners, i.e., catch of fish > 25 cm must be of stream origin since no shore spawners > 25 cm.

Fecundity of Okanagan Lake kokanee

Despite thousands of data points entered on the main database (OKFISH) there was little reliable data available to determine kokanee fecundity. The most common problem encountered was the uncertainty as to whether or not egg counts were made from partially spawned fish. A thorough review of the data revealed that only 104 samples from all years (all Mission creek data) was reliable enough, i.e., it was clear from the database notes that the eggs had been separated from intact skeins and then counted. Three of the samples were removed from the data set as they were clearly outliers and the remaining 101 samples were then used to refine a regression formula using female lengths originally developed by Dill (1992). The regression model (Fig. 12) that best fits the data (n = 101) is:

$$\text{Log}_{10}\,(\text{fecundity}) = 3.289 \cdot \log_{10}(\text{length in mm}) - 5.275 \qquad (r^2 = 0.823)$$

This formula, using more data points, is very close to the original derived by Dill (1992). Mission Creek spawning channel data was summarized by Andrusak (*in* Ashley et al. 1999) using fecundity estimates derived from Dill's formula. The summary for Mission Creek fecundity has been updated (Table 9) using the above revised formula.

Table 9. Derived fecundity estimates for Mission Creek kokanee 1989-1999.

Year	Sample Size	Mean Length	Derived Fecundity
1971[1]	50	259	480
1989	47	318	1,021
1990	307	289	762
1991	278	283	737
1992	468	258	525
1993	257	249	425
1994	275	266	578
1995	124	280	687
1996	105	290	755
1997	135	263	546
1998	13	369	1,592
1999	25	281	746
Total	**2,034**	**286**	**761**

[1] Direct measurements as reported by Northcote et al. 1972.

The unusually large fecundity estimate for 1998 was based on a very small sample size and is somewhat suspect since a few very large fish will bias the estimate when the regression formula is used. The average fecundity from 1989-1999 is calculated at 761 but within this eleven year period there has been a wide range (425-1592).

Age of Okanagan Lake kokanee

Perhaps the most confusing part of the biology of Okanagan Lake kokanee is determination of their age. More to the point, the method for age determination using scales has been brought into question despite years of age analysis using scales from mature fish due to severe scale resorption. It was for this reason that otoliths were taken from spawning fish in 1997 and 1999.

Northcote et al. (1972) determined the age of Okanagan Lake kokanee caught in gillnets in 1971. They indicated that kokanee caught in the lake ranging in size from approximately 170 mm-280 mm were 1-3 years old (Fig. 11 of Northcote et al. 1972). Unfortunately, the raw data has been lost, but the report refers to the ages as “completed years”, therefore, these fish scales would have all shown summer growth as they were all captured in the summer of 1971, i.e., the reported ages were in fact 1+, 2+, and 3+. This is reasonable to conclude since the smallest fish (age 1 or rather 1+) was approximately 170-180 mm and, therefore, based on size alone could not be age 0+. Shepherd (*in* Ashley et al. 1998) summarized Mission Creek kokanee age data (all from scales) from 1987-1995 indicating a range in ages from 2+ to 4+ with the vast majority comprised of ages 3+(30%) and 4+(43%). However, Shepherd (*in* Ashley et al. 1998) expressed doubt about the accuracy of the age composition because of difficulty in reading scales of older fish.

To resolve the problem of age determination of Okanagan Lake kokanee two sources of data lines are analyzed:

1. Age structure as determined from annual hydroacoustic and trawl data.
2. Analysis of age determination from otoliths collected from mature fish in 1997 and 1999.

Trawl data

Sebastian and Scholten (*in* Ashley et al. 1999) have summarized Okanagan Lake kokanee acoustic and trawl data collected from 1988 to 1998. Distinct modes are evident in the trawl catch as shown in Figures 13a,b,c representing ages 0+, 1+, 2+ and 3+ fish. Sebastian and Scholten (*in* Ashley et al. 1999) have also determined the mean length-at-age (data adjusted to October 1 of each year) for these kokanee using trawl catch data from 1985-1998. This data is reproduced in Figure 14. These fish have been aged from scales and it is clear that there are at least four primary age groups with means at ~55 mm, 120 mm, 200 mm and 235 mm. Since this data was collected after the stream spawners had ascended the streams, but before shore spawning occurs (i.e., in late September) the length frequencies should reflect the age groups of all shore spawners and ages 0+ to 2+ of the stream spawners. Superimposing length frequencies of the trawl catches with stream spawner length frequencies as shown in Figures 15-17a indicate that stream spawners must be largely age 3+ and older fish. Similarly, superimposing the trawl length frequencies with shore spawning lengths suggest that it is most likely that they too are age

3+ (Figs. 15-17b). This interpretation will be verified or amended once the current otolith analyses are completed.

Food habits

Despite the thousands of kokanee sampled over the decades and recorded in the databases there is virtually no quantifiable data on food habits. Smith (1978) reported some data collected in 1935 (from Clemens et al. 1939) and 1974 file data from angler caught fish. Shepherd (1994) summarized kokanee food habits (presence or absence) of 1,150 angler caught kokanee from 1982-1992 and Sebastian et al (1995) examined presence of some food items in trawl caught fish. Food habit data from Smith (1978) and Shepherd (1994) for Okanagan Lake kokanee are summarized here:

	1935[1] **% occurrence**	**1974[2]** **% occurrence**	**1982-1992[3]** **% occurrence[4]**
Copepods	22.7	12.3	29.0
Cladocerans	63.6	71.8	12.0?
Midge larvae/pupae	9.1	<1.0	12.0
Algae	4.6	---	---
Mysids	---	12.5	22.0

[1] 14 samples from July and October (Clemens et al. 1939)
[2] 63 samples July only
[3] 1150 samples (Shepherd 1994)
[4] only stomachs with food were reported in each study

The significance of the data Smith (1978) summarized is the appearance of mysids in the kokanee diet (1994) after their introduction into Okanagan Lake in 1960. Shepherd (1994) noted that the smaller kokanee (< 250mm) utilized copepods almost exclusively while the larger kokanee (>250 mm) utilized mysids with greater frequency. Kokanee >400 mm examined by Shepherd (1994) almost always had some mysids present. Sebastian et al (1995) reported some general observations (i.e., presence and absence) of food habits from trawl caught juvenile fish. They also noted that mysids were important, not only to large fish (>200 mm), but also age 2+ fish utilized them as much as copepods, at least during late summer.

Thompson (1999) examined the food habits of each year class of Kootenay Lake kokanee in a very detailed study from 1992-1995. When available, *Daphnia* spp. were by far the preferred food item for all year classes. Kokanee fry switch from copepods to *Daphnia* spp as soon as they were available, usually in late July. Rieman and Bowler (1980) similarly noted that Lake Pend Oreille kokanee preferred *Daphnia* and they quickly became the dominant food item as soon as they were abundant. Kootenay Lake kokanee fry seldom utilized mysids whereas older (ages 1-2) kokanee commonly had some in their stomachs (Thompson 1999 MS). Adult kokanee stomachs were not examined to any extent by Thompson (1999 MS).

In Okanagan Lake McEachern (*in* Ashley et al. 1999) reported *Daphnia* spp. were present in low densities by August in most years. *Cyclops* sp. were the most abundant copepods and

Diaphanosoma spp the dominant cladoceran and these zooplanktors are usually utilized by kokanee in the absence of *Daphnia*. It is most likely that Okanagan Lake kokanee have very similar food habits to those in Kootenay Lake but it is suggested that greater consumption of mysids occurs in Okanagan Lake given the much larger size of kokanee compared to those in the main portion of Kootenay Lake. This is perhaps not surprising since Okanagan Lake has significantly more shallow water habitat where mysids would be unable to avoid kokanee by sounding during the daytime.

Vertical migration

Kokanee utilize the open water, pelagic zone of large lakes and undergo diel vertical migration at least during the summer months (Northcote et al. 1964). In Okanagan Lake, two groups of kokanee were identified using an echosounder (Levy 1991). Adult fish remained in 10-20 m during the day while juvenile fish were found at 50-80 m. The juveniles underwent diel migration during the summer months from 80 to 20 m at dusk and returning to 80 m at dawn. The recent extensive trawl and acoustic work of Sebastian et al. (1995) determined that kokanee are found between 10 m and 60 m at night during the fall surveys, but few, if any, are in less than 10 m of water. Most of the fish concentrate just below the thermocline, which in Okanagan Lake is usually at the 10-25 m depth in the summer and fall (see McEachern *in* Ashley et al. 1999 for recent summer temperature profiles). As Sebastian et al. (1995) point out this distribution can change slightly over the length of large lakes such as Okanagan Lake possibly due to internal seiches.

Thompson (1999) did not find Kootenay Lake kokanee fry migrating to deeper water as observed by Levy (1991) on Okanagan Lake. All size groups were found between 10 to 20 m at dawn with some variation between east and west sides of the lake due to differing light intensity (i.e., shadow effect due to mountains). The fry formed schools at dawn and Thompson (1999) suggests the lack of a descent to deeper water by fry might be due to the very high densities observed in the lake and school formation was sufficient to deter predation. At dusk Thompson (1999) found that kokanee descended to the thermocline but the accompanying data (in graph form only) is somewhat ambiguous about the actual location of the thermocline. It appears to be only 20-25 m. suggesting the fish underwent very little vertical migration.

A closer examination of the differences between the vertical migration pattern of Okanagan and Kootenay lake kokanee would be useful because of the developing mysid fishery on Okanagan Lake and possibility of high kokanee by-catch.

Fish kills

Kokanee “die-offs” are a common occurrence throughout the Pacific Northwest, including the Okanagan. Several have been reported on Kootenay, Arrow, Shuswap and Moyie lakes over the last three decades. In the 1986 to 1999 period alone, there have been three kokanee kills in Okanagan Lake. The cause of these mid-summer kills remains uncertain (e.g., disease or internal seiches have been suggested), but the majority of dead were age 2+ fish. The 1989 kill on Okanagan Lake was the largest since routine monitoring of spawners began. An estimated 39,000 dead fish were observed floating plus an unknown number that had sunk. A kill of this magnitude should have had a noticeable impact on stream escapements in 1989 or 1990, but the returns were actually higher than expected for those cohorts (Figs. 2,3). It is always possible but unlikely that most of the mortalities were shore spawners that are more difficult to enumerate at spawning.

SUMMARY

Okanagan Lake supports two sympatric spawning populations of kokanee that have diverged since the retreat of the last glacier some 11,000 years ago (Taylor et al. 1997). Research on genetic differentiation is on-going and recent evidence suggests that these two populations can be distinguished using microsatellite assay techniques (S. Pollard in this report). Certainly, the two populations have a number of biological characteristics that allow fisheries workers to separate them including different spawning habitat selection, differences in timing of spawning, size differences and some possible differences at age at maturity**.** Attempts to determine meristic differences between stream and shore spawners were unsuccessful (see Haas *in* Ashley et al., 1998). It may well be that these stocks are currently diverging and can only be separated at this time through molecular analysis.

The value of enumerating the shore and stream spawning populations should be clear from the data summarized in this report. Both populations have undergone a gradual downward trend in numbers since the 1970s. Indeed, some run sizes have become so small that enumerations have been deleted from the annual counts. Shore spawning in some locations has also ceased since the 1970s. Andrusak (*in* Ashley et al. 1999) suggests that fry to adult survival rates have been below replacement level in recent years. Sebastian and Scholten (*in* Ashley et al. 1999) in-lake kokanee population estimates also support the spawner trend data, i.e., continued long-term downward trend. All of this information reaffirms the belief that in-lake productivity has declined probably due to nutrient reduction or imbalance and mysid competition with kokanee for preferred zooplankters (Ashley et al. 1999).

Key biological characteristics such as fecundity, mean length and length at age require annual monitoring to assist in interpretation of long-term trends in Okanagan Lake kokanee populations. Again, data summarized in this report has been instrumental in the interpretations of Ashley and Shepherd (1996) and Ashley et al. (1998; 1999) that Okanagan Lake carrying capacity has diminished thus causing the dramatic decline in kokanee numbers.

Okanagan Lake kokanee have been the subject of considerable research and study particularly in the 1990s. An extensive kokanee database has been developed but much of the older data is of little use due to a lack of a consistent approach. Lack of standard methods (in the past) for data collection has also limited the value of the data.

In recent years, there has been an improvement in data collection and a greater focus on key data requirements. Stream escapement estimates are critically important for monitoring stock status and the data set is considered good. Continuation of and even greater emphasis on stream counts on the eight most important systems provides the best data for trend analysis. Shore counts could be reduced to 3-4 key sites and used as an index of abundance for trend analysis.

Larger sample sizes of kokanee are required from Mission Creek. A minimum of 100 length measurements is required each year and a concerted effort is required to improve the fecundity data base. Age determination remains problematic and requires more detailed analysis of otoliths from fish caught in the trawl net as well as from spawners.

Food habits of Okanagan Lake kokanee are largely unknown and it could argued that it is not an essential requirement for fisheries stock management. Food habits of kokanee in nearby Kootenay Lake have been well documented recently by Thompson (1999 MS), therefore, a repeat of such work probably is not warranted for Okanagan Lake. However, the much larger size of Okanagan Lake kokanee suggests that they probably utilize *Mysis relicta* to a greater extent. This possibility should be documented for at least one season given the current focus on mysis removal through fishing exploitation. Trawl caught fish could be used for much of the diet study but adult fish also need to be examined. Kokanee by-catch while mysid fishing is another potential source of kokanee for food and age analysis.

Summary table of current (2000) key biological attributes of Okanagan Lake kokanee.

Attribute	**Mean**	**Range**	**Maximum**
Length at age[1]			
0+	59 mm	+/- 2 mm	
1+	131 mm	+/- 6 mm	
2+	214 mm	+/- 2 mm	
Length at maturity			
- Stream[2]	268 mm	218-378 mm	602 mm
- Shore[3]	240 mm	228-256 mm	282 mm
Fecundity	761	425-1592	1592
Age at maturity	3+	2+-5+	?
Number of stream spawners[4]	36,400	13,000-500,000	
Number of shore spawners[5]	114,000	1,000-500,000	
Abundance (in-lake)[6]	5 M	5-14 M	

[1] Trawl data (1985-1996) from Sebastian and Scholten (in Ashley et al. 1999).
[2] File data
[3] File data
[4] Peak x 1.5 (1992-1999)
[5] Peak x 3.5 (1992-1999)
[6] Sebastian and Scholten (*in* Ashley et al. 1999).

RECOMMENDATIONS

The following recommendations are made with a view of what data has been collected to date, the method of collection and what data requirements are envisioned for the next five years. Okanagan Lake is undergoing dramatic change and the fish surveys need to continue to track basic biological characteristics in an accurate and consistent manner.

1. The databases should be updated annually and consideration should be given to converting all data to Access.
2. Collect biological data on a planned basis. There is no point in collecting random data on an opportunistic basis.
3. Data collection should focus on fish length, numbers of spawners, age and fecundity. Recordings of data such as number of eggs in spawned fish, fish weights, and miscellaneous water temperature notes, should be deleted as this information is of little value.
4. Stream escapement estimates methods should continue as described in this report and all data entered should be converted to a total estimate using the 1.5 factor.
5. Shore spawning estimates should continue and used as an indice of abundance until an adequate alternative can be found. The factor of 3.5 should be used to convert peak estimates to total estimates. Continued effort is required to correlate the spawner indices with in-lake estimates. The depth of spawning should be examined to see if the preferred depth of 0.5 m is valid. If it isn’t, the shore spawner estimates need to be adjusted.
6. Kokanee data should be collected on a planned basis with a focus on Mission, Peachland, Penticton and Powers creeks. Annually a minimum of 100 length measurements should be taken from each of these four streams using live (trapped) fish or fresh, dead fish.
7. The fecundity data requires improvement by counting eggs from live, unspawned fish (i.e., eggs in skein). A minimum of 50 fish should be counted (for eggs) each year from Mission Creek. There is little point in determining fecundity from other streams unless fry production and or fry-to-adult survival rates are to be determined. Mission Creek should continue to be the focus of such estimates given that the time series information is already available.
8. Otoliths should be collected annually from 50 Mission creek fish for age determination.
9. Hydroacoustic and trawl data should continue to be collected annually as described by Sebastian and Scholten (*in* Ashley et al. 1999).
10. Genetic analysis of the trawl caught fish should continue in pursuit of a reliable means of estimating the contribution of each stock to the total population.
11. A field study should be initiated to examine the depth zone utilized by local spawning kokanee.
12. A food habit study should be conducted for one year to document the extent of mysid utilization. Much of the data could be obtained from the trawl samples.

REFERENCES

Andrusak, H. and C. Brown. 1987. Kootenay Lake Fisheries Management Plan 1987-89. B.C. Ministry of Environment, 56 pp.

Anon. 1969. Report on the fisheries problems associated with the proposed diversion of water from Shuswap River to Okanagan Lake. Rep. prep. by Tech. staffs of Dept. Fish. and For. Can., Intenat. Pac. Sal. Fish. Comm., and Fish Wildl. Br., BC Dept. Rec. Cons., Vancouver, BC.

Anon. 1973. List of Okanagan Basin Study Report Publications (revised). Prelim. Rep. No. B. Prep. for Okanagan Study Comm., Penticton, BC.

Anon. 1980. Fisheries Management Plan for Okanagan Main Valley Lakes. Prep. by Fisheries staff, Okanagan Reg., BC Min. Env., Penticton, BC.

Ashley, K., and B. Shepherd. 1996. Okanagan Lake workshop report and Action Plan. Fish. Proj. Rep. No. RD - 45, Univ. BC, Vancouver, BC.

Ashley, K., Bruce Shepherd, Dale Sebastian, Lisa Thompson, Lidija Vidmanic, Dr. Peter Ward, Hansen A. Yassien, Laurie McEachern, Rick Nordin, Dr. Dave Lasenby, Janice Quirt, J.D. Whall, Dr. Peter Dill, Dr. Eric Taylor, Susan Pollard, Cecilia Wong, Jan den Dulk, George Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Ashley, K.A., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, and G. Scholten. 1999. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. 78. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch

Bryan, J.E. 1990. Water Quality of Okanagan, Kalamalka and Woods Lakes. B.C. Ministry of Environment 69 pp.

Bull, C. J. 1987. Okanagan Lake Plan. Draft Rep., BC Min. Env., Penticton, BC.

Burger, C.V., J.E. Finn, L. Holland-Bartels. 1995. Pattern of Shoreline Spawning by Sockeye Salmon in a Glacially Tturbid Lake: Evidence for Subpopulation Differentiation. Trans. Amer. Fish. Soc. 124 : 1-15.

Burger, C.V., W.J. Spearman, and M.A. Cronin. 1997. Genetic Differentiation of Sockeye Salmon Subpopulations from a Geologically Young Alaskan Lake System. Trans. Amer. Fish. Soc. 126 : 926-938.

Canada-British Columbia Okanagan Basin Agreement. 1974. Main Report of the Consultative Board Including the Comprehensive Framework Plan. Office of the Study Director. Penticton, BC. 536 pp.

Clemens, W.A., D.S. Rawson and J.L. McHugh. 1939. A Biological Survey of Okanagan Lake, British Columbia. Fish. Res. Bd. Can. Bull. LVI.

Dill, P. A. 1992. Migration of Kokanee Salmon Adults into Mission Creek Spawning Channel and Estimate of Egg Deposition, 1992. Contractor rep. prep. for Min. Env. Fish. Sect., Penticton, BC.

Dill, P.A. 1996. Migration of Kokanee Salmon Adults into Mission Creek Spawning Channel and Estimate of Egg Deposition, 1996. Contractor rep. prep. for Min. Env. Fish. Sect., Penticton, BC.

Harper, W.L. 1985. Kokanee Management Plan for the Okanagan Main Valley Lakes. Reg. 8. Fish & Wildl. Progr., Min. Env., Penticton, BC.

Levy, D.A. 1991. Acoustic Analysis of Diel Vertical Migration Behavior of *Mysis relicta* and Kokanee (*Oncorhynchus nerka*) within Okanagan Lake, British Columbia. Can. J. Aquat. Sci. Vol. 48, 1991.

Lorz, H.W., and T.G. Northcote. 1965. Factors Affecting Stream Location, and Timing and Intensity of Entry by Spawning Kokanee (Oncorhynchus nerka) into an Inlet of Nicola Lake, British Columbia. J. Fish. Res. Bd. Canada, 22 (3), 1965.

Marr, B.E., A.T. Prince, H.D. DeBeck, E.R. Tinney, W.N. Venables and R.L. McLaren. 1974. Summary Report of the Consultation Board Including the Comprehensive Framework Plan. BC Wat. Resour. Serv., Victoria, BC.

Matthews, S. and C.J. Bull. 1981. Effect of Water Level Fluctuations on Shore Spawning Kokanee in Okanagan Lake. Ministry of Environment Fish and Wildlife Program 20p.

Northcote, T.G. and P.A. Larkin. 1956. Indices of Productivity in British Columbia Lakes. J. Fish. Res. Bd. Canada 13 (4).

Northcote, T.G., H.W. Lorz and J.C. Macleod. 1964. Studies on Diel Movement of Fishes in a British Columbia Lake. Veh. Internat. Verein. Limnol. XV 940-946

Northcote T. G. and H. W. Lorz. 1966. Seasonal and Diel Changes in Food of Adult Kokanee (*Oncorhynchus nerka*) in Nicola Lake, British Columbia. J. Fish. Res. Bd. Canada, 23(8): 1096-1106.

Northcote, T.G., T.G. Halsey, and S.J. MacDonald. 1972. Fish as Indicators of Water Quality in the Okanagan Basin Lakes, British Columbia. Okanagan Basin Study Comm. Prelim. Rep. No. 22.

Northcote, T.G. 1973. Some Impacts of Man on Kootenay Lake and Its Salmonids. Great Lakes Fisheries Commission Tech. Rep. 25.

Reiman, B.E. and B. Bowler. 1980. Kokanee Trophic Ecology and Limnology in Pend Oreille Lake Forest, Wildlife and Range Experiment Station University of Idaho

Redfish Consulting Ltd. 1999. Evaluation of Six Kokanee Spawning Channels in British Columbia. Unpubl. MS. Contractor report prepared for the Ministry of Fisheries, Province of British Columbia, Victoria, BC.

Sebastian, D., H. Andrusak, G. Scholten, and L. Brescia. 1999. Arrow Reservoir Fish Summary. Stock Management Report. Province of BC, Ministry of Fisheries.

Shepherd, B.G. 1990. Okanagan Lake Management Plan, 1990 - 1995. BC Min. Env., Recreational Fish. Progr., Penticton, BC.

Shepherd, B.G. 1994. Angler surveys of Okanagan Main Valley Lakes, 1982 - 1992. Fish. Proj. Rep. No. OK -17, Okanagan Sub-Reg., S. Int. Reg., Penticton, BC.

Smith, D.R. 1978. A Summary of Existing Data on Kokanee (*O. nerka*) in Okanagan Lake. Fish. Sect., Tech. Rep., Okanagan Sub-Reg., S. Int. Reg., BC Min. Env., Penticton, BC.

Taylor, D., and P.A. Dill. 1997. Migration of Kokanee Salmon Adults into Mission Creek Spawning Channel and Estimate of Egg Deposition, 1997. Contractor rep. prep. for Min. Env. Fish. Sect., Penticton, BC.

Thompson, L.C. 1999. Abundance and Production of Zooplankton and Kokanee Salmon (*Oncorhynchus nerka*) in Kootenay Lake, British Columbia During Artificial Fertilization. PHD Thesis University of British Columbia, Vancouver BC. 252 p.

Vernon, E. H. 1957. Morphometric Comparison of Three Races of Kokanee (*Oncorhynchus nerka*) Within a Large British Columbia Lake. Journal of the Fisheries Research Board of Canada 27: 1239-1250.

Zyblut, E.R. 1967. Temporal and Spatial Changes in Distribution and Abundance of Macrozooplankton in a Large British Columbia Lake. M.Sc. thesis, Zoology Department, University of British Columbia, Vancouver, B.C.

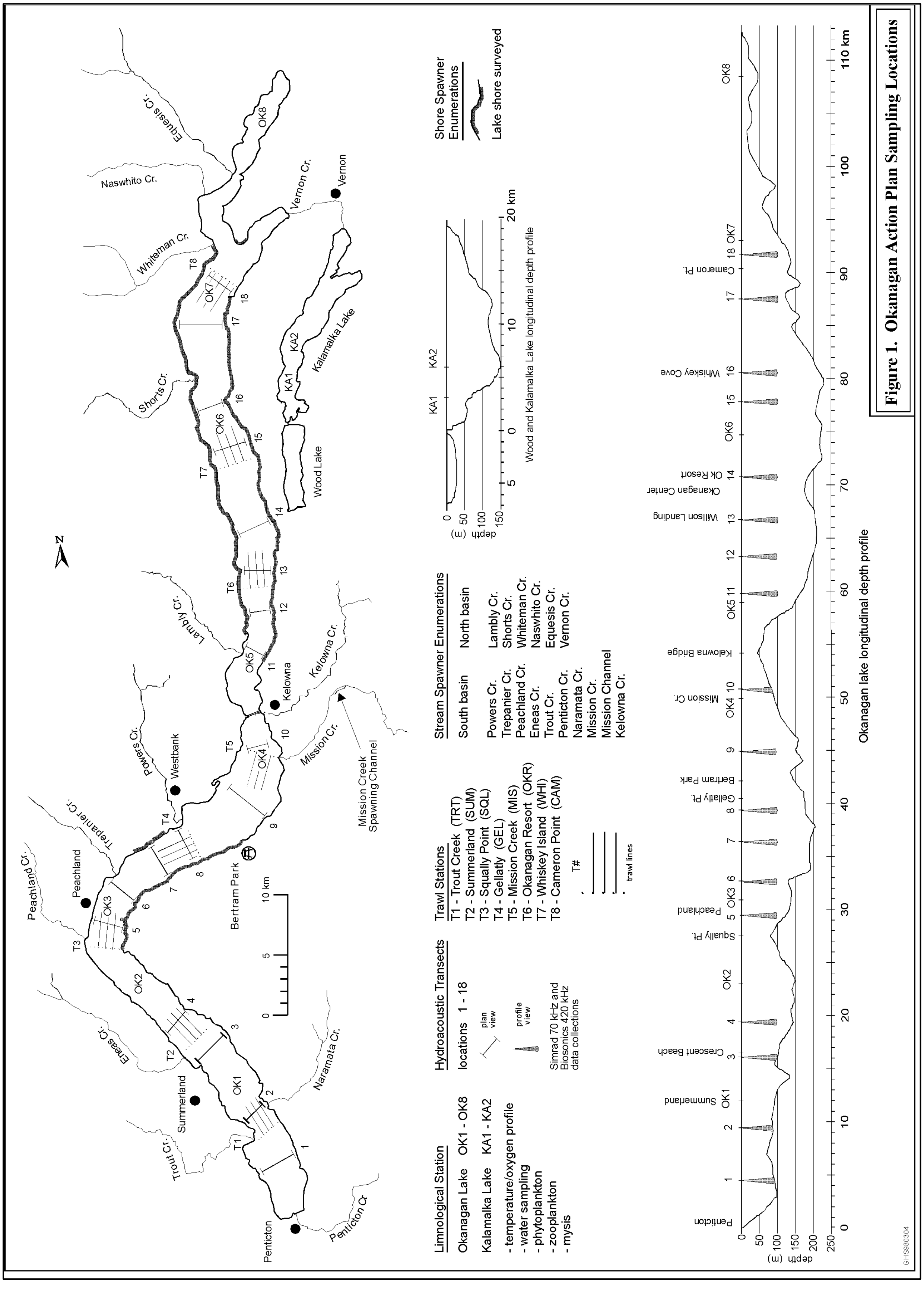

Figure 1. Okanagan Action Plan Sampling Locations

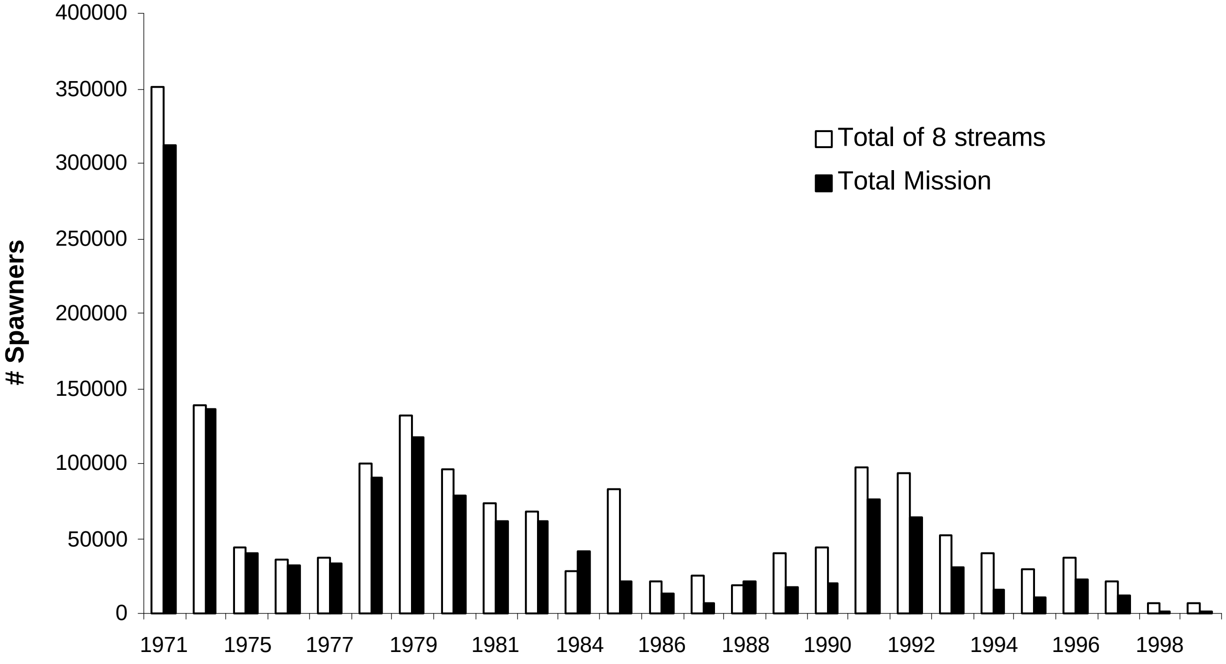

Figure 2. Escapement estimates for Mission Creek and the seven primary streams (including Mission Creek). Other streams include Powers, Peachland, Trepanier, Penticton, Lambly, Naramata and Mill creeks where data is available.

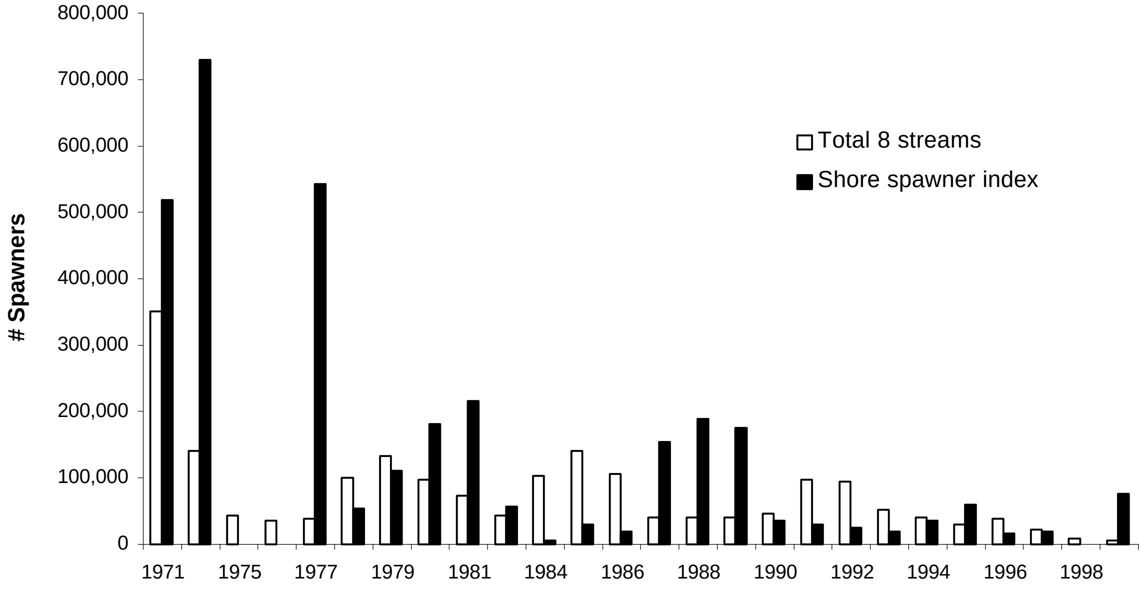

Figure 3. Kokanee stream escapements (eight streams) and shore spawner index.

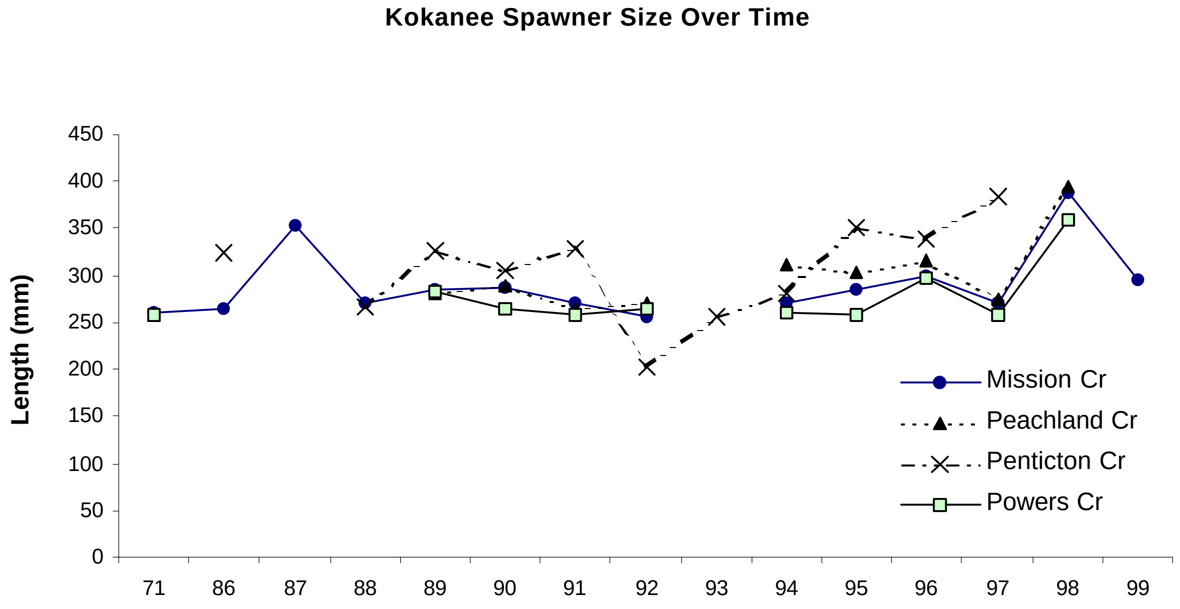

Figure 4. Mean size of kokanee spawners from the primary spawning streams on Okanagan Lake.

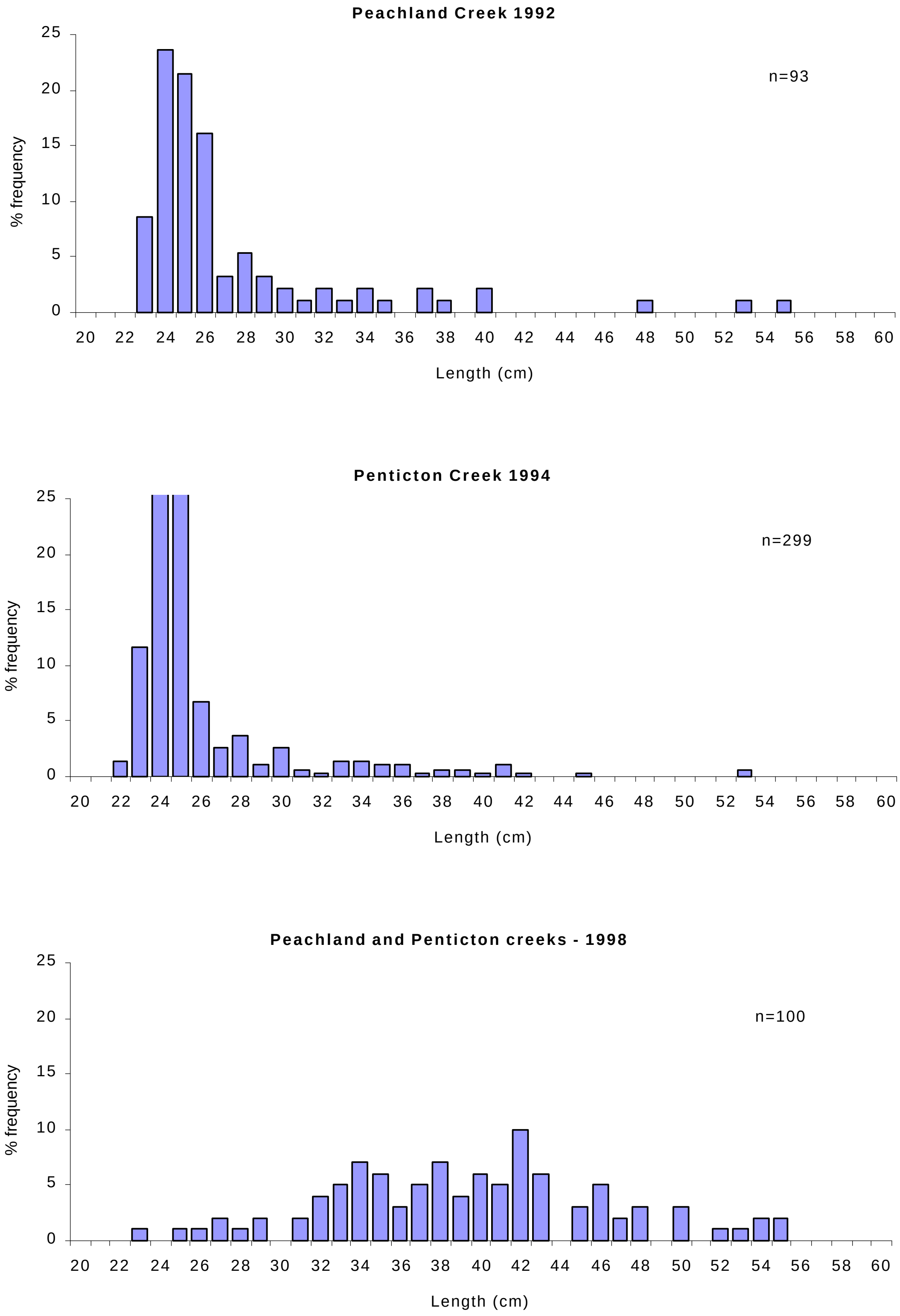

Figure 5. Length frequency of kokanee spawners (a) Peachland Creek (1992), (b) Penticton Creek (1994), and (c) Penticton and Peachland creeks combined (1998).

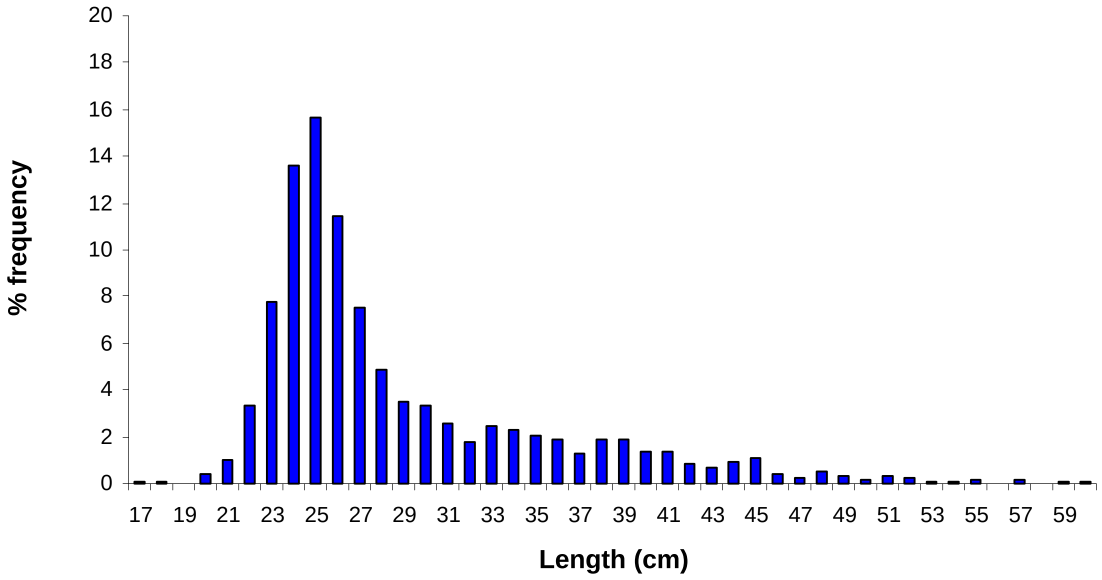

Figure 6a. Average length frequency of Mission Creek kokanee 1986-1999.

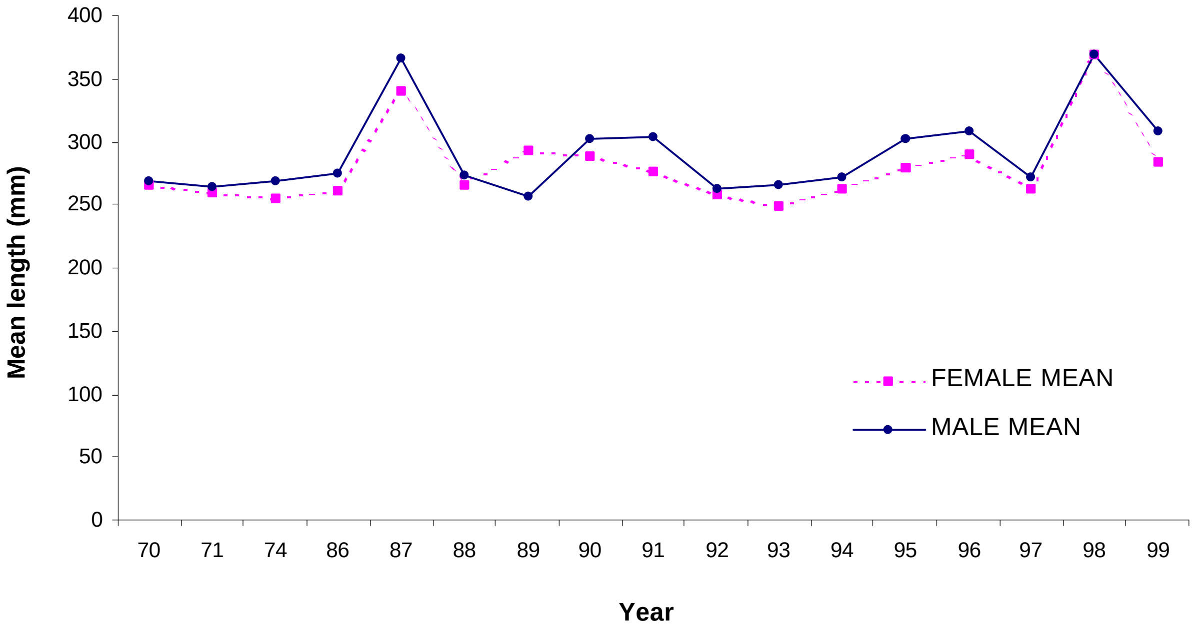

Figure 6 b. Mean size of male and female kokanee spawners from Mission Creek.

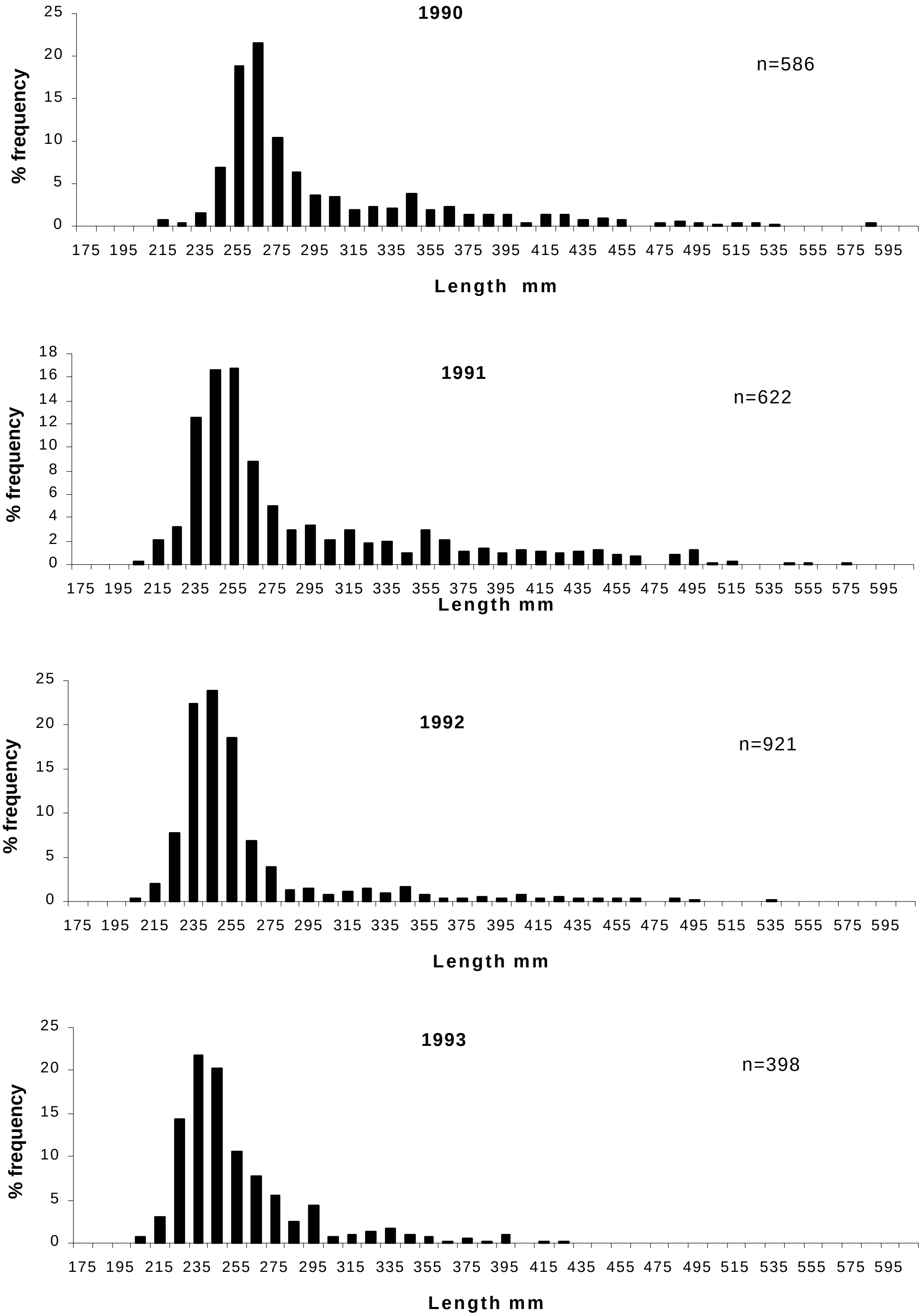

Figure 7a. Length frequency of Mission Creek kokanee, 1990-1993.

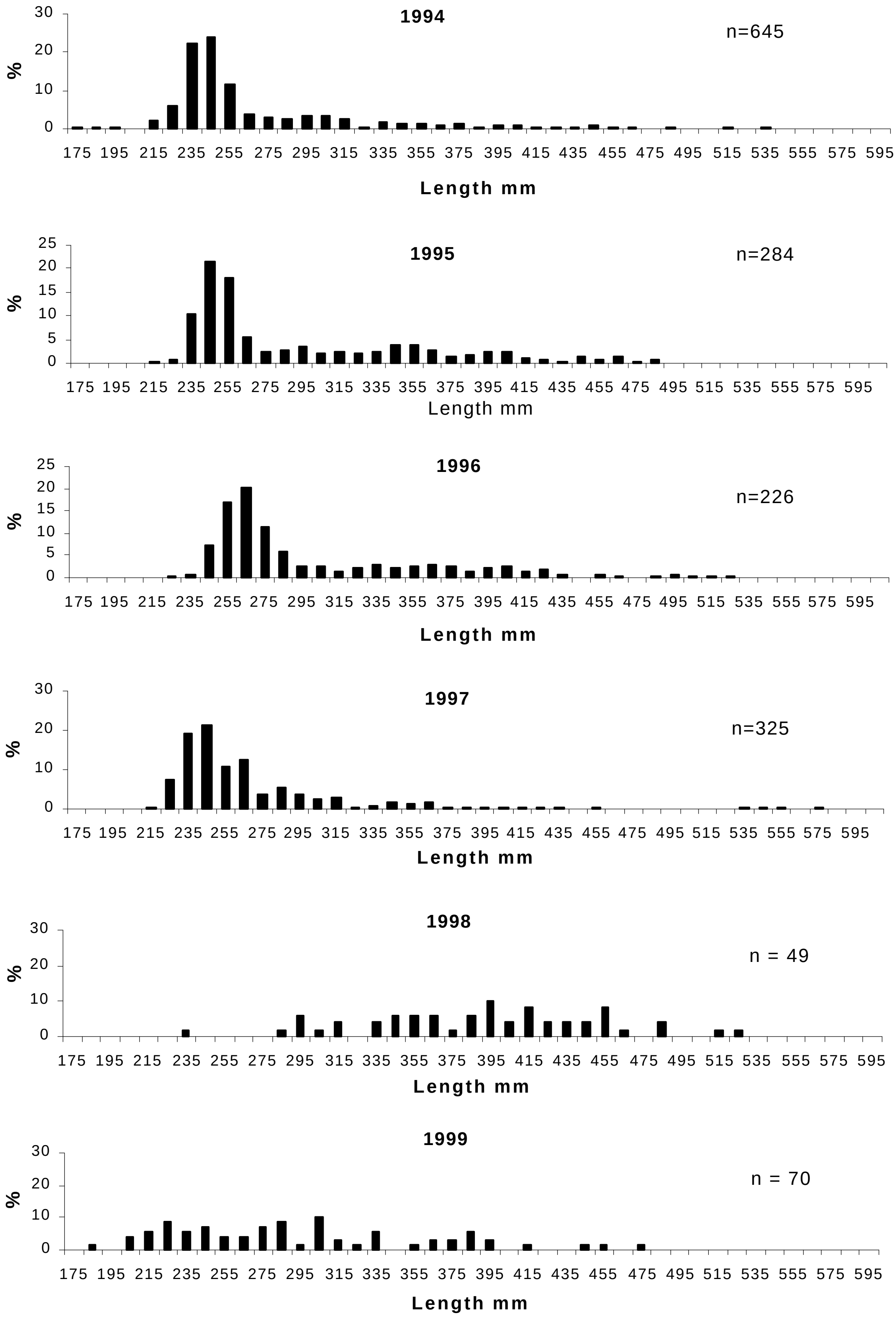

Figure 7b. Length frequency of Mission Creek kokanee, 1994-1999.

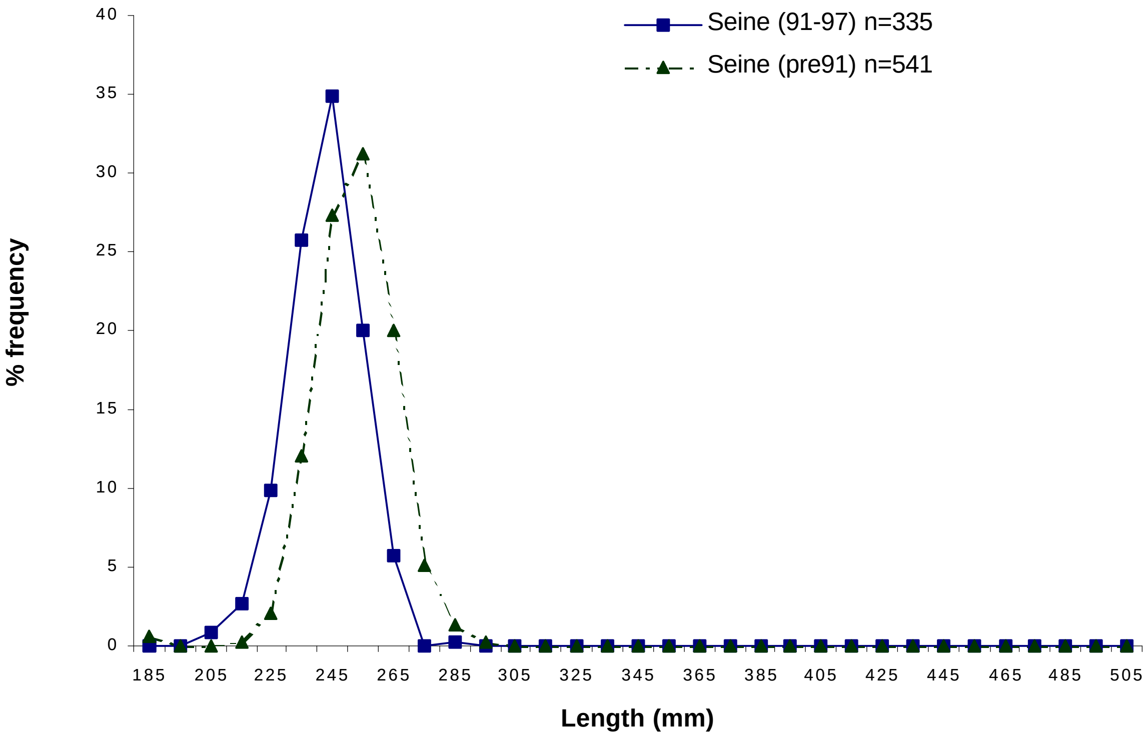

Figure 8. Length frequency of shore spawning kokanee pre 1991-1997. Note: line graphs used to illustrate modes although data is not continuous.

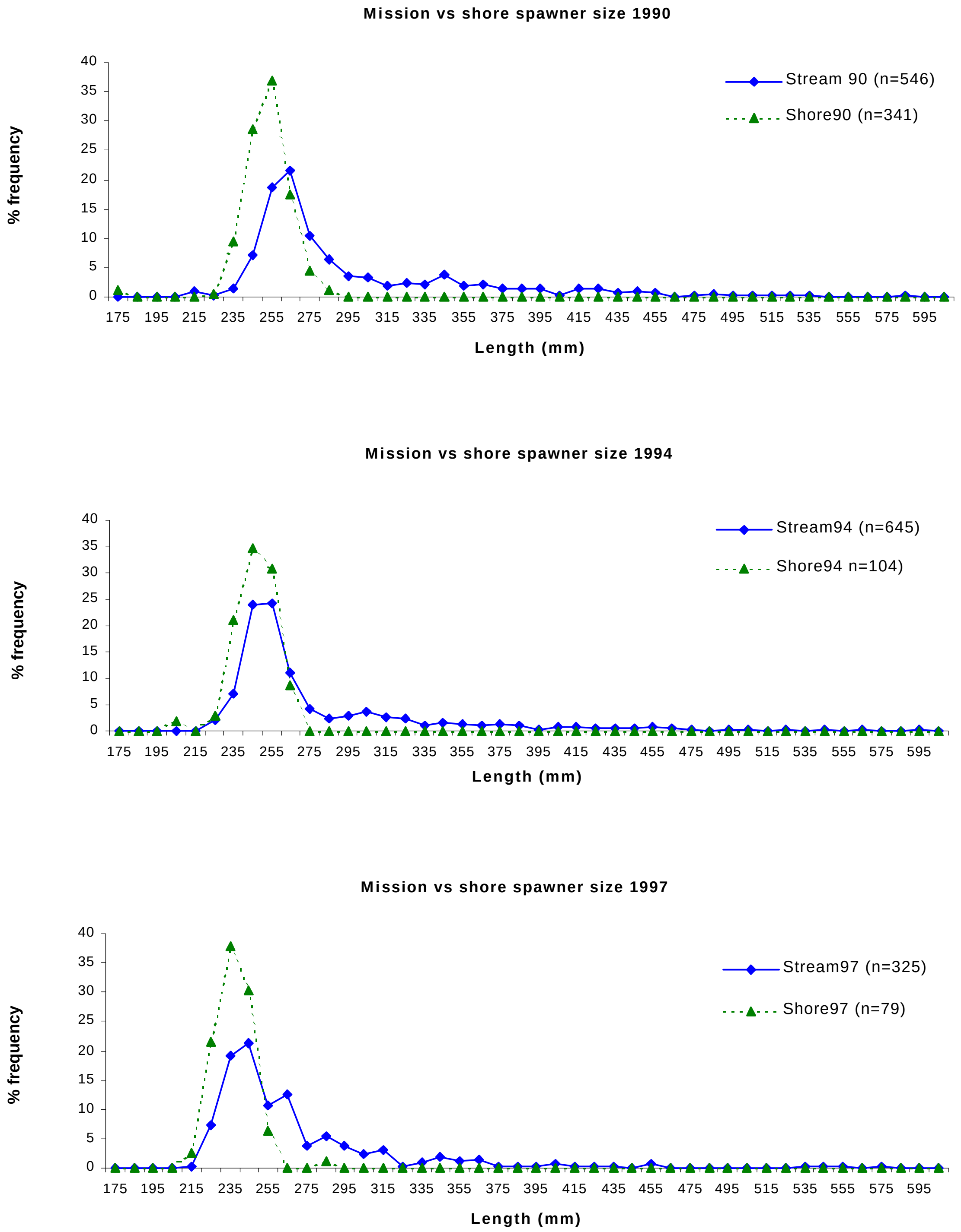

Figure 9. Length frequency of stream (Mission Creek) and shore spawning kokanee for 3 different time periods. Note: line graphs were used although data is not continuous to compare modes.

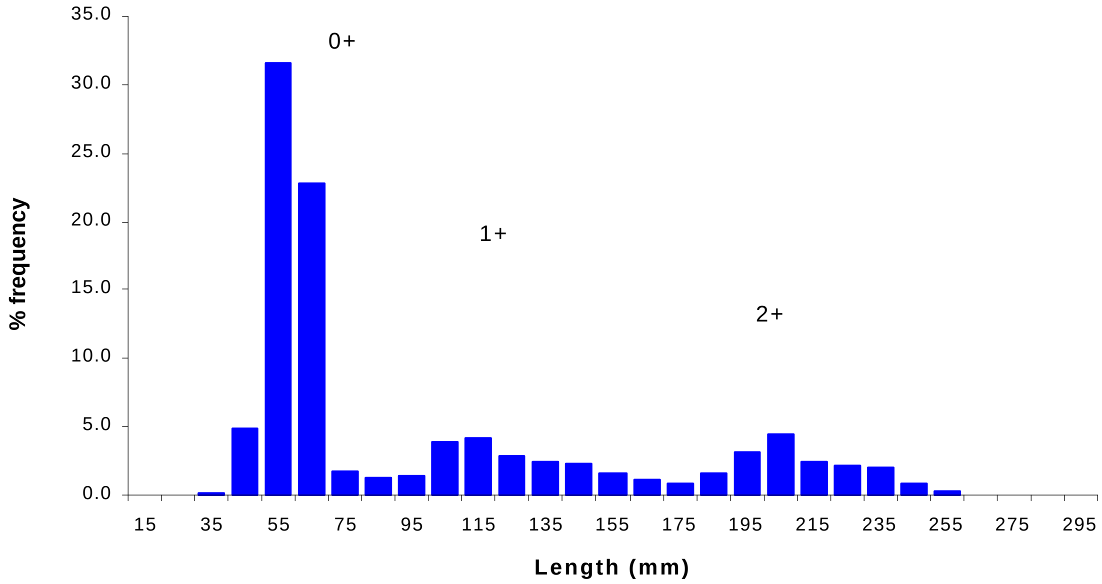

Figure 10. Length frequency of trawl caught kokanee from 1988-1997 (n = 6071).

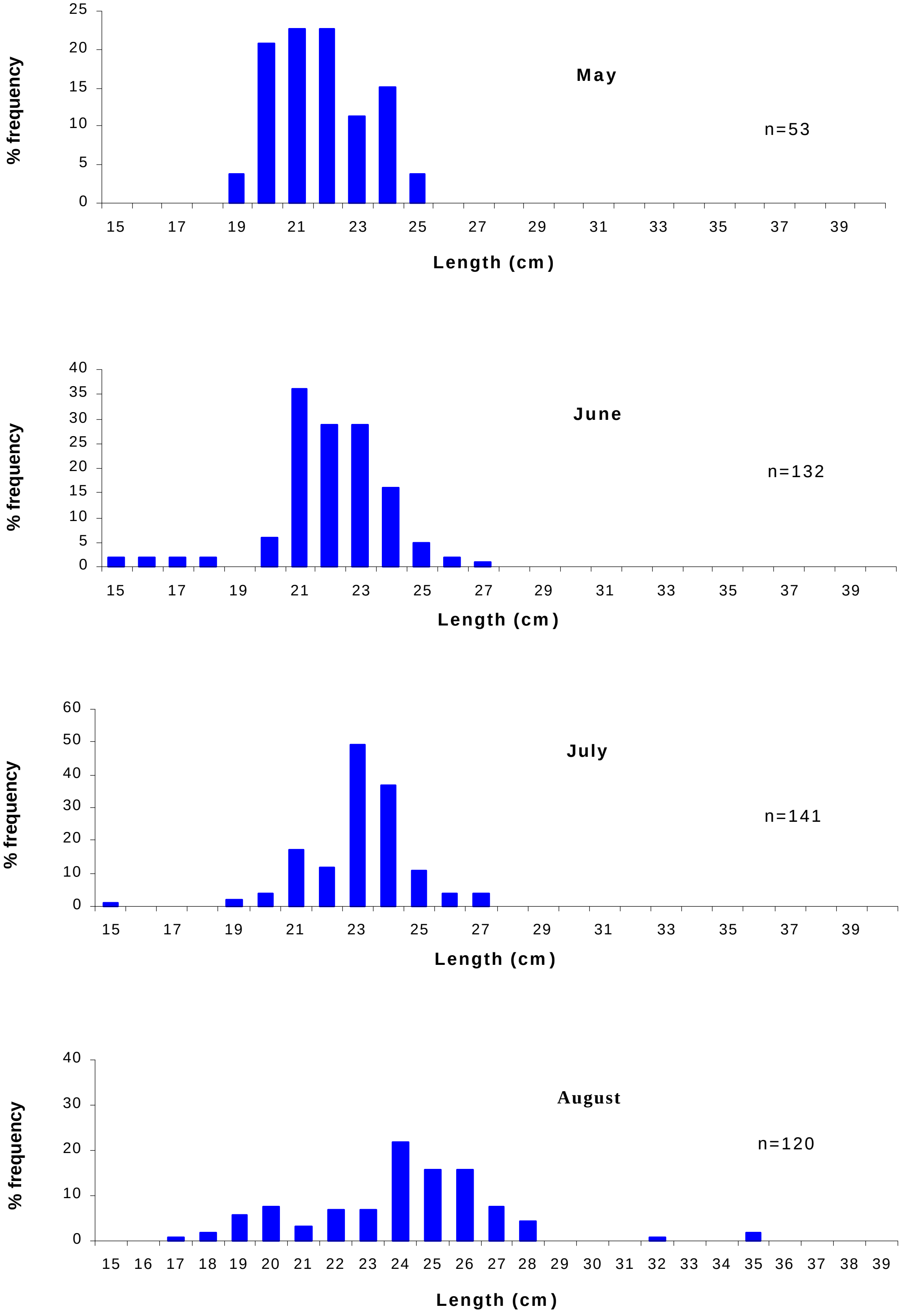

Figure 11a. Length frequency of Okanagan Lake sport caught kokanee May-August, 1981.

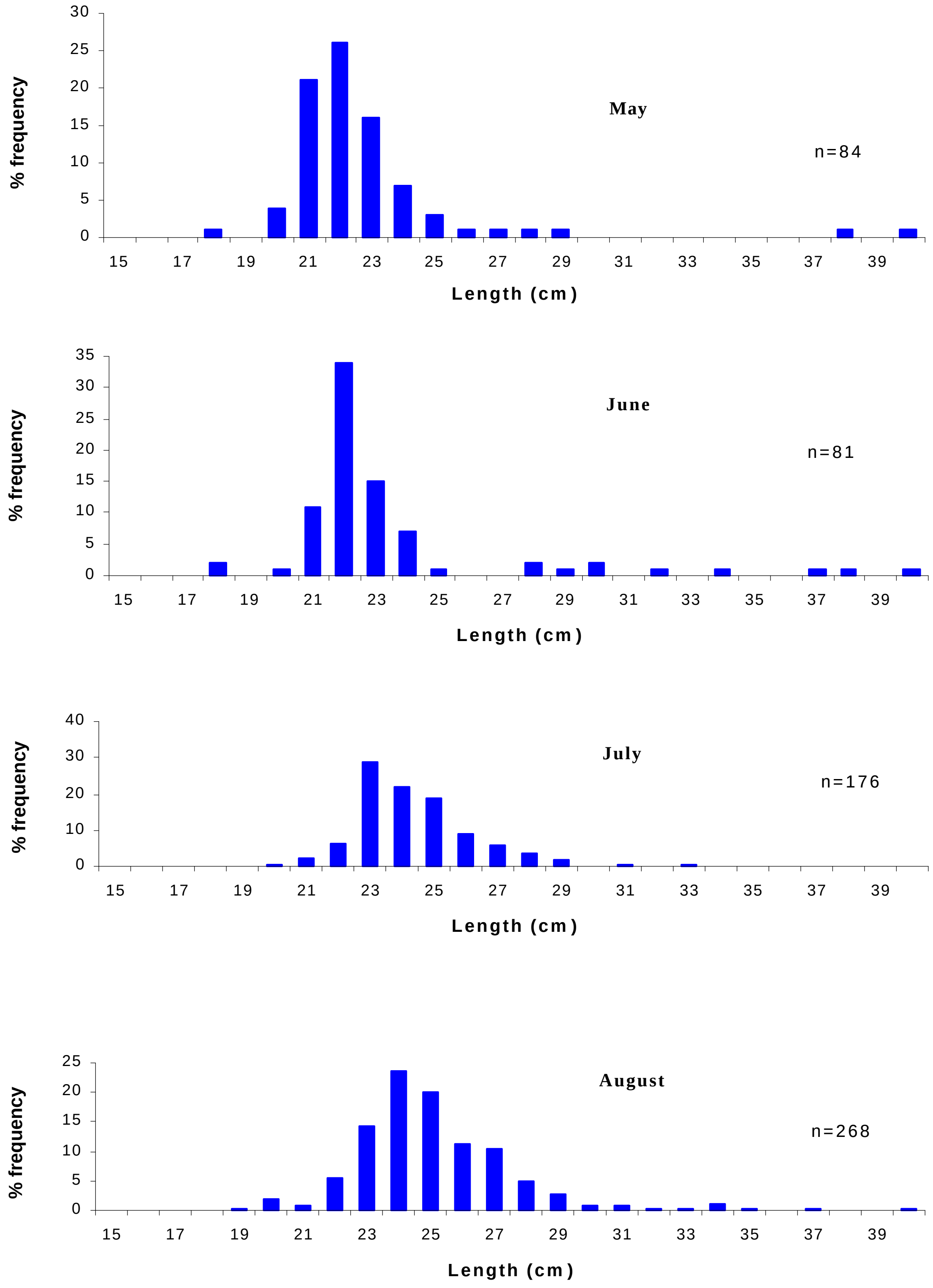

Figure 11b. Length frequency of Okanagan Lake sport caught kokanee May-August, 1981.

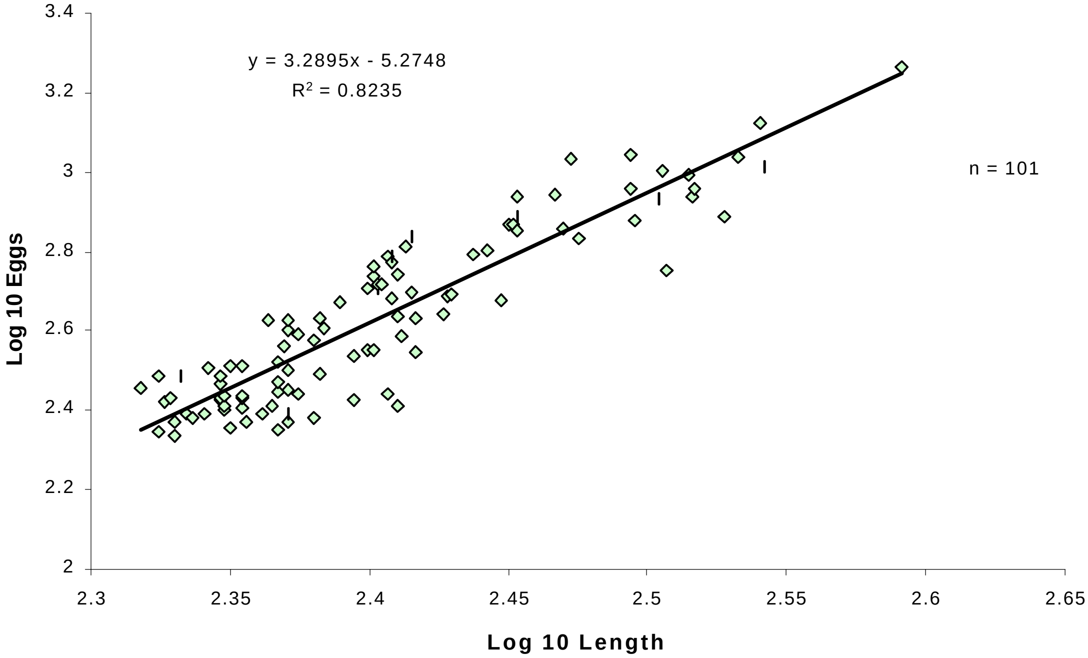

Figure 12. Regression model of fecundity to length (log 10) of Mission Creek kokanee spawners.

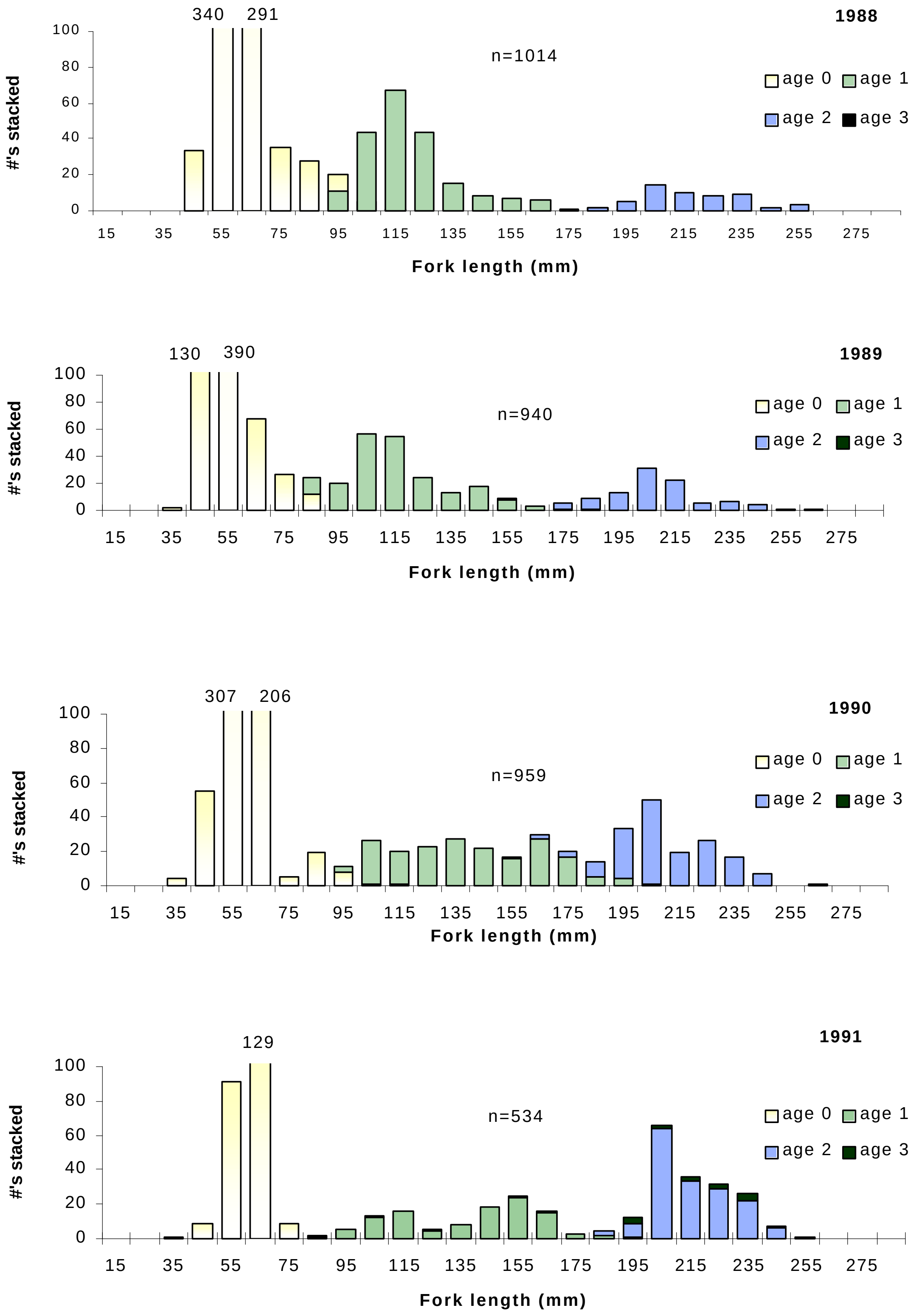

Figure 13a. Length-at-age of trawl caught fish adjusted to October 1. Note that the few age 3+ captured were mature.

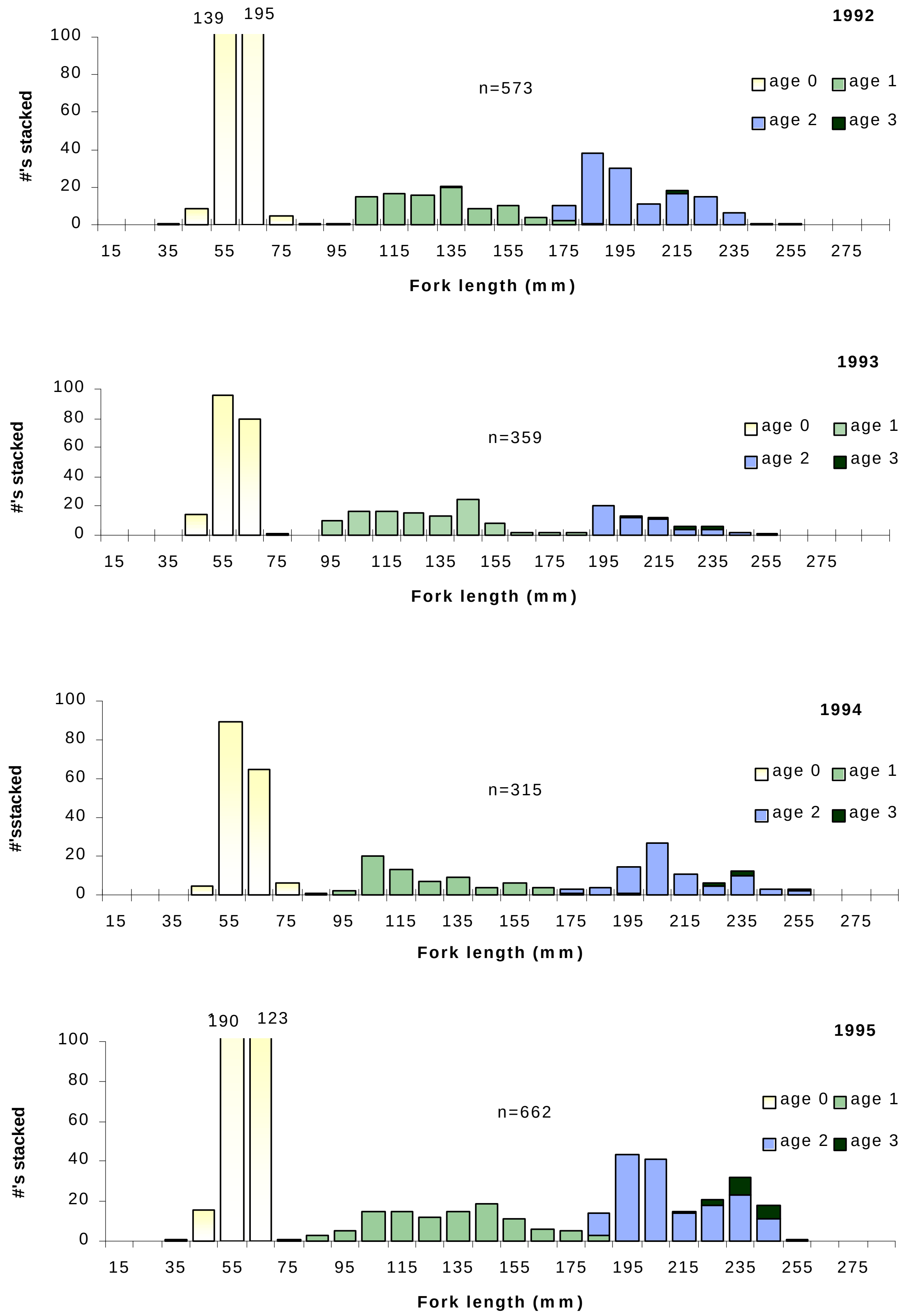

Figure 13b. Length-at-age of trawl caught fish adjusted to October 1. Note that the few age 3+ captured were mature.

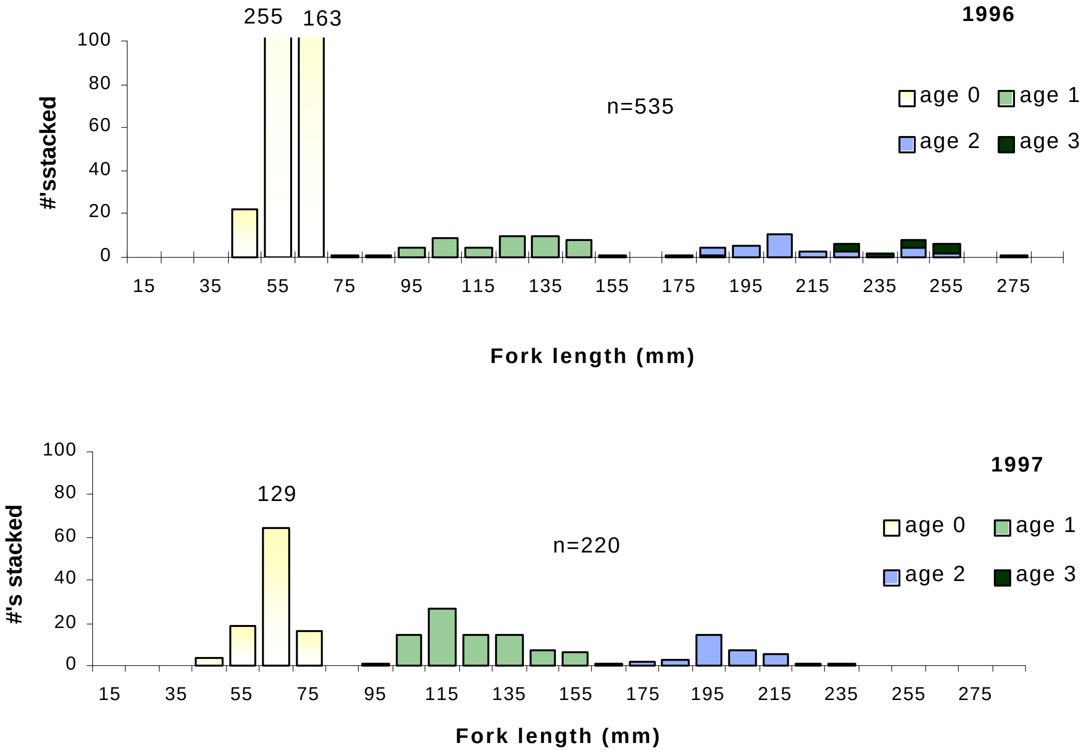

Figure 13c. Length-at-age of trawl caught fish adjusted to October 1. Note that the few age 3+ captured were mature.

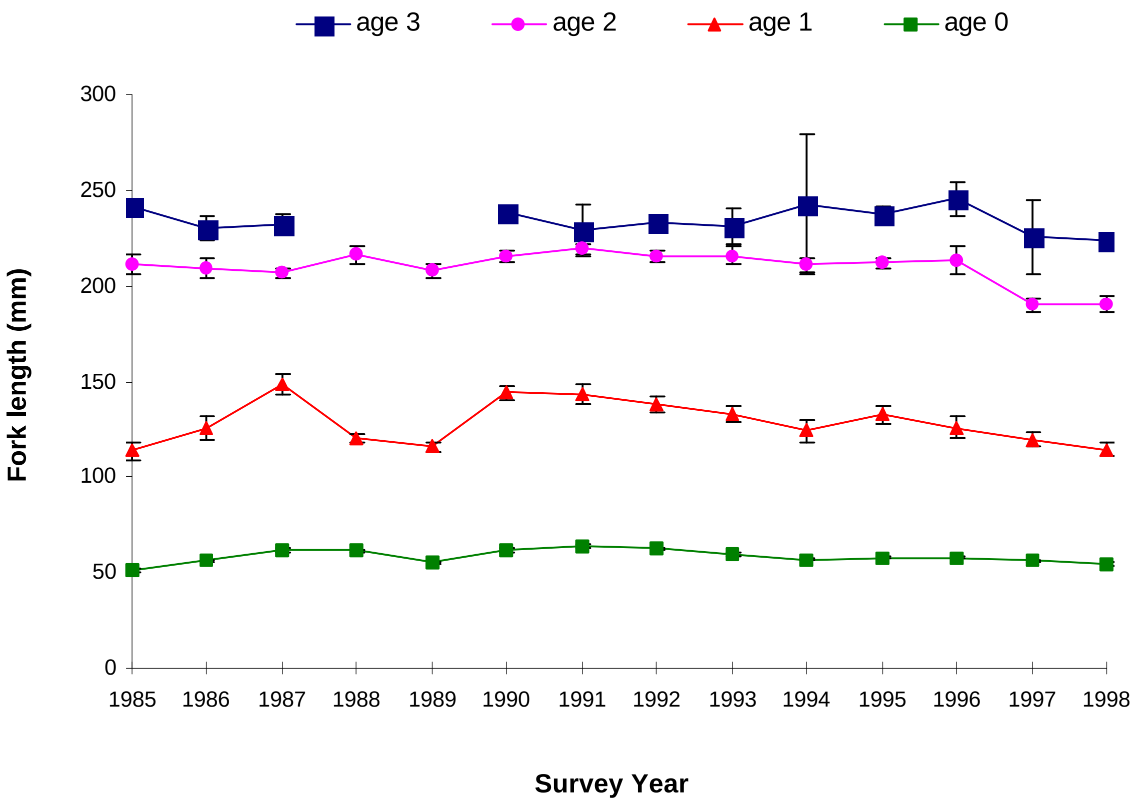

Figure 14. Kokanee mean fork length-at-age for Okanagan Lake adjusted to October 1 based on sampling 1985-1998. Adopted from Sebastian and Scholten (*in* Ashley et al. 1999).

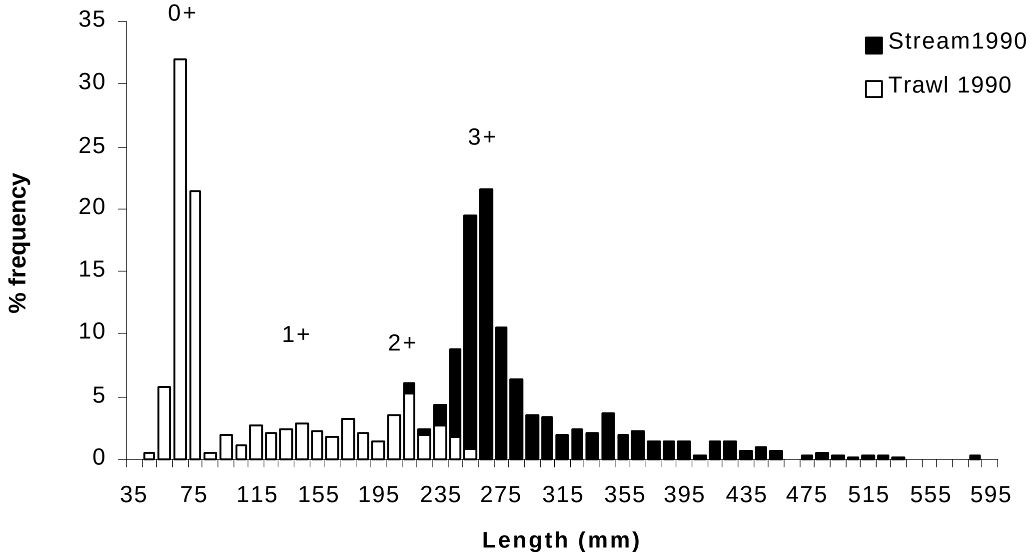

Figure 15a. Percent length frequency of Okanagan Lake kokanee captured by trawl net (white bars) plotted with % length frequency of stream spawners (black bars), 1990.

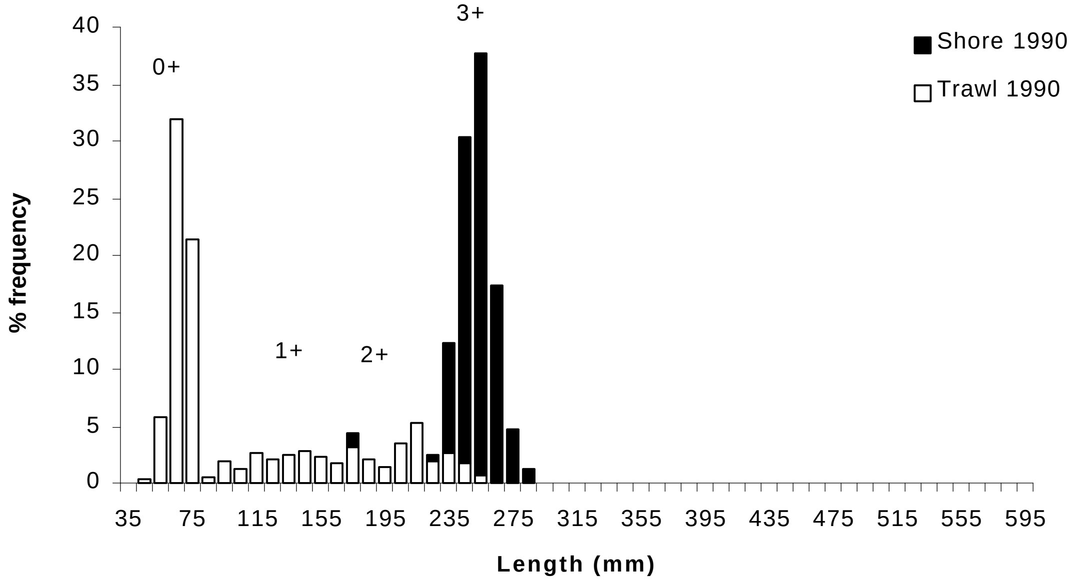

Figure 15b. Percent length frequency of Okanagan Lake kokanee captured by trawl net (white bars) plotted with % length frequency of shore spawners (black bars), 1990.

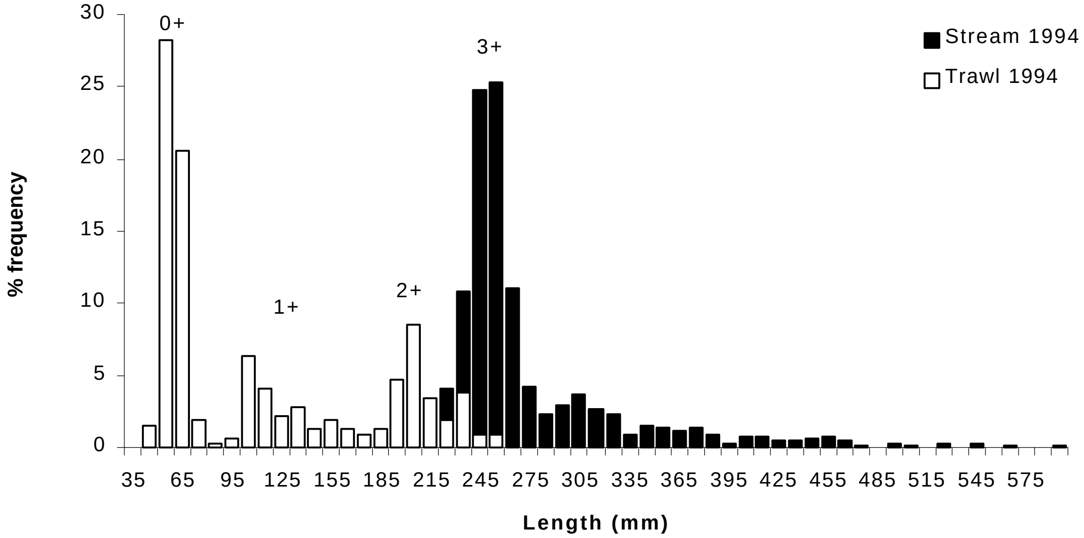

Figure 16a. Percent length frequency of Okanagan Lake kokanee captured by trawl net (white bars) plotted with % length frequency of stream spawners (black bars), 1994.

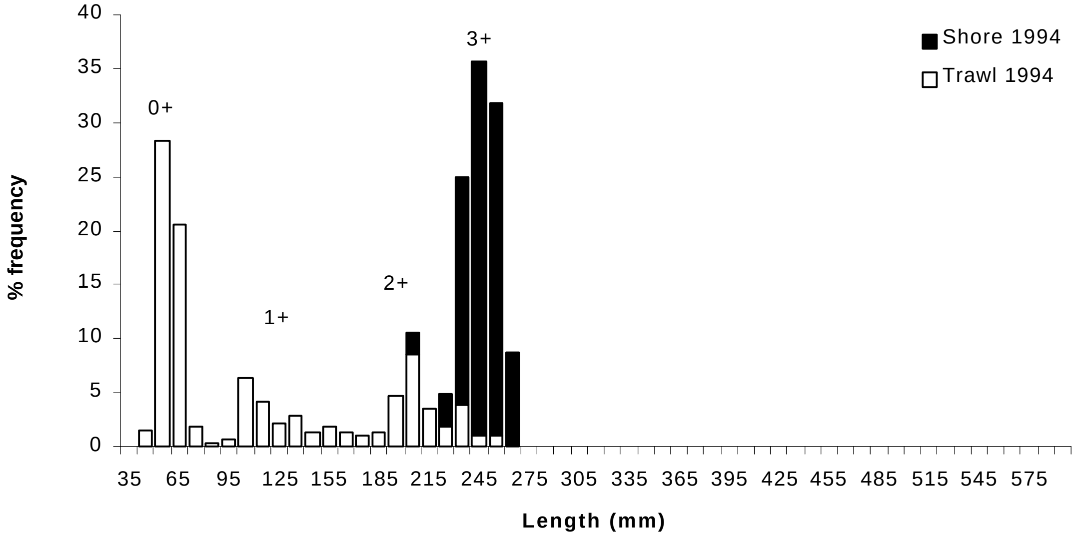

Figure 16b. Percent length frequency of Okanagan Lake kokanee captured by trawl net (white bars) plotted with % length frequency of shore spawners (black bars), 1994.

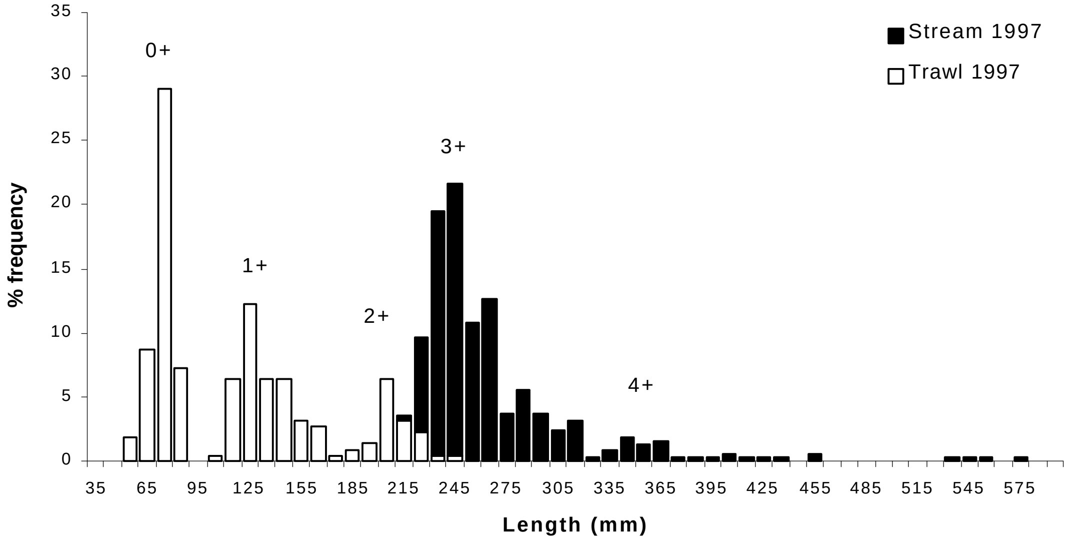

Figure 17a. Percent length frequency of Okanagan Lake kokanee captured by trawl net (white bars) plotted with % length frequency of shore spawners (black bars), 1994.

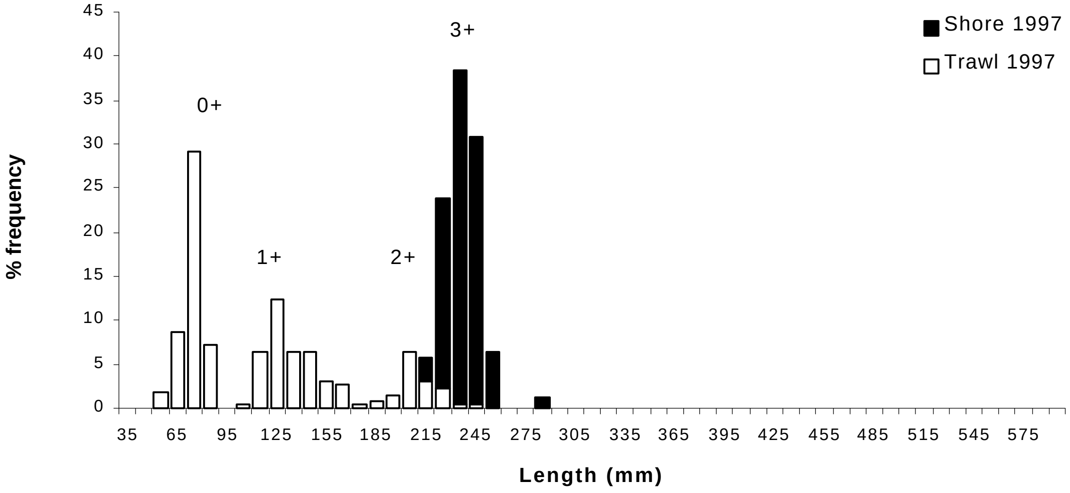

Figure 17b. Percent length frequency of Okanagan Lake kokanee captured by trawl net (white bars) plotted with % length frequency of shore spawners (black bars), 1994.

Appendix 1. Kokanee stocking history for Okanagan Lake and tributaries.

System	Location	Year	Month	Species	Stock	Life Stage	Number	Size (G)	Hatchery
Deep Creek	Vernon	1941		KO	Meadow-Creek	Eyed Egg	250,000	0.0	NEH
Deep Creek	Vernon	1943		KO	Meadow-Creek	Eyed Egg	50,000	0.0	KAH
Eneas Creek	Summerland	1930		KO	Kootenay	Eyed Egg	200,000	0.0	NEH
Kelowna Creek	Kelowna	1944		KO	Meadow- Creek.	Eyed Egg	25,000	0.0	NEH
Kelowna Creek	Kelowna	1945		KO	Meadow- Creek	Eyed Egg	25,000	0.0	NEH
Kelowna Creek	Kelowna	1946		KO	Meadow- Creek	Eyed Egg	25,000	0.0	NEH
Kelowna Creek	Kelowna	1947		KO	Meadow Creek	Fry	25,000	0.0	NEH
Kelowna Creek	Kelowna	1948		KO	Meadow- Creek	Eyed Egg	25,000	0.0	NEH
Mission Creek	Kelowna	1944		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Mission Creek	Kelowna	1945		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Mission Creek	Kelowna	1946		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Mission Creek	Kelowna	1947		KO	Meadow- Creek	Fry	100,000	0.0	NEH
Mission Creek	Kelowna	1948		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Mission Creek	Kelowna	1949		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Mission Creek	Kelowna	1973		KO	Kelowna	Eggs	868,000	0.0	SLH
Mission Creek	Kelowna	1986	10	KO	Mission	Eyed Egg	400,000	0.0	SKH
Mission Creek	Kelowna	1987	3	KO	Mission	Fry	296,756	1.5	SKH
Mission Creek	Kelowna	1987	5	KO	Meadow Creek	Fry	319,700	1.5	SKH
Mission Creek	Kelowna	1988	4	KO	Mission	Fry	60,000	2.0	SKH
Mission Creek	Kelowna	1988	4	KO	Mission	Fry	120,000	2.0	SKH
Mission Creek	Kelowna	1988	4	KO	Mission	Fry	252,000	3.0	SKH
Mission Creek	Kelowna	1988	5	KO	Meadow Creek	Fry	205,000	1.8	SKH
Mission Creek	Kelowna	1988	5	KO	Meadow Creek	Fry	231,000	1.8	SKH
Mission Creek	Kelowna	1989	4	KO	Mission	Fry	478,000	1.3	SKH
Mission Creek	Kelowna	1989	6	KO	Meadow Creek	Fry	237,600	2.2	SKH
Mission Creek	Kelowna	1989	6	KO	Meadow Creek	Fry	256,700	2.2	SKH
Mission Creek	Kelowna	1990	6	KO	Mission	Fry	465,930	3.0	SKH
Mission Creek	Kelowna	1991	6	KO	Mission	Fry	588,000	3.0	SKH
Okanagan Lake	Peachland	1928		KO	Kootenay	Fry	205,000	0.0	NEH
Okanagan Lake	Peachland	1933		KO	Kootenay-L.(W-A)	Fry	239,250	0.0	SLH
Okanagan Lake	Peachland	1934		KO	Kootenay-L.(W-A)	Fry	149,200	0.0	SLH
Okanagan Lake	Peachland	1938		KO	Meadow- Creek	Eyed Egg	700,000	0.0	NEH
Okanagan Lake	Peachland	1939		KO		Eyed Egg	590,000	0.0	NEH
Okanagan Lake	Peachland	1942		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Okanagan Lake	Peachland	1943		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Okanagan Lake	Peachland	1944		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Okanagan Lake	Peachland	1945		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Okanagan Lake	Peachland	1946		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Okanagan Lake	Peachland	1947		KO	Meadow- Creek	Fry	100,000	0.0	NEH
Okanagan Lake	Peachland	1948		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Okanagan Lake	Peachland	1949		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Okanagan Lake	Peachland	1950		KO	Meadow- Creek	Eyed Egg	100,000	0.0	NEH
Okanagan Lake	Peachland	1950		KO	Meadow- Creek	Fingerling	6,283	0.0	SLH
Okanagan Lake	Peachland	1951		KO	Meadow- Creek	Eyed Egg	50,000	0.0	NEH
Peachland Creek	Peachland	1984	5	KO	Mission	Fry	62,000	1.6	SKH
Trepanier Creek	Peachland	1941		KO	Meadow- Creek	Eyed Egg	50,000	0.0	NEH
Trout Creek	Summerland	1941		KO	Meadow- Creek	Eyed Egg	50,000	0.0	NEH
Trout Creek	Summerland	1978		KO	Mission	Unknown	130,000	0.0	SLH
Trout Creek	Summerland	1981	11	KO	Meadow Creek	Eyed Egg	895,010	0.0	KTH

NEH = Nelson Hatchery
KAH = Kootenay Hatchery
SLH = Summerland Hatchery
SKH = Skaha Hatchery

Appendix 2. Number of fish in OKFISHP.DBF having length data as of November 26, 1998.

Counts	Burbot	Carp	Brook Trout	Fine Scale Sucker	Kokanee	Large Mouth Bass	Large Scale Sucker	Longnose Sucker	Lake Trout
YEAR	**BB**	**CP**	**EB**	**FSS**	**KO**	**LMB**	**LSS**	**LSU**	**LT**
1943									
1944									
1948									
1949									
1950									
1951									
1952									
1953									
1954									
1956									
1967									
1970					1				
1971									
1974									
1975					1				
1976									
1977									34
1978					467				31
1979					635				68
1980	1				930				
1981					636				111
1982					6				
1983						1			
1984						1			
1985	5				128				
1986					193				3
1987	17				964	11			
1988	7				610	8	2		
1989					1,141				1
1990	44				2,066				1
1991	1				1,263				1
1992	18	1		2	1,618				
1993			2		590			1	
1994	24			1	1,560				
1995	1				487			3	
1996	6				418				
1997					546				
1998					214				
Total	**124**	**1**	**2**	**3**	**14,474**	**21**	**2**	**4**	**250**

Appendix 2 con't. Number of fish in OKFISHP.DBF having length data as of November 26, 1998.

Counts	Lake Whitefish	Mountain Whitefish	Mountain Whitefish	Nerka	Rainbow	Small Mouth Bass	Minnow Pike	Whitefish	Yellow -perch	
YEAR	**LW**	**MW**	**MWF**	**NK**	**RB**	**SMB**	**SQ**	**WF**	**YP**	**TOTAL**
1943					2					2
1944					3					3
1948					2					2
1949					3					3
1950					66					66
1951					229					229
1952					76					76
1953					48					48
1954					160					160
1956					19					19
1967							23			23
1970										1
1971					6					6
1974					75					75
1975					74					75
1976					127					127
1977					151					185
1978					281					779
1979					605					1,308
1980					323			3		1,257
1981					328					1,075
1982					140					146
1983					79	1				83
1984					247					248
1985					243		1			377
1986					124					320
1987	2				84	1	2			1,081
1988	2	6			146	2	18		24	825
1989					288					1,430
1990		8			306		87			2,512
1991	1				247		2			1,515
1992	2	1			275	1	17			1935
1993	1	1	2		148		1			746
1994				551	213	1	41	70		2462
1995	38				42		2			575
1996					13					437
1997										546
1998										215
Total	**46**	**16**	**2**	**551**	**5,173**	**6**	**194**	**73**	**24**	**20,972**

Appendix 2. Number of Kokanee lengths by system by year.

System	70	75	78		80	81	82	85	86	87	88	89	90	91	92	93	94	95	96	97	98	Total
Coldstrean Cr												50					50					**100**
Ellis Cr											105											**105**
Equesis Cr															50							**50**
Kelowna Cr												16			4		11					**31**
Lambly Cr															1		43					**44**
Mid Vernon Cr																	45					**45**
Mission Creek									100	201	100	97	218	56	63		351	50	50	50	34	**1370**
Mission Ch													369	570	858		294	234	185	277	15	**3200**
Naramata Cr																	22					**22**
Nashwito Cr															50							**50**
Okanagan Lake	1	1	467	635	915	628	6	116	86	429	287	637	584	336	261	102	220	51		79		**5841**
Peachland Cr												49	100	101	93		82	50	67	25	50	**617**
Penticton Cr										10		100	595	100	55		299	48	51	50	50	**1448**
Powers Cr												92	100	100	50		86	50	50	50	40	**618**
Trepanier Cr																	16					**16**
Vernon Cr																	8					**8**
Whiteman Cr															50							**50**
TOTAL	**1**	**1**	**467**	**635**	**930**	**636**	**6**	**128**	**193**	**964**	**610**	**1141**	**2066**	**1263**	**1618**	**590**	**1560**	**487**	**418**	**546**	**214**	**14474**

Appendix 2. Kokanee average lengths by system by year.

System	71[*]	75	78	79	80	81	82	85	86	87	88	89	90	91	92	93	94	95	96	97	98	Total
Coldstrean Cr	215											255					281					**268**
Ellis Cr											232											**232**
Equesis Cr	254														260							**260**
Kelowna Cr												248			231		254					**248**
Lambly Cr															265		254					**254**
Mid Vernon Cr																	345					**345**
Mission Cr	260								265	352	270	285	287	270	255		270	284	299	270	389	**289**
Mission Ch													300	289	261	255	166	295	301	168	389	**276**
Naramata Cr																	275					**275**
Nashwito Cr															246							**246**
Peachland Cr	258											281	290	265	270		313	3044	315	276	393	**297**
Penticton Cr												267	325	305	328	202	256	280	351	339	383	**300**
Powers Cr	259								324			282	265	258	265		259	258	297	259	358	**273**
Trepanier Cr	260																243					**243**
Vernon Cr																	218					**218**
Whiteman Cr															258							**258**
TOTAL	**1506**	**0**	**0**	**0**	**0**	**243**	**390**	**278**	**312**	**317**	**276**	**269**	**291**	**283**	**270**	**251**	**274**	**285**	**311**	**271**	**378**	**4283**

[*] data from Northcote et al. 1972.

Appendix 3. Estimating Kokanee Spawning Run Size From Peak Daily Counts.

Data from three separate spawning channels were used to see how consistent the relation was between peak spawner counts and the total number of spawners each year. For this comparison both peak and total fence counts were used from Hill and Redfish spawning channels. For Mission Creek spawning channel where no fence counts were available, we used total counts summarized by Andrusak (*in* Ashley et al. 1999), who use daily live and dead counts in a mathematical simulation first described by Dill (1992).

Regression through origin was used to eliminate the Y-intercept and enable direct comparison of slope estimates between the three channels. The resulting slopes can then be considered as the most appropriate expansion factor to multiply peak counts by to estimate the total run size. Separate regressions all showed slopes of approximately 1.5 (Table A). Correlation coefficients indicated very good fits for both Mission and Hill data (i.e., $r^2 = 0.88\text{-}0.90$). When one “outlier” was removed from Redfish Creek data, the fit improved considerably (Table A). Because of the similarity in “slopes” for all three regressions, it is reasonable to combine these into a single regression. The resulting regression slope was 1.49 (or 1.5 rounded) with a correlation coefficient of 0.94 (Fig. 00). For the purpose of predicting total spawner run size for kokanee based on peak stream counts, it is recommended that a factor of 1.5 be used to expand peak spawner counts, unless better on-site total counts are available. It is quite surprising how consistent this relation was from year to year, considering that it assumes a unimodal and normal distribution of the spawning run.

Table A: Comparison of slopes and correlation coefficients for peak to total spawner counts in three kokanee spawning channels (n= years of data).

	n	**slope**	**r^2**
Mission Creek	7	1.52	0.90
Hill Creek	9	1.49	0.88
Redfish Creek	10	1.53	0.53
Redfish (outlier removed)	9	1.51	0.68
Combined	**25**	**1.49**	**0.94**

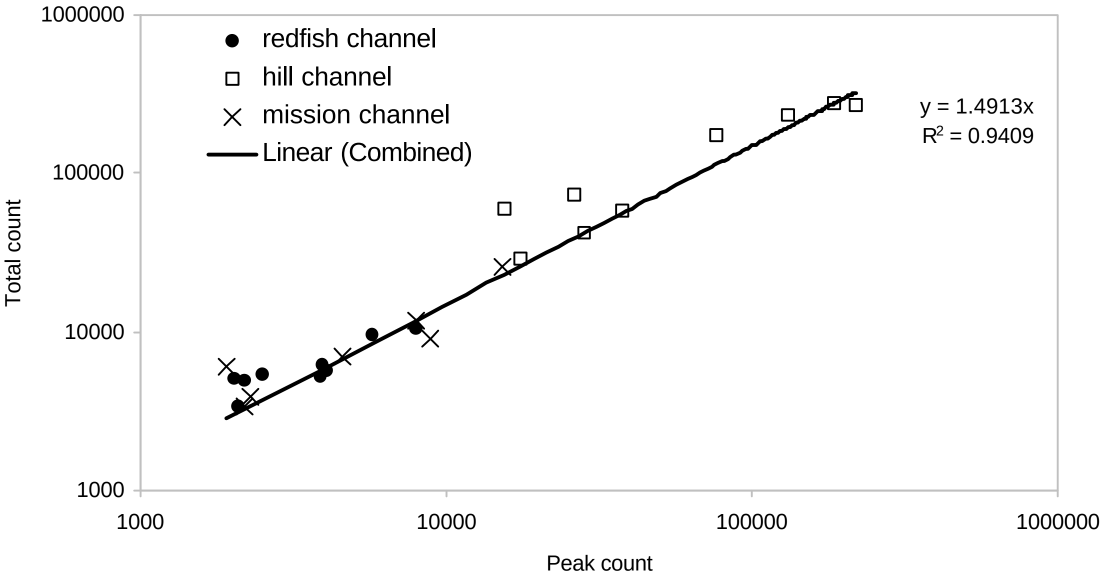

Figure 00. Relation of peak to total spawner counts for kokanee based on fence counts at Redfish and Hill Creek spawning channels and intensive stream-side counts at Mission Creek.

OKANAGAN LAKE KOKANEE STREAM SPAWNER ESCAPEMENTS
1999

by

Jason Webster[1]

INTRODUCTION

Enumeration and biological sampling of Okanagan Lake's stream spawning kokanee (O*ncorhynchus nerka*) have been on-going since the early 1970s and provides long-term trend data of the lakes' kokanee population. Since the mid 1970s there has been considerable concern for the long-term viability of Okanagan Lake kokanee. A detailed description of the problems and more information on kokanee stream spawning enumerations is described in this Okanagan Lake Action Plan (OLAP) report (see Andrusak in this OLAP report).

This particular report summarizes data collected from September 17, 1999, to and including November 10, 1999. Kokanee numbers, stream temperature, migration timing, and kokanee sampling during this escapement period are reported.

SITE DESCRIPTION

Okanagan Lake is located in the southern interior of British Columbia near the 49th parallel positioned in a north-south axis between the Monashee and Cascade mountain ranges. The lake is not fed by a major river system with inflow coming from very few tributary streams of any size. The largest tributary is Mission Creek (Map. 2). The Okanagan River flows through the south end of the lake near Penticton, British Columbia into Skaha Lake, then south through Osoyoos Lake and eventually joins the Columbia River in northern Washington. At the outlet located near Penticton, British Columbia is a small dam that effectively regulates the lake between elevations 341 m to 342.5 m (Ward et al. *in* Ashley et al. 1999).

METHODS

Enumeration

In 1999, 12 tributaries of Okanagan Lake were enumerated for spawning kokanee. They included: Vernon Creek, Shorts Creek, Lambly Creek, Kelowna (Mill) Creek, Mission Creek (and spawning channel), Powers Creek, Trepanier Creek, Peachland Creek, Eneas Creek, Prairie Valley Creek, Naramata Creek, and Penticton Creek. Trout Creek was not enumerated in 1999.

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[1] Chara Consulting Ltd., Penticton, BC.

The basic enumeration schedule did not change significantly from the previous year described by Matthews and Shepherd (*in* Ashley et al. 1999). Although the schedule was extended over a longer time period than previous years the days between counts (three), remained the same.

A survey crew conducting ground counts performed enumerations of all streams. Polaroid sunglasses and brimmed hats were worn on all counts to increase visibility and to decrease the water surface glare. Keeping the sun at the counter's back whenever possible, proved to be most effective. Because fish tend to move upstream when frightened, counting while moving downstream also proved to work well. When possible, the field crew walked along the stream banks and observed from a higher vantagepoint down onto the water surface. Hand counters (tally whackers) were used to count live and dead kokanee. Andrusak (in this OLAP report) describes the schedule of stream counts and the length(s) of stream accessible to spawning kokanee.

Water temperature was taken slightly upstream of the mouth of all the streams enumerated in 1999.

Sampling

A target number of 50 kokanee were to be sampled from Mission, Peachland, Powers, and Penticton creeks. Only carcasses in decent shape (recently dead) were collected. All fish were collected by hand or with a dip net. All carcasses collected were recorded as dead pitch or "near dead". Live capturing to fulfill sample targets numbers was not considered an option in 1999.

Once collected, all samples were placed on a portable measuring board where fork length and weight were measured. Kokanee were sexed by identification of external features and by internal examination. Maturity was recorded as "spent" for both males and females. The only exceptions were, if a significant number of retained eggs (in relation to the size of the female) were counted. In this case, maturity was noted as "ripe". Any retained eggs were counted individually from all female samples after an incision of the body wall.

Otoliths were collected from all samples of fish from Mission, Peachland, and Powers creek. An incision was made through the top of the head bisecting it as closely as possible. An otolith was then removed from the lower portion of the brain cavity with a pair of tweezers, then dipped in water and placed in a scale sample envelope. In most cases only one of the otoliths was collected.

RESULTS

Enumeration

In 1999, the estimated total of kokanee stream-spawners for Okanagan Lake was 6,322 (Table 1). This number is the sum of the 12 streams enumerated. Peak counts for each stream have been adjusted by a conversion factor of 1.5 and Andrusak (in Ashley et al. 1999) describes the rationale for this conversion.

The 1999 estimated escapement was very low compared to 1998 (7,189) and 1997 (21,200). These estimates are a far cry from the escapements of the 1970s that were several hundred thousand (see Matthews and Shepherd *in* Ashley et al. 1999 and 1998; Andrusak in this OLAP report).

Table 1. Summary of Kokanee Stream Enumerations 1999 – Okanagan Lake.

Creek Name	Temperature	# of Counts	Peak Count	Date	Adjusted Total
Vernon	10.0c	2	70	06/10/99	112
Mission	11.0c	8	1,075	18/09/99	1,613
Powers	11.0c	9	407	14/09/99	611
Trepanier	13.0c	9	303	17/09/99	455
Peachland	9.5c	9	1,105	14/09/99	1,658
Eneas	12.5c	2	18	20/09/99	27
Prairie Valley	11.0c	2	nil	26/09/99	nil
Naramata	12.0c	2	92	20/09/99	138
Penticton	14.0c	9	1,036	17/09/99	1,554
Shorts	6.0c	2	8	05/10/99	12
Kelowna	6.0c	8	1,645	03/10/99	246
Lambly	9.0c	2		29/09/99	8
Total					**6,322**

Sampling

A target number of fifty carcasses were obtained in Powers and Peachland creeks. Only 49 carcasses were found to be suitable in Mission creek, 42 from Mission Creek spawning channel, and 23 from Penticton Creek.

The mean size of 1999 Mission Creek spawners (Table 2) was considerably larger compared to other years reported by Andrusak (*in* Ashley et al. 1999). The mean size from 1971-1999 was 28.9 cm. Mean size of spawners in 1999 from Peachland, Penticton and Powers creeks were also of similar size to those from Mission Creek.

It should be noted that all carcass sampling performed in this study should be regarded as non-random sampling, due to the fact that only carcasses deemed to be in good shape were collected. All data taken from kokanee samples is stored in the BC Environment database in Penticton in file (G:\DBASE_U\DBASE\AGEGR\OKFISHP.DBF).

Table 2. Summary of Kokanee Stream Escapement Fish Sampling 1999.

Okanagan Lake

Stream	***n***	***Males* Mean (in mm)**	***Range* (in mm)**	***n***	***Females Mean* (in mm)**	***Range* (in mm)**
Peachland	14	392	235-505	36	363	228-535
Penticton	14	369	210-508	9	305	220-452
Powers	25	293	214-600	25	313	209-470
Mission	33	360	224-538	17	378	222-538

ACKNOWLEDGEMENTS

A special thanks goes to Dan Taylor for his substantial involvement in this project. Also, thanks go to Jeff Niehaus for his help on enumerating Mill Creek.

REFERENCES

Ashley, K., Bruce Shepherd, Dale Sebastian, Lisa Thompson, Lidija Vidmanic, Dr. Peter Ward, Hansen A. Yassien, Laurie McEachern, Rick Nordin, Dr. Dave Lasenby, Janice Quirt, J.D. Whall, Dr. Peter Dill, Dr. Eric Taylor, Susan Pollard, Cecilia Wong, Jan den Dulk, George Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch

Ashley, K.A., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor A. Kuiper, P.M. Troffe, C. Wong, and G. Scholten. 1999. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. 78. Province of British Columbia Ministry of Fisheries, Fisheries Management Branch.

OKANAGAN LAKE KOKANEE SHORE SPAWNER ESCAPEMENTS

1999 Brood

by

Dave Smith[1]

INTRODUCTION

This is a summary report of a component of a long-term data set for kokanee populations in Okanagan Lake that has been conducted continuously since 1971. Kokanee escapements are based on visual observations and sources of error can be highly variable year to year (see Thompson, *in* Ashley et al. 1998). The shore estimates should be used as trend over time, not total number estimates.

METHODS

Except where identified otherwise, the following survey procedures have been used since the 1970s (described by Shepherd *in* Ashley et al. 1998). The standard method has been to run a boat parallel to the shoreline at 800-1200 RPM parallel to the 3-4 m depth contour. The numbers of spawners inshore of this point are estimated visually by MELP Fisheries staff with previous survey experience. Estimates were made separately for reaches designated by landmarks on aerial photographs, and then, summed by quadrant (Fig. 1).

Shore Spawner Surveys

Visual observations and counts of shore spawning kokanee were conducted using four methods in 1999. The standard boat counts used for detailed enumeration and distribution were conducted twice for quadrants with kokanee present, October 17 to 20 and October 26 and 27. These counts were supplemented with aerial overflights on October 15 and 25, and November 1. Alternate day land-based observations were also made at known shore spawning locations at Paul's Tomb and Bertram Creek Park (Map 2; Fig. 1) from October 1 to November 4. Further, periodic reports from landowners with property adjacent to known shore spawner locations were received, from October 15 to November 15. The aerial flight data is useful in giving a more instantaneous distribution of kokanee shore spawners. During the three flights in 1999 observations were conducted between 09:30h and 11:00h. The aerial flights and reports from the public were useful for confirming initiation and completion of shore spawning.

During the standard boat counts, water temperature (ºC) was measured (by hull-mounted thermistor), and presence or absence of fish on the electronic sounder were noted when spawning

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[1] MELP Fisheries Branch, Penticton, BC.

groups were observed. The presence or absence information gave an indication of kokanee that were not enumerated since any kokanee seen on the sounder would not be included in the onshore count.

The boat counts were conducted after reviewing the information from each aerial flight to ensure the boat crew was focussing on reaches that showed active shore spawning. Aerial flights also covered reaches not observed by boat to confirm absence of kokanee shore spawning. Figure 1 illustrates the standardized quadrants and assigned reaches used for shore spawning enumeration. The first boat enumeration began in the NE quadrant on October 17 (Reaches 23 to 45), NW quadrant on October 18 (Reaches 51 to 63) and October 19 (Reaches 64 to 75). The SE quadrant was enumerated October 19 (Reaches 4 to 7) and October 20 (Reaches 8 to 22a).

The second pass boat count was initiated October 26, NE quadrant (Reaches 24 to 45) and NW quadrant (Reaches 59 to 68). On October 27, SE quadrant (Reaches 4 to 22a) and NW quadrant (Reaches 74 and 75). All daily observations were made between 09:00h and 16:30h.

RESULTS AND DISCUSSION

An estimated peak count of 78,000 shore spawning kokanee was made for 1999, the highest since 1989 (Appendix 1). Peak index estimates showed the SE quadrant accounted for 43.7% of the total fish counted, while the NE was 21%, and the NW was 35.3% respectively. The timing of shore spawning was typical of the pattern observed in most years; kokanee started spawning about October 14th, and continued until about October 29th. Locations of spawning sites within the reaches coincided with previously known sites and habitat. Interestingly, there were some sites used in 1999 where spawning kokanee have not been observed for 10 years or more.

Fish behavior was also quite typical, in that onshore schooling behavior of spawning groups was unaffected by the observer's boat unless the vessel was extremely close to shore. In fact, wading activity only caused fish to move ~7 m away along shore. Spawning was observed in both northern quadrants prior to the onset of spawning in the SE quadrant, which is atypical of conventional timing in most years.

Surface temperature measurements taken during boat counts show that spawning activity occurred between 14.2 ^{o}C, and 11.9 ^{o}C with the SE quadrant consistently cooler than the two north quadrants (Appendix 1).

Fish numbers declined by 41% between count 1 and count 2. Some reaches showed a slight increase in fish numbers during the second count indicating a variation in timing between some spawning sites. During count 2, most of the spawning kokanee were displaying signs of lethargy and erosion marks on fins and body. A second observation that also suggests spawning was nearly completed during count 2 involved comparison of echo sounder target intensity at sites where kokanee schools could be observed offshore. During count 1 kokanee schools were not all located along the shore shallow shoreline (<1 m depth). Many orientated at the drop off zone (~5 m) where they were seen on the echo sounder. Near completion of shore spawning, the kokanee schools associated with the drop off were less evident. Enumeration offshore kokanee schools were estimated to be 75% of the count 1 spawning groups onshore, but only 32% of the count 2 spawning groups.

The aerial flights confirmed that shore spawning had not started in the SE quadrant on October 15th, but was in progress on the NE and NW quadrants. The October 25th flight indicated that spawner distribution was still limited to the reaches that were being enumerated by boat. Some NW, SW, and SE quadrant shoreline reaches normally not used by shore spawners were observed by air to confirm they were still void of kokanee.

During the November 1st flight no kokanee shore spawning was observed confirming the earlier visual observations from the two fixed land sites that no kokanee spawners were present after October 29.

Lake Levels for Brood 99

At the 50% milestone for spawning, October 21, the lake level was 341.822 (m above sea level). The operational plan currently used by MELP Water Management Branch has an October 15 target of 341.920 m; and the corresponding February 1 target of 341.770 m. The water level for initiating impacts on incubating kokanee eggs or alevins has been calculated at 341.53 m on March 1 (Dill 1997).

REFERENCES

Ashley, K., B.Shepherd, D. Sebastian, L. Thompson, L. Vidmanic, Dr. P. Ward, H.A. Yassien, L. McEachern, R.Nordin, Dr. D. Lasenby, J. Quirt, J.D. Whall, Dr. P. Dill, Dr. E. Taylor, S. Pollard, C. Wong, J. den Dulk, G. Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Province of British Columbia. Ministry of Fisheries. Fisheries Management Branch.

Dill, P.A. 1997. A Study of Shore-Spawning Kokanee Salmon (*Oncorhynchus nerka*) at Bertram Creek Park, Okanagan Lake, BC, Fall 1996. Report prepared for BC Environment, Penticton, B.C.

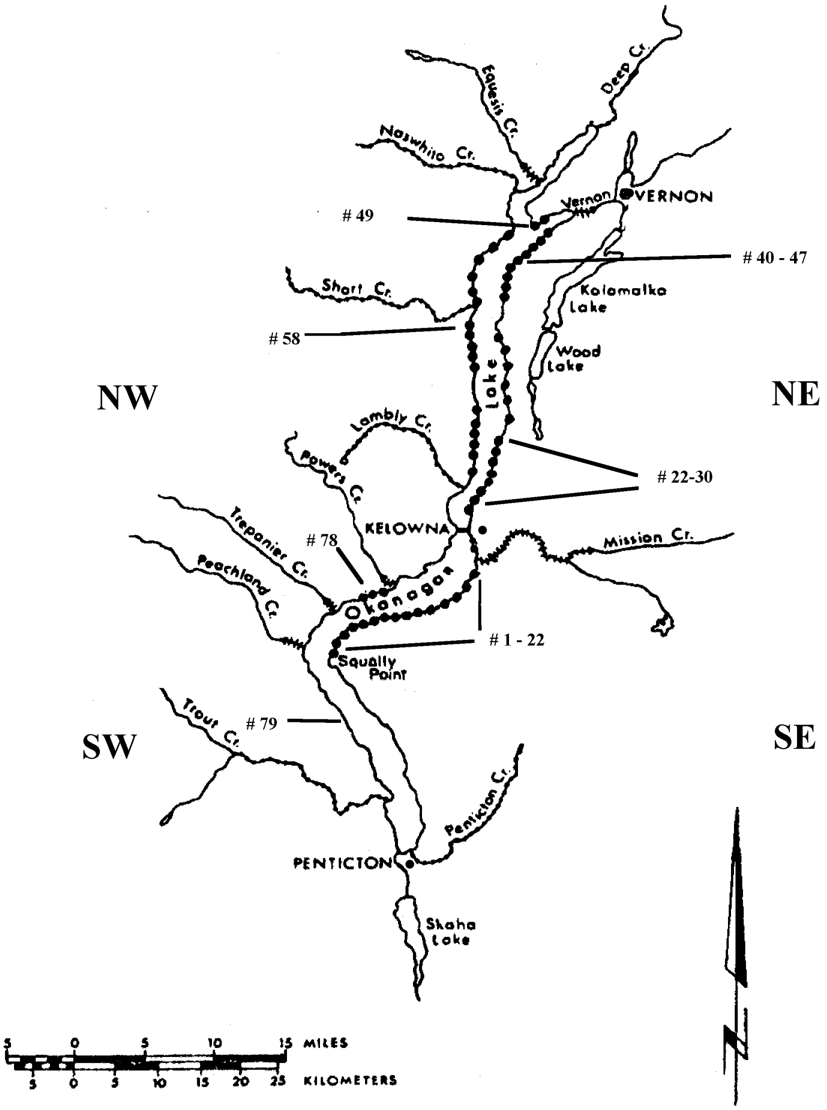

Figure 1. Location of shore spawning sites in the Northwest (50-77), Northeast (22-49), Southeast (L-22) and Southwest (79) quadrants of Okanagan Lake.

Appendix 1. Okanagan Lake Shore Spawner Enumeration - 1999.

		Boat Counts				Temperature (C)	
		Oct.17-20	Oct.26-27	1999			
Quadrant	**Reach No.**	**Count 1**	**Count 2**	**PEAK**	**C2/C1x100**	**Count 1**	**Count 2**
SE	4	200	400	400			
SE	5	0	1,100	1,100			
SE	6	1,200	500	1,200			
SE	7	0	500	500			
SE	8	2,000	700	2,000			
SE	9	2,400	1,800	2,400			
SE	10	2,800	1,600	2,800			
SE	11	1,300	600	1,300			
SE	12	3,900	900	3,900			
SE	13	800	900	900			
SE	14	2,700	0	2,700			
SE	15	1,400	300	1,400			
SE	16	1,200	500	1,200			
SE	17	800	200	800			
SE	18	6,900	1,100	6,900			
SE	19	1,100	400	1,100			
SE	20	1,200	700	1,200			
SE	21	1,500	600	1,500			
SE	22a	200	600	600			
TOTAL		**31,600**	**13,400**	**33,900**	42.40%	12.2 to 12.7	11.9 to 12.2
NE	23	0	*	0			
NE	24	0	1,200	1,200			
NE	25	0	300	300			
NE	26	0	*	0			
NE	27	0	*	0			
NE	28	0	*	0			
NE	29	0	*	0			
NE	30	0	*	0			
NE	31	0	*	0			
NE	32	0	*	0			
NE	33	0	*	0			
NE	34	2,600	1,900	2,600			
NE	35	100	50	100			
NE	36	700	0	700			
NE	37	700	25	700			
NE	38	1,600	0	1,600			
NE	39	0	*	0			

Appendix 1 con't. Okanagan Lake Shore Spawner Enumeration - 1999.

		Boat Counts					
		Oct.17-20	**Oct.26-27**	**1999**		**Temperature (C)**	
Quadrant	**Reach No.**	**Count 1**	**Count 2**	**PEAK**	**C2/C1x100**	**Count 1**	**Count 2**
NE	40	4,000	25	4,000			
NE	41	0	0	0			
NE	42a	1,500	1,200	1,500			
NE	42b	200	700	700			
NE	43	0	200	200			
NE	44	0	0	0			
NE	45	2,700	700	2,700			
TOTAL		**14,100**	**6,300**	**16,300**	44.60%	13.5 to 14.2	12.7
NW	51	250	*	250			
NW	52	0	*	0			
NW	53	25	*	25			
NW	54	0	*	0			
NW	55	450	*	450			
NW	56	200	*	200			
NW	57	*	*				
NW	58	*	*				
NW	59	4,100	2,200	4,100			
NW	60	600	200	600			
NW	61	3,500	700	3,500			
NW	62	0	*	0			
NW	63	7,800	1,300	7,800			
NW	64	3,800	3,900	3,900			
NW	65	2,200	1,600	2,200			
NW	66	2,400	100	2,400			
NW	67	300	100	300			
NW	68	1,500	25	1,500			
NW	69	0	*	0			
NW	70	25	*	25			
NW	71	0	*	0			
NW	72	*	*	*			
NW	73	0	*	0			
NW	74	0	0	0			
NW	75	100	0	100			
TOTAL		**27,250**	**10,125**	**27,350**	37.20%	13.5 to 14.0	12.6 to 12.7
GRAND TOTAL		**72,950**	**29,825**	**77,550**	40.90%		

* denotes reach not enumerated

CHAPTER 3

LONG-TERM APPLIED RESEARCH

This component of the Action Plan involves results of on-going research that has been specifically directed at problems associated with Okanagan lake kokanee. Work reported in 1997 and 1998 has been completed and or terminated in favor of research that appears to have some promise of success. The genetic technique developed for differentiating the two stocks of kokanee in the lake is a good example of research that now has practical application. There is now cautious optimism about the experimental mysid fishery and more effort is planned for this research work in 2000.

REVIEW AND CONCLUSIONS OF ASSESSMENTS TO GENETICALLY DISCRIMINATE BETWEEN STREAM AND BEACH SPAWNING KOKANEE IN OKANAGAN LAKE

by

S. Pollard[1]

INTRODUCTION

Okanagan Lake supports two co-existing spawning types or ecotypes of kokanee, beach spawners and stream spawners. Beach spawning kokanee utilize some specific sites along the shoreline described by Dill (*in* Ashley et al. 1998). Stream spawning kokanee migrate up several of the lake's major tributaries to spawn (see Andrusak 2000 in this action plan report).

Until the mid 1990s the genetic relationships between the two ecotypes and among the various spawning locations were unknown. Studies have demonstrated genetic differences between sympatrically occurring kokanee and sockeye (Taylor et al. 1996; Foote et al. 1989; Winans et al. 1996). Varnavskaya et al. (1994) have noted differences between beach and stream spawning sockeye while Burger and Spearman (1997) describe differences between inlet and outlet spawning sockeye. Genetic differences have also been observed between some early- and late-run sockeye (Wilmot and Burger 1985;Varnavskaya et al. 1994). However, very little information exists for genetic variation among kokanee populations within watersheds. The only known study within British Columbia was an unpublished report to the Ministry of Environment, Nelson which noted some genetic differences exist among kokanee collected from different locations in Kootenay Lake (University of Montana 1994, MS).

Annual enumeration of spawning kokanee is essential to estimating population size and trend analysis in Okanagan Lake. Spawner counts on major contributing streams are fairly reliable (Dale Sebastian, Victoria, BC Fisheries, pers comm.) and also provide a good index to evaluate fluctuations over time. However, a combination of variable weather conditions, poor understanding of spawning cues (e.g., time of day, preferred habitat) and shoreline length, make beach spawner estimates unreliable. While these counts may provide an index to measure major changes over time (in terms of magnitudes), they cannot be used to estimate yearly population size. One alternative to determining relative beach spawner numbers would be to estimate relative contributions of the two ecotypes to the non-spawning lake population where both ecotypes co-exist. Sebastian and Scholten (*in* Ashley et al. 1999) have sampled the mixed lake population(s) using a trawl net since the late 1980s but have been unable to distinguish between the two stocks based on phenotypic differences. In order to estimate relative contributions of this mixed population, some method of differentiation is required. Given that potentially many different spawning units (or populations) within ecotypes exist, and that it is impossible to

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account for all of these populations in a baseline sample, distinguishing characters should be at the ecotype rather than the populations level.

To address this issue, several studies have been conducted since 1994 to evaluate the utility of phenotypic and or genetic markers that can consistently (i.e., spatially and temporally) differentiate the two spawning ecotypes. Specifically, two questions were considered:

- Does Okanagan Lake contain one or more genetically distinct populations? If there is more than one population, are these organized so that differences between ecotypes are greater than differences among populations within ecotypes?
- If ecotypes are genetically differentiated, are the differences great enough to allow genetic stock identification of a mixed non-spawner lake sample?

Sample Collections

Appendix 1 summarizes all kokanee samples used in genetic and morphological analyses. Stream spawning kokanee were seined or captured in a portable trap. Beach spawning kokanee were all beach seined. Juvenile trawl samples were captured in night trawl nets in 1994, 1998 and 1999. All kokanee samples were sacrificed and placed immediately on ice for further analyses. Tissue sampling for DNA analyses occurred within 8 hours of capture.

REVIEW OF STUDY RESULTS

A summary of genetic related studies on Okanagan Lake kokanee is provided in Appendix 2. The following is a review and updated interpretation of these studies.

1. Taylor et al. (1997)

In 1994, a preliminary assessment of genetic variation of kokanee in Okanagan Lake was conducted to determine the viability of using genetic markers or morphological features to distinguish the two spawning ecotypes in the system. Three independent genetic markers were applied including:

- allozymes (enzymatic proteins that are the product of functional nuclear DNA genes);
- mitochondrial DNA restriction fragment length polymorphisms (RFLP's - applying restriction enzymes that cut mtDNA at particular recognition sites resulting in DNA fragments of different lengths); and
- minisatellite nuclear DNA loci (repeating units of non-coding DNA that vary in length or number of repeats). Nuclear markers are biparentally inherited (and undergo recombination) while mtDNA is maternally inherited (and does not undergo recombination).

In addition, several morphological features were measured or counted – these features were selected based on the likelihood of being associated with variation in spawning behaviour.

Although variable, neither nuclear DNA marker (allozyme or minisatellite) differentiated populations or ecotypes. In contrast, significant differences in the frequencies of mtDNA haplotypes (maternal genotypes) were observed between ecotypes but not among populations. At the very least, there appeared to be restricted female-mediated gene flow between ecotypes. However, the majority of both stream and beach spawners shared a common haplotype (90.7% in stream spawners and 88.9% in beach spawners) making stock identification using this genetic marker impossible (Table 1).

Little morphological variation was consistently observed between ecotypes. Sexual dimorphism seemed to be greater within populations than differences among ecotypes. While anal fin ray counts were slightly higher in stream spawners (on average, 0.6 more rays) than beach spawners, this difference was not great enough to provide reliable separation of the two ecotypes.

2. Taylor et al. (2000, in press)

By 1997, a highly discriminatory molecular genetic marker, microsatellite nuclear DNA, became widely available for application to fish. At the same time, the Okanagan Lake Action Plan was established with one activity endorsed to pursue stock identification of the two kokanee ecotypes. This provided the impetus for more evaluation of genetic tools for application in kokanee stock identification.

The 1997 study evaluated both genetic and phenotypic variation between ecotypes. Given the significant differences between spawning sites and the potential for very distinct selective environments, one might expect a divergence in phenotypes associated with spawning ecology and early developmental biology. Phenotypic variation was examined by comparing early developmental rates of both beach and stream spawning kokanee under relatively constant lab conditions (7.5^{o}C in Heath tray incubators at UBC) to determine if time to 50% hatch or emergence differed. Genetic differentiation was measured by resolving variation at several microsatellite DNA loci. Simulated mixture analyses were conducted, and variation at loci was also measured in the 1994 trawl sample to assign individuals to ecotypes.

Developmental studies indicated that the beach spawners were significantly smaller than two stream spawner populations and that beach spawner eggs were smaller than stream spawner eggs (Table 2). Families with larger eggs tended to hatch faster than those with smaller eggs but this correlation was not significant ($r=0.26$, $P>0.05$). Once egg size was accounted for, there appeared to be population differences, but not ecotype differences in time to 50% hatch. However, beach spawners had slightly faster developmental rates from hatching to emergence as measured by yolk absorption compared to stream spawners ($P<0.001$). This difference persisted when initial egg size was accounted for. In-situ subgravel temperature profiles suggested that even though beach spawning occurs approximately 3-4 weeks after stream spawning, beach spawner embryos experienced more ATUs (accumulated thermal units) over a 6 month period (October 16 to April 16) than did stream spawner embryos over a 7 month period (September 16 to April 16) for 1997-1998.

Genetic results indicated that significant variation existed within ecotypes (12/13 pairwise comparisons were significant) and between ecotypes (18/18 pairwise comparisons were significant). Allelic frequency distributions did not suggest any recent genetic bottlenecks had occurred, at least none at the magnitude to be observed using these microsatellite loci. Simulated mixture analyses (using 20 randomly selected kokanee and 50 simulations to understand variance around estimates) assigned individuals to their correct ecotype on average 70% of the time, where predicted proportions were within an average of 11% of true proportion. An analysis of the 1994 trawl estimated that 92% of the sample was of beach spawner origin.

In summary, these results indicated that microsatellite analysis could estimate proportions within the mixed lake population provided estimates required did not need to be very precise. These estimates could provide a general idea of relative contributions on a year-to-year basis.

3. Nelson and Raap, Seastar Biotech Inc. (1999, MS)

A future analysis was conducted in 1999 using microsatellite loci to increase sample size and include more recent trawl samples. This analysis was conducted under contract with Seastar Biotech Inc. Since a slightly different technique was applied to evaluate variation at loci all samples from Taylor et al (*in* Ashley et al. 1999) were re-analyzed.

Similar to Taylor et al. (1999, draft MS), significant variation was observed both among populations and between ecotypes. Simulations (using 150 fish and 500 simulations) indicated that proportions of beach and stream spawners could be estimated within a reasonable degree of certainty (predicted within 1-9% of true value). A bias towards overestimation of beach spawners occurred which was very pronounced when stream spawners made up a large majority of the sample. This was similar to what Taylor et al. (*in* Ashley et al. 1999) found and was probably due to Mission Creek fish dominating the stream spawner sample and also because Mission Creek fish appeared to be genetically intermediate between the other stream populations and the beach populations.

Assessment of the 1998 and 1999 trawl samples suggested quite different relative contributions. In 1998, the beach component made up 61% (s.d. 8%) of the mixture whereas in 1999, it only made up 27% (s.d. 12%) of the mixture (Table 3). Although sample sizes were small and there was some error around these estimates, results suggested a major change in contribution between years. This change may be real reflecting a significant decrease in beach spawners from 1994 to 1997. However, it may also be partially an artifact of poor sample size.

4. Ritchie and Haas (1999, MS)

The second morphological study considered 5 meristic traits from the 1997 spawner samples. Univariate analyses found no single character was able to discriminate between the ecotypes or populations. Multivariate analyses using principle component analysis found any differences between ecotypes only occurred between Mission Creek and Paul's Tomb spawners. Peachland Creek spawners could not be distinguished from beach spawners. Generally, too much overlap of trait values existed among groups to be useful in field assessments.

CONCLUSIONS

Microsatellite DNA analysis can provide estimates of stock composition to differentiate between stream and beach spawners. These estimates are not extremely precise (amount of variance associated with estimate) or accurate (difference between true and mean predicted value) at present and may contain some bias towards overestimation of beach spawners. However, they can provide some level of precision (i.e. within 10%) and could be useful to follow yearly trends. While significant morphological variation exists within Okanagan Lake kokanee, the variation in the traits measured or counted to date are not informative at the ecotype level. It appears that many of the morphological differences existed at the population level or between sexes.

RECOMMENDATIONS

- Shore and stream spawning estimates should continue in combination with further genetic analysis to better determine the contribution of the two ecotypes.

- Microsatellite DNA analysis appears to provide reasonable estimates of contributing ecotypes in mixture analyses. However, given that most of the informative variation is occurring at 1 or 2 microsatellite loci, it is advisable that more loci be tested to improve the resolution of the technique. This would reduce the error around estimates and possibly reduce the bias.

- It is possible that full representation of the two ecotypes in the baseline has not been examined. For example, only one year of a small sample from Powers Creek fish were examined. It is recommended that populations be represented by at least 50, preferably 100 individuals. This will improve resolution to some degree.

- Resolution in mixture analyses improves as sample size of mixed group increases. A recommended minimum is 50 per group. Below this, error increases significantly. It would be useful to consider (a) contributions of different age groups (b) contributions from different areas in the lake. Sample size must be adjusted accordingly if these groupings are considered.

- At a cost estimate of approximately $10K, it is recommended that the above recommendations be implemented in the year 2000.

REFERENCES

Ashley, K., Bruce Shepherd, Dale Sebastian, Lisa Thompson, Lidija Vidmanic, Dr. Peter Ward, Hansen A. Yassien, Laurie McEachern, Rick Nordin, Dr. Dave Lasenby, Janice Quirt, J.D. Whall, Dr. Peter Dill, Dr. Eric Taylor, Susan Pollard, Cecilia Wong, Jan den Dulk, George Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Ashley, K.A., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor A. Kuiper, P.M. Troffe, C. Wong, and G. Scholten. 1999. Okanagan Lake Action Plan Year 3 (1998) Report. Fisheries Project Report No. 78. Province of British Columbia Ministry of Fisheries, Fisheries Management Branch.

Burger, C.V. and W. J. Spearman. 1997. Genetic Differentiation of Sockeye Salmon Subpopulations from a Geologically Young Alaskan Lake System. Trans. Am. Fish. Soc.

Foote, C.J., C.C. Wood and R.E. Withler. 1989. Biochemical Genetic Comparison of Sockeye Salmon and Kokanee, the Anadromous and Nonanadromous Forms of *Oncorhynchus nerka*. Can. J. Fish. Aquat. Sci. 46:149-158.

Nelson, J. and M. Raap. Seastar Biotech Inc. 1999, MS. Okanagan Lake Kokanee Microsatellite DNA Genetic Analysis: Population Structure and Mixed Stock Analysis of Samples From 1998 and 1999. Unpublished Report to the Ministry of Fisheries, Victoria.

Ritchie, L. and G. Haas. 1999, MS. Unpublished Report to the Ministry of Fisheries, Victoria on Application of Meristic Techniques to Identify Okanagan Lake Kokanee Ecotypes.

Taylor, E.B., C.J. Foote and C.C. Wood. 1996. Molecular Genetic Evidence for Parallel Life-history Evolution Within a Pacific Salmon (Sockeye Salmon and Kokanee, *Oncorhynchus nerka*). Evolution 50:401-416.

Taylor, E.B., S. Harvey, S. Pollard and J. Volpe. 1997. Postglacial Genetic Differentiation of Reproductive Ecotypes of Kokanee, *Oncorhynchus nerka* in Okanagan Lake, British Columbia. Molecular Ecology 6:503-517.

Taylor, E.B., A. Kuiper, P.M. Troffe, D. Hoysak and S. Pollard. 2000. Variation in Developmental Biology and Microsatellite DNA in Reproductive Ecotypes of Kokanee (Oncorhynchus nerka): Implications for Declining Populations in a Large British Columbia Lake. Conservation Genetics (in review).

University of Montana. 1994, MS. Unpublished Report to British Columbia Ministry of Environment, Nelson, Describing Allozyme Variation in Kokanee Collected from Kootenay Lake.

Varnavskaya, N.V., C.C. Wood, R.J. Everett, R.L. Wilmot, V.S. Varnavsky, V.V. Midanaya and T.P. Quinn. 1994. Genetic Differentiation of Subpopulations of Sockeye Salmon (*Oncorhynchus nerka*) Within Lakes of Alaska, British Columbia, and Kamchatka, Russia. Can.J. Fish. Aquat. Sci. 51 (Suppl. 1):147-157.

Wilmot, R.L. and C.V. Burger. 1985. Genetic Differences Smong Populations of Alaskan Sockeye Salmon. Trans. Am. Fish. Soc. 114:236-243.

Winans, G.A., P.B. Aebersold and R.S. Waples. 1996. Allozyme Variability of *Oncohynchus nerka* in the Pacific Northwest, with Special Consideration to Populations of Redfish Lake, Idaho. Trans. Am. Fish. Soc. 125:645-663.

Table 1. Proportion (in %) of mitochondrial DNA haplotypes among populations and between ecotypes (from Taylor et al. 1997).

	Mission Creek	Peachland Creek	Powers Creek	**Stream Total**	Okanagan Centre	Squally Point	**Beach Total**	Trawl Sample
Haplotype								
AA	82.8	89.7	100	**90.7**	85.2	92.6	**88.9**	90.7
BA	0	0	0	**0**	11.1	7.4	**9.3**	5.6
CA	0	0	0	**0**	3.7	0	**1.9**	0
AB	17.2	10.3	0	**9.3**	0	0	**0**	3.7
N total	*29*	*29*	*28*	***86***	*27*	*27*	***54***	*54*

Table 2. Comparisons of mean spawner body size (using all 1997 spawner samples), egg size and developmental rates among kokanee populations based on 24 full-sib families (i.e., 48 spawners) Taylor et al. (1999, draft MS). Standard errors in brackets.

Population	**N**	**Fork Length (cm)**	**N**	**Egg Weight (mg)**	**Atu To 50% Hatch**	**% Yolk at 1000 ATU**
Paul's Tomb - beach	79	22.8 (0.12)	11	43.3 (2.5)	682 (7.4)	7.1 (0.6)
Mission Cr. - stream	60	26.5 (1.0)	10	49.8 (4.7)	712 (13.2)	11.4 (1.4)
Peachland Cr. - stream	43	32.4 (0.54)	10	61.3 (4.7)	674 (7.5)	14.2 (1.3)

Table 3. Mixed stock analysis of Okanagan Lake trawl samples collected in 1998 and 1999. (From Seastar Biotech Inc. 1999). Bracketed numbers indicate samples successfully analyzed.

Sample	**N**	**% Stream**	**% Beach**	**S.D.**
1998 – 0+	71 (46)	58	42	13
1998 – 1+	71 (59)	26	74	10
1998 – 2+	32 (28)	34	66	17
1998 - total	174 (133)	39	61	8
1999 - total	56 (56)	71	27	12

Appendix 1. Summary of samples used.

Population	***1994 samples*** **morphology**	***1994 samples*** **allozymes**	***1994 samples*** **mtDNA**	***1994 samples*** **minisatellites**	***1997 samples*** **morphology**	***1997 samples*** **microsatellites UBC 1994 samples in ( )'s**	***1997 samples*** **microsatellites SeaStar 1994 samples in ( )'s**
Mission Cr. mainstem - stream	97	97	29	25	0	0 (21)	0 (92)
Mission Cr. channel - stream	0	0	0	0	25	43	43 (37)
Peachland Creek - stream	31	31	29	29	25	38 (22)	55 (31)
Powers Creek – stream	36	36	28	33	0	0 (22)	0 (34)
Okanagan Centre – beach	30	50	27	23	0	0 (20)	0 (49)
Squally Point – beach	30	49	27	25	0	0 (22)	0 (50)
Paul’s Tomb - beach	0	0	0	0	50	40	63
trawl 1994	0	72	54	0	0	50	0
trawl 1998	0	0	0	0	0	0	174
trawl 1999	0	0	0	0	0	0	56
TOTAL	**224**	**559**	**154**	**135**	**100**	**278**	**684**

Appendix 2. Summary of studies.

Year of Study	Report Reference	Characters Used	Key Findings
1994	Taylor, E.B., S. Harvey, S. Pollard and J. Volpe. 1997. Postoglacial genetic differentiation of reproductive ecotypes of kokanee *Oncorhynchus nerka* in Okanagan Lake, British Columbia. Molecular Ecology 6:503-517.	1. Morphology: 2 meristics (gill rakers and anal fin rays) and 9 morphological measurements (fork length, orbit diameter, upper jaw length, snout length, head length, had depth, pectoral fin insertion to insertion of dorsal fin, caudal peduncle depth). 2. 18 enzyme loci (allozymes - nuclear DNA products). 3. Mitochondrial DNA (full length) restriction fragment length polymorphisms (RFLP's) using 6 enzymes. 4. 2 nuclear DNA minisatellite loci.	1. No consistent differences except that anal fin rays tended to be higher in stream spawners. 2. 4 loci were variable; none differentiated ecotypes. 3. 2 enzymes were polymorphic producing significant differences in frequencies between ecotypes; not enough variation for stock identification. 4. No significant differences were observed between ecotypes.
1997	Ritchie, L. and G. Haas. 1998. Unpublished report to Ministry of Fisheries to compare morphological traits between kokanee ecotypes (contract).	1. 5 meristics: vertebrae (x-rayed),anal fin rays, pectoral fin rays, branchiostegal rays (left and right), and pelvic fin rays.	1. Univariate analyses revealed no single character that could discriminate among ecotype or population. 2. Multivariate analyses using PCA could only discriminate between Mission Cr. and Paul's Tomb – Peachland could not be distinguished from beach spawners.

Appendix 2 con't. Summary of studies.

Year of Study	Report Reference	Characters Used	Key Findings
1994, 1997	Taylor, E.B., A. Kuiper, P.M. Troff, D. Hoysak, and S. Pollard. 1999. Nested analysis of biodiversity within a lake ecosystem: phenotypic and genetic differentiation between reproductive ecotypes of kokanee, *Oncorhynchus nerka*. To be submitted to *Conservation Genetics* in January 2000.	1. Early developmental rates at a set temperature (7.5^{o}C) including measures of egg size, time to hatch (50%), time to emergence (measured by yolk remaining). 2. 8 nuclear DNA microsatellite loci (using denaturing gels).	1. Beach spawners produce significantly smaller eggs; no difference between ecotypes at 50% hatch; beach spawners appeared to develop faster from hatch to emergence; thermal regime measured in 1997/8 indicated that beach spawners experience more ATU's over a 6 month period than stream spawners over a 7-moth period. 2. All 8 loci were variable; significant pairwise differences were observed among populations (within ecotypes) and among ecotypes; populations did not appear to have undergone any recent genetic bottlenecks; simulated mixtures indicated that stream spawners could accurately be classified 71% of time and beach spawners 68% of time – averaging 11% difference between predicted and actual proportions in known mixture; assessment of 1994 trawl indicated 92% was of beach spawner origin.
1997	Nelson, J. and M. Raap, SeaStar Biotech. Unpublished report to Ministry of Fisheries. Okanagan Lake kokanee microsatellite DNA genetic analysis: population structure and mixed stock analysis of samples from 1998 and 1999.	1. 4 nuclear DNA microsatellite loci (non-denaturing gels).	1. 2 loci discriminated between ecotypes; simulations indicated that estimated proportions were within 1-9% of actual proportion, with a bias when stream spawners made up majority of mixture; analysis of 1998 trawl (n=174) indicated stream-39% and beach-61% and 1999 trawl (n=56) stream-71% and beach-27%.

COMPARISON OF THE TROPHIC ROLE OF THE FRESHWATER SHRIMP *(Mysis relicta)* IN TWO OKANAGAN VALLEY LAKES, BRITISH COLUMBIA

by

J.D. Whall[1] and D. Lasenby[1]

INTRODUCTION

The recent collapse of Okanagan Lake kokanee (*Oncorhynchus nerka*) has instigated an intensive sampling regime of the freshwater opossum shrimp *Mysis relicta*, a known zooplanktivore and potential competitor with this valuable sport fish (Ashley et al. 1999; Johannsson et al. 1994). This study compares the distribution, abundance and bioenergetics of *M. relicta* from Okanagan Lake and Kalamalka Lake. Kalamalka Lake has similar morphometry and species composition but supports a viable kokanee population. The following research program was initiated in an attempt to answer three questions regarding *M. relicta* in Okanagan and Kalamalka lakes: 1) is there a difference in the caloric requirements of mysids between the two lakes?; 2) is there a difference in mysid impact on resident zooplankton populations in both lakes?; and, 3) is there a difference in mysid trophic position between lakes?

Previous Okanagan Lake Action Plan (OLAP) reports (Ashley et al. 1998; 1999) recorded the distribution, abundance, life history, *in situ* feeding habits and trophic relationships of *Mysis relicta* in Okanagan and Kalamalka lakes (Whall and Lasenby *in* Ashley et al. 1998; 1999). This report summarizes the estimated caloric requirements and predatory impacts on selected zooplankton by mysids in both study lakes.

METHODS

A more complete description of experimental methods used is in the Okanagan Lake Action Plan Year 2 Report (Whall and Lasenby *in* Ashley et al. 1998).

Zooplankton Production Estimates

In the absence of a detailed lake productivity assessment, estimates of daily zooplankton production were derived from daily production/biomass (P/B) ratios using empirical models of Shuter and Ing (1997) for copepods and Stockwell and Johannsson (1997) for cladocerans. This combination of approaches was used as it provided the best approximation of production estimates calculated from the *in situ* egg ratio method (Stockwell and Johannsson 1997; Johannsson 1999, pers comm.). Estimates of daily production were assumed to be constant throughout the monthly sampling period.

For all zooplankton dry weight estimates, average monthly values were derived from the Kootenay Lake database for 1995 (Thompson and Ashley 1997), as complete seasonal

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zooplankton mass estimates for Okanagan Lake were not available. Since zooplankton masses were only determined for the growing period from April to October in the Kootenay Lake database production estimates for Okanagan and Kalamalka lakes were also restricted to this period.

Mysid Bioenergetic Requirements

Energetic requirements of mysids were modelled for each age cohort (Yr0, Yr1M, Yr1F, Yr2M and Yr2F) for all months for which mysids were collected. Observed growth patterns and temperature data for Stations #OK3 and KA2 were chosen to approximate deep-site mysid energy requirements within each lake (Map 2). To estimate population requirements, energetic requirements from all cohorts were summed for the duration of each sampling period. The Bioenergetics Model (Hanson et al. 1997) was used to calculate the consumption of specific mysid cohorts. The model requires as input data temperatures at which mysids are found, diet proportions of prey items, mysid energy densities, prey energy density, sampling period, and mysid weight at the beginning and end of the sampling period. Details of how these were determined can be found in Whall (2000, MS).

Mysid Population Impacts

Mysid population consumption estimates based on *in situ* clearance rate experiments were used to estimate the amount of zooplankton removed from the water column throughout the year.

Clearance rates from the Yr0 mysids were applied to the average number of mysids present in the Yr0 cohort using the mean zooplankton density, and the total available time for feeding in the meta- and epilimnion. The average number of zooplankton removed $\cdot\ m^2$ per sampling interval was then determined for each lake. Similarly, clearance rates from the Yr1 mysids were applied to the appropriate proportions of Yr1 and Yr2 male and female mysids to estimate the average number of zooplankton removed $\cdot\ m^2$ for each mysid cohort present throughout the year. Consumption estimates from each cohort were then summed to give a total population impact for each sampling interval.

Mysid Gut Content Analysis

Mysid gut contents from both lakes were examined for zooplankton mandibles to provide an independent check of potential food sources and to assess potential mysid consumption over a single evening. Gut contents of the ten largest (2nd year cohort) and ten smallest (1st year juvenile cohort) mysids captured at 04:00 h (August 1997 stage hauls) were compared to three similar sized individuals from each cohort captured at the beginning of the diurnal migration into the metalimnion at 20:00 h.

For each mysid, the gut packet was isolated from the body, placed on a glass slide in a drop of glycerine, homogenized and then viewed under a microscope at 100X. For each gut, rotifer genera and each zooplankton mandible type (calanoid, cyclopoid, *Daphnia* and *Diaphanasoma*) were tallied. Differences between the mean number of mandibles found in the gut at 04:00 h and the mean number at 20:00 h were attributed to feeding over the 8 h period.

Stable Isotope Analysis: Mysid Trophic Positioning

Food web collections for August 1997 and June 1998 stable isotope results were outlined in Whall and Lasenby (*in* Ashley et al. 1999).

Trophic positions (TP) were determined from an assumed $\delta^{15}N$ difference of 3.4‰ between predator and prey (Minegawa and Wada 1984; Wada *et al*. 1993; Cabana and Rasmussen 1994; and Vander Zanden *et al*. 1997), with TP1 being equal to the $\delta^{15}N$ signature of phytoplankton in the lake where $TP_{mysid} = (1/3.4)\ (\delta^{15}N_{mysid} - \delta^{15}N_{phytoplankton}) + 1$ (modified from Wada et al. 1993).

RESULTS

Zooplankton Production Estimates

Mean daily production during a complete growing season (April to October 1997) showed a seasonal peak in August for Okanagan Lake (Fig. 1a) and July in Kalamalka Lake (Fig. 1b). In both lakes, *Cyclops* and *Daphnia* are on average, the most productive taxa, followed by *Diaptomus* or *Diaphanasoma* and then *Epischura.*

There does not appear to be a consistently significant trend in the difference in the average daily production for individual zooplankton taxa between the two lakes. Differences between lakes were not significant for *Epischura*, *Cyclops* and *Daphnia* (I-Way ANOVA, $P \geq 0.092$), while *Diaptomus* production was significantly greater in Okanagan Lake (1-Way RM ANOVA, $F_{1df} = 8.01$, $P = 0.015$), and *Diaphanasoma* production was significantly greater in Kalamalka Lake (Friedman RM ANOVA on Ranks, $\text{Chi-square}_{1df} = 6.40$, $P = 0.022$).

Mysid Bioenergetic Analysis

Individual Mysid Caloric Requirements

Following brood pouch release in December (Okanagan Lake) and February (Kalamalka Lake), mean Yr0 mysid energy consumption rate (calories · mysid · day) determined by the bioenergetics model peaked by August then decreased slightly throughout the fall (Fig. 2). Periods of greatest increase in caloric intake for Yr1 cohorts generally occurred during the growing season between March and August (Fig. 2). With the exception of Yr2 females in March 1997, there was little difference in the daily caloric requirements of Yr2 mysids in either lake between 1997 and 1998 (Fig. 2).

For both lakes, the overall mean daily caloric intake per mysid over the year increased with cohort age (Table 1). The difference in mean daily caloric intake between lakes was not significant for Yr0 mysids (Friedman RM ANOVA on Ranks, $\text{Chi-square}_{1df} = 2.63$, $P = 0.105$). However, intake was significantly higher for Yr1 male mysids in Kalamalka Lake (Friedman RM ANOVA on Ranks, $\text{Chi-square}_{1df} = 10.20$, $P = 0.001$) and Yr1 female mysids in Okanagan Lake (Friedman RM ANOVA on Ranks, $\text{Chi-square}_{1df} = 119.67$, $P \leq 0.001$; note: insufficient samples to compare Yr2 mysids). In both Okanagan and Kalamalka lakes the greater mean body size of Yr1 females relative to Yr1 males resulted in significantly greater mean daily caloric requirements for females (Table 1; Friedman RM ANOVA on Ranks, Chi-square_{1df} = 264.99 and 169.89, for Okanagan and Kalamalka lakes respectively, $P < 0.001$).

Table 1. Mean daily and total annual caloric requirements determined from bioenergetics modelling for individual mysids according to age cohort during the period from March 1, 1997 to February 28, 1998 in Okanagan and Kalamalka lakes.

Cohort	**Mean # Calories Mysid Day (± S.E.) Okanagan**	**Kalamalka**	**Total # Calories/Mysid/Year Okanagan**	**Kalamalka**
Yr0	0.25 (0.01)	0.29 (0.01)	91.5	104.6
Yr1 male	1.18 (0.03)	1.10 (0.01)	429.6	403.0
Yr1 female	1.61 (0.03)	1.27 (0.02)	586.1	463.1
Yr2 male	1.26 (0.00)	1.05 (0.02)	110.8	55.8
Yr2 female	1.71 (0.02)	1.45 (0.02)	224.2	164.1
Total lifetime male			631.9	563.4
Total lifetime female			901.8	731.8

When comparing the sum of daily calories required by mysids in Okanagan and Kalamalka lakes, males will consume 30% and 23% fewer calories (respectively) than females over the course of their lives (Table 1). In total, an average male mysid in Okanagan Lake will consume 12% more calories than in Kalamalka Lake and an average female in Okanagan Lake will consume 23% more calories than in Kalamalka Lake (Table 1).

Average mysid clearance rates for Yr0 and Yr1 and 2 cohorts were applied to mean whole-lake zooplankton densities to determine whether individual mysids were capable of fulfilling their energetic requirements by feeding solely on metalimnetic zooplankton during their diel feeding migration. Daily caloric intake for an individual mysid determined from clearance rates were only similar to bioenergetically derived caloric intake estimates for Yr0 mysids from the time of release until April in 1997 and from release until March in 1998 (Fig. 2). On average, mysid *in situ* clearance rate intake estimates of zooplankton calories accounted for ≤ 40% for Yr0 and ≤ 10% for Yr1 and Yr2 cohorts of bioenergetically derived mysid requirements over the course of the study.

Mysid Population Caloric Requirements

The average caloric daily intake from each sampling period was combined with mean whole-lake mysid densities to determine caloric demand by the mysid population $\cdot$ m^{2} (Fig. 3). The mean total population impact (± S.E.) on zooplankton calories removed between August 1996 and June 1998 in Kalamalka Lake (343.7 ± 46.8 cal $\cdot$ m^{2} $\cdot$ day) was greater than mysids in Okanagan Lake (273.6 ± 23.5 cal $\cdot$ m^{2} $\cdot$ day), but was not significant between lakes (Friedman 1-Way RM ANOVA, Chi-square$_{1df}$ = 0.39, *P* = 0.532). There was however, a significant increase in mean daily caloric demand (± S.E.) in Okanagan Lake between the periods of August 1996 to June 1997 (210.4 ± 26.4 cal $\cdot$ m^{2} $\cdot$ day) and August 1997 to June 1998 (340.7 ± 31.1 cal $\cdot$ m^{2} $\cdot$ day; 1-way ANOVA, F$_{1df}$ = 10.2, *P* = 0.005). Mean daily caloric demands during the same periods in Kalamalka Lake also increased (267.5 ± 52.2 cal $\cdot$ m^{2} $\cdot$ day vs. 357.5 ± 49.8 cal $\cdot$ m^{2} $\cdot$ day), but were not significantly different (1-way ANOVA, F$_{1df}$ = 1.56, *P* = 0.226).

Mysid Population Impacts on Zooplankton Production

Estimates of mysid consumption of zooplankton production were determined using *in situ* clearance rate results and bioenergetic modelling based on mean mysid population sizes to calculate the percentage of daily zooplankton production removed from April to October 1996 to 1998. According to clearance rate-derived consumption estimates for both lakes the average impact on zooplankton production over the modelled periods was greatest on *Diaptomus*, followed by either *Epischura* (Okanagan Lake) or *Diaphanasoma* (Kalamalka Lake), then *Cyclops* and finally *Daphnia* (Fig. 4). Mysid impact on *Daphnia* and *Diaphanasoma* production was greatest at the beginning and end of the summer when cladoceran abundance was lowest (Fig. 4). Although Kalamalka Lake mysids were capable of consuming >100% of daily *Diaphanasoma* production, mysid impact on daily cladoceran production was on average ≤ 38% in Kalamalka Lake and ≤ 20% in Okanagan Lake (Fig. 4).

When comparing mysid impact on production between lakes for each taxon, the average percentage of daily production removed over the modelled months was lower in Okanagan Lake than Kalamalka Lake (Fig. 4). This difference between lakes, however, was not significant for all taxa (*Epischura*, *Cyclops*, *Daphnia*: 1-Way RM ANOVA, F$_{1df}$ ≥ 1.671, *P* ≥ 0.221; *Diaphanasoma*: Friedman RM ANOVA on Ranks, Chi-square$_{1df}$ = 6.40, *P* = 0.109) with the exception of *Diaptomus* (1-Way RM ANOVA, F$_{1df}$ = 5.82, *P* = 0.033). Therefore, it appears that mysids were not removing significantly more zooplankton production from Okanagan Lake than Kalamalka Lake.

The use of bioenergetically derived consumption estimates for the mysid population revealed similar consumption trends to those derived from clearance rates (Fig. 5). With the exception of a significantly greater proportion of *Diaptomus* copepod production being consumed in Kalamalka Lake relative to Okanagan Lake (1-Way RM ANOVA, F$_{1df}$ = 3.40, *P* = 0.090), there was no clear indication that mysids in either lake were consuming a consistently greater proportion of daily zooplankton production. However, what becomes immediately obvious is the increase in scale of consumption. Only *Daphnia* and *Epischura* did not consistently have more than 100% of their estimated daily production removed by mysids using bioenergetically derived consumption estimates (Fig. 5).

Mysid Gut Content Analysis

Gut contents revealed that both Yr0 and Yr1 mysids contained rotifer remains (*Keratella* and *Kellicotia spp*.) and zooplankton mandibles in their guts (Table 2). Although not quantified, mysids taken at the start of their ascent (20:00 hr collections) were found to contain more sediment and detrital material in their guts than those collected at 04:00 h.

Table. 2. Average number of zooplankton mandibles and rotifers (± S.E.) found in the guts of Okanagan and Kalamalka lake mysids collected at 04:00 h attributed to a single night's feeding (n = 10 mysids per group).

	Mean # Mandibles and Rotifers Per Mysid Gut Sample			
Prey Type	**Okanagan Yr0**	**Kalamalka Yr0**	**Okanagan Yr1**	**Kalamalka Yr1**
Calanoids	0.27 (0.43)	2.50 (0.80)	1.07 (0.92)	1.30 (1.98)
Cyclopoids	0.30 (0.15)	0.90 (0.91)	12.93 (3.30)	17.67 (4.63)
Daphnia	5.57 (1.72)	0.77 (0.62)	37.53 (5.46)	9.67 (2.90)
Diaphanasoma	0.00 (0.00)	3.27 (0.79)	0.00 (0.00)	2.43 (2.53)
Bosmina	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.50 (0.40)
Rotifers	0.30 (0.15)	7.97 (1.44)	0.20 (0.68)	1.57 (0.67)
Total mean # of mandibles (excl. rotifers) =	6.13 (1.78)	7.43 (1.48)	51.53 (6.44)	31.57 (6.35)
Mean length of mysids (mm) =	6.5 (0.23)	7.5 (0.23)	15.4 (0.39)	15.4 (0.22)

With the exception of Yr1 mysids in Kalamalka Lake, cladoceran mandibles were found in greater quantities than copepod mandibles (Table 2). In the larger Yr1 cohorts from both lakes, substantially more cyclopoid mandibles were found in the guts than calanoids. The total mean number of zooplankton mandibles found in the guts of Yr1 mysids were greater than the smaller Yr0 mysids by a factor of 2.4 and 2.1 in Okanagan and Kalamalka lakes, respectively. Comparison of total mean mandible abundance showed little difference between lakes for Yr0 mysids, while Yr1 mysids in Okanagan Lake contained 63% more mandibles per gut than similarly sized mysids in Kalamalka Lake (Table 2).

To determine which prey taxa were selected, Vanderploeg and Scavia's Selectivity Coefficient Index (Lechowicz 1982) was applied to the mean number of items found in the guts of each mysid cohort. W-values for prey taxa range from 0 to 1with W < 0.20 (= 1/5 food items) indicating predator avoidance and W > 0.02 indicating a feeding preference for that taxa. W-values ranged from 0.01 to 0.11 for copepods, generally indicating fairly strong selection against these potential prey, while cladocerans were generally highly selected for (range = 0.00

to 0.98; Fig. 6). *Bosmina* were absent in Okanagan Lake samples and the 0.00 W-values for *Diaphanasoma* in Okanagan Lake and *Bosmina* in Kalamalka Lake were likely a result of the low abundance of these potential prey items in the lake relative to other prey. Their overall abundance in the top 45 m was ≤ 0.18 animals· L, compared to up to 12 cyclopoids· L determined for both lakes.

Stable Isotope Analysis – Mysid Trophic Positioning

Calculations of mean mysid trophic position based on differences in $\delta^{15}N$ between mysids and phytoplankton showed that for both sampling periods, Kalamalka Lake mysids occupied a significantly higher trophic position than those in Okanagan Lake over all size categories (independent t-tests, $t_{4df} \leq -5.512$, $P \leq 0.005$; Figs. 7 a, b). Estimates of trophic position tended to increase with mysid size category from small to large. Okanagan Lake mysids ranged in mean trophic position from 2.3 to 2.4 for August 1997 and 1.9 to 2.5 for June 1998. In Kalamalka Lake mysids exhibited a wider range in trophic positions from 2.5 to 3.3 in August 1997 and June 1998 (see Whall and Lasenby *in* Ashley et al. 1999 for details).

DISCUSSION

Mysid Impact on Zooplankton Abundance

Mysid impact on the abundance of prey populations in Okanagan Lake appears to be relatively similar to, or less than, that of Kalamalka Lake. Average mysid daily consumption estimates resulted in a total mysid impact of ≤ 1% of each species' population removed per day for all prey groups except *Diaphanasoma* (< 4%) (Whall and Lasenby *in* Ashley et al. 1999). These levels of consumption are similar to Kootenay Lake mysids where kokanee populations have increased again (Ashley *et al*. 1997). Smokorowski (1998) determined that mysids in Kootenay Lake were able to remove between 2 to 4% of the total available zooplankton standing crop per day. In Lake Michigan an observed *Daphnia* mortality due to mysid predation of generally < 1% per day would be insufficient to control the daphnid population with a mean estimated *Daphnia* birth rate of ~ 10%· d^1 (Lehman et al. 1990). Although birth rates of daphnid populations in Okanagan and Kalamalka lakes are not known, mysids were not capable of consuming more than 60% of their estimated daily production (Fig. 4) and therefore are not likely to be responsible for completely restricting the *Daphnia* population.

Impact on Total Zooplankton Calories

Mean daily mysid caloric consumption· m^2 in Okanagan Lake was less than in Kalamalka Lake but increased in both lakes between August and June 1996-1997 to 1997-1998, following increased mysid abundance. With the exception of Kalamalka Lake mysids in July 1997, peak caloric demand on the zooplankton population in both lakes was similar to that found during the summer and fall months in Lake Ontario at just under 600 calories· m^2· day (Johannsson *et al*. 1994).

Impact on Zooplankton Production

Data from this study does not support the original hypothesis that mysid impact on zooplankton production would be significantly greater in Okanagan Lake than Kalamalka Lake. In general, mysids removed comparable or less zooplankton production in Okanagan Lake than in Kalamalka Lake. Using clearance rates to estimate consumption, at no point in this study did mysids in either lake remove more than 60% (generally < 20%) of daily *Daphnia* production. Only during the October 1997 and May 1998 sampling periods were mysids in Kalamalka Lake capable of removing more than 100% of *Diaphanasoma* production. However, even then *Diaphanasoma* were still present the following month (June 1998), indicating that mysids were not capable of completely removing the population.

Although bioenergetically derived estimates of zooplankton production removal also showed no significant differences between lakes it is apparent that either overestimation of mysid consumption or underestimation of zooplankton production occurred. Consumption often greatly exceeds 100% of daily production and would therefore theoretically eliminate the prey populations from the lake. In a similar study, Rand et al. (1995) also found that bioenergetic consumption estimates for planktivorous forage fish in Lake Ontario feeding on zooplankton and mysids exceeded their best estimates of prey production by a factor of 1.7 and 2.0, respectively. It is possible that by estimating zooplankton production from mid-lake pelagic locations only, production available for lake-wide consumption may be underestimated as near-shore zones may provide critical nursery areas for zooplankton (Rand *et al*. 1995). A strong inverse relationship between cladoceran abundance and depth was found in a deep (max. depth = 112 m) tropical lake (Lewis 1980). Future Okanagan Lake zooplankton production estimates should include regular collections along a transect from near-shore to offshore to determine whether a gradient in zooplankton biomass exists.

It is not known what level of zooplankton production removal by mysids would be required to significantly diminish zooplankton populations in Okanagan or Kalamalka lakes. Johannsson et al. (1994) determined that mysids residing between 150–200 m depths were capable of removing a significant proportion of daily epilimnetic zooplankton production (between 30% in July and 85% in October). Clearly, mysids potentially compete with planktivorous fish for zooplankton.

Detailed *in situ* estimates of zooplankton production are traditionally done using the egg-ratio method therefore the models used here can only be considered an approximation of actual zooplankton productivity. One limitation of the empirical zooplankton production models used is that they are sensitive to changes in zooplankton length-weight relationships which may differ between systems and/or time according to available food quality and quantity (Stockwell and Johannsson 1997). This factor, combined with potentially high variability in zooplankton collection means that production estimates within a factor of 5 to 10 of true production may be the best anyone can expect (Stockwell and Johannsson 1997).

The co-existence of *Daphnia thorata* in lakes with *Mysis relicta* has been attributed to the life history characteristics of these zooplankton. Spencer et al. (1999) also found that despite great susceptibility to mysid predation in the spring and early fall, *D. thorata* populations persisted in Flathead Lake due to the presence of an overwintering diapause stage whereby the cladoceran would produce resting eggs. Spencer et al. (1999) also reports the use of thermal refugia by *D. thorata*, which would effectively isolate them from mysid predation. However, it is unlikely that thermal refugia play a critical role in preserving cladoceran populations in Okanagan and Kalamalka lakes. Vertical distribution profiles of mysids and *Daphnia* in Okanagan and Kalamalka lakes show that the two populations do overlap in the top 10 m at night. Stomach content data also showed that mysids did have access to *Daphnia* during their nighttime feeding cycle during a thermally stratified period (August 1997).

Insights from stable isotopes

Data from this study does not support the original hypothesis that mysid trophic position (TP) in Okanagan Lake would be significantly greater than that of Kalamalka Lake. Indeed, the opposite was determined to be the case. The magnitude of difference between lakes is somewhat surprising given that daily caloric requirements as determined from bioenergetics modelling were very similar between lakes, especially for the smaller Yr0 cohort (Table 1).

Higher trophic positions in Kalamalka Lake would indicate that individual mysids in this lake consumed greater amounts of zooplankton relative to Okanagan Lake mysids. Based on caloric intake estimates from *in situ* feeding trials larger Yr1 mysids in Kalamalka Lake consumed marginally more calories per day (x ± S.E. = 0.11 ± 0.01 cal/mysid/d) than those in Okanagan Lake (x ± S.E. = 0.10 ± 0.01 cal/mysid/d). Smaller Kalamalka Lake Yr0 mysids consumed less (x ± S.E. = 0.04 ± 0.01 cal/mysid/d) than Okanagan Lake (x ± S.E. = 0.07 ± 0.01 cal/mysid/d). In addition, comparison of zooplankton mandibles found in the mysid guts, (Table 2) revealed that Kalamalka Lake mysids generally contained similar amounts of copepods, fewer *Daphnia* and more *Diaphanasoma* and rotifers.

Kling et al. (1992) found that inclusion of microheterotrophs (such as rotifers) may influence food chain lengths in Arctic lakes. If the greater amounts of rotifer remains in Kalamalka Lake mysid guts is an indication of relative lake abundance (no known quantitative comparisons exist), then their inclusion in the planktonic food web may serve to lengthen the food chain, and therefore, increase TP estimates for zooplankton feeding on them. Both copepods and *Daphnia* in Kalamalka Lake exhibited greater δ^{15}N signatures relative to POM than ones in Okanagan Lake.

A possible confounding factor in the interpretation of trophic positioning results is the potential for temporal variations in phytoplankton N signatures. Yoshioka et al. (1994) attributed seasonal declines in phytoplankton δ^{15}N in June and August in a eutrophic lake to blooms of the blue-green algae *Anabaena*, which contains isotopically lighter nitrogen. As phytoplankton samples in both Okanagan and Kalamalka lakes were dominated by blue-greens such as *Lyngbya limnetica* and *Anabaena* spp. (Jensen *in* Ashley et al. 1999), future isotope studies should take into account possible temporal variability in phytoplankton.

There appears to be isotopic evidence that mysids were feeding on different food sources according to their stage in life. With the exception of Okanagan Lake in August 1997, large mysids were enriched in δ^{15}N relative to small mysids by ~ 2 ‰ which results in an elevated TP estimation for large mysids of 0.6 to 0.8 compared to the smaller mysids. This nitrogen isotope enrichment in larger mysids likely represents a shift in diet to incorporate a greater proportion of the more enriched zooplankton food source relative to POM. This ontogenetic shift corresponds to the greater clearance rates on zooplankton found in larger mysids in this study (Whall and Lasenby *in* Ashley et al.1999) and the generally greater abundance of zooplankton mandibles found in the guts of Yr1 mysids over the Yr0 cohort (Table 2).

CONCLUSIONS

Comparison of mysid impact on zooplankton populations did not support the original hypotheses that impact would be significantly greater in Okanagan Lake than Kalamalka Lake. As individual mysid energetic requirements were found to be higher in Okanagan Lake, the greater consumption in Kalamalka Lake must be due to mysid abundance in this lake. Impact calculations show that mysids are exerting mortality pressure on zooplankton comparable to other deep oligotrophic or mesotrophic systems. Due to the similarities in limnology and basin morphometry between lakes, it is unlikely that Kalamalka Lake kokanee would have a competitive advantage in using mysids as a food source (e.g., the West Arm of Kootenay Lake) over Okanagan Lake. Therefore, it is unlikely that mysid competition for zooplankton alone can fully account for the kokanee decline in Okanagan Lake.

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REFERENCES

Ashley, K, L. Thompson, D. Lasenby, L. McEachern, K. Smokorowski and D. Sebastian. 1997. Restoration of an Interior Lake Ecosystem: the Kootenay Lake Fertilization Experiment. Water Qual. Res. J. Can. 32: 295-323.

Ashley, K., Bruce Shepherd, Dale Sebastian, Lisa Thompson, Lidija Vidmanic, Dr. Peter Ward, Hansen A. Yassien, Laurie McEachern, Rick Nordin, Dr. Dave Lasenby, Janice Quirt, J.D. Whall, Dr. Peter Dill, Dr. Eric Taylor, Susan Pollard, Cecilia Wong, Jan den Dulk, George Scholten. 1998. Okanagan Lake Action Plan Year 1 (1996-97) and Year 2 (1997-98) Report. Fisheries Project Report No. RD 73. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch.

Ashley, K., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, G. Scholten, M. Zimmerman, P. Epp, V. Jensen, R. Finnegan. 1999. Okanagan Lake Action Plan Year 3 (1998-99) Report. Fisheries Project Report No. RD 78. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch, Victoria BC.

Cabana, G. and J.B. Rasmussen. 1994. Modelling Food Chain Structure and Contaminant Bioaccumulation Using Stable Nitrogen Isotopes. Nature. 372: 255-257.

Hanson, P., T. Johnson, D. Schindler and J. Kitchell. 1997. Fish Bioenergetics 3.0 for Windows. University of Wisconsin Sea Grant Institute. Madison, Wisconsin, USA.

Johannsson, O., L. Rudstam and D. Lasenby. 1994. *Mysis relicta*: Assessment of Metalimnetic Feeding and Implications for Competition with Fish in Lakes Ontario and Michigan. Can. J. Fish. Aquat. Sci. 51: 2591-2602.

Kling, G., B. Fry and W.J. O'Brien. 1992. Stable Isotopes and Planktonic Trophic Structure in Arctic Lakes. Ecology. 73: 561-566.

Lechowicz, M. 1982. The Sampling Characteristics of Electivity Indices. Oecologia 52: 22-30.

Lehman, J., J. Bowers, R. Gensemer, G. Warren and D. Branstrator. 1990. *Mysis relicta* in Lake Michigan: Abundances and Relationships with Their Potential Prey, Daphnia. Can. J. Fish. Aquat. Sci. 47: 977-983.

Lewis, W. Jr. 1980. Evidence for Stable Zooplankton Community Structure Gradients Maintained by Predation. *In:* Evolution and Ecology of Zooplankton Communities. Ed. W. Kerfoot. pp. 625-634. University Press of New England. Hanover, New Hampshire, USA.

Minagawa, M. and E. Wada. 1984. Stepwise Enrichment of ^{15}N Along Food Chains: Further Evidence and the Relation between Delta ^{15}N and Animal Age. Geochemica et. Cosmochemica Acta. 48: 1135-1140.

Rand, P., D. Stewart, B. Lantry, L. Rudstam, O. Johannsson, A. Goyke, S. Brandt, R. O'Gorman and G. Eck. 1995. Effect of Lake-wide Planktivory by the Pelagic Prey Fish Community in Lakes Michigan and Ontario. Can. J. Fish. Aquat. Sci. 52: 1546-1563.

Shuter, B. and K. Ing. 1997. Factors Affecting the Production of Zooplankton in Lakes. Can. J. Fish. Aquat. Sci. 54: 359-377.

Smokorowski, K. 1998. The Response of the Freshwater Shrimp, *Mysis relicta*, to the Partial Fertilization of Kootenay Lake, British Columbia. Ph.D. thesis. Trent University Peterborough, ON.

Spencer, C., D. Potter, R. Bukantis and J. Stanford. 1999. Impact of Predation by *Mysis relicta* on Zooplankton in Flathead Lake, Montana, USA. J. Plankton Res. 21: 51-64.

Stockwell, J. and O. Johannsson. 1997. Temperature-dependent Allometric Models to Estimate Zooplankton Production in Temperate Freshwater Lakes. Can. J. Fish. Aquat. Sci. 54: 2350-2360.

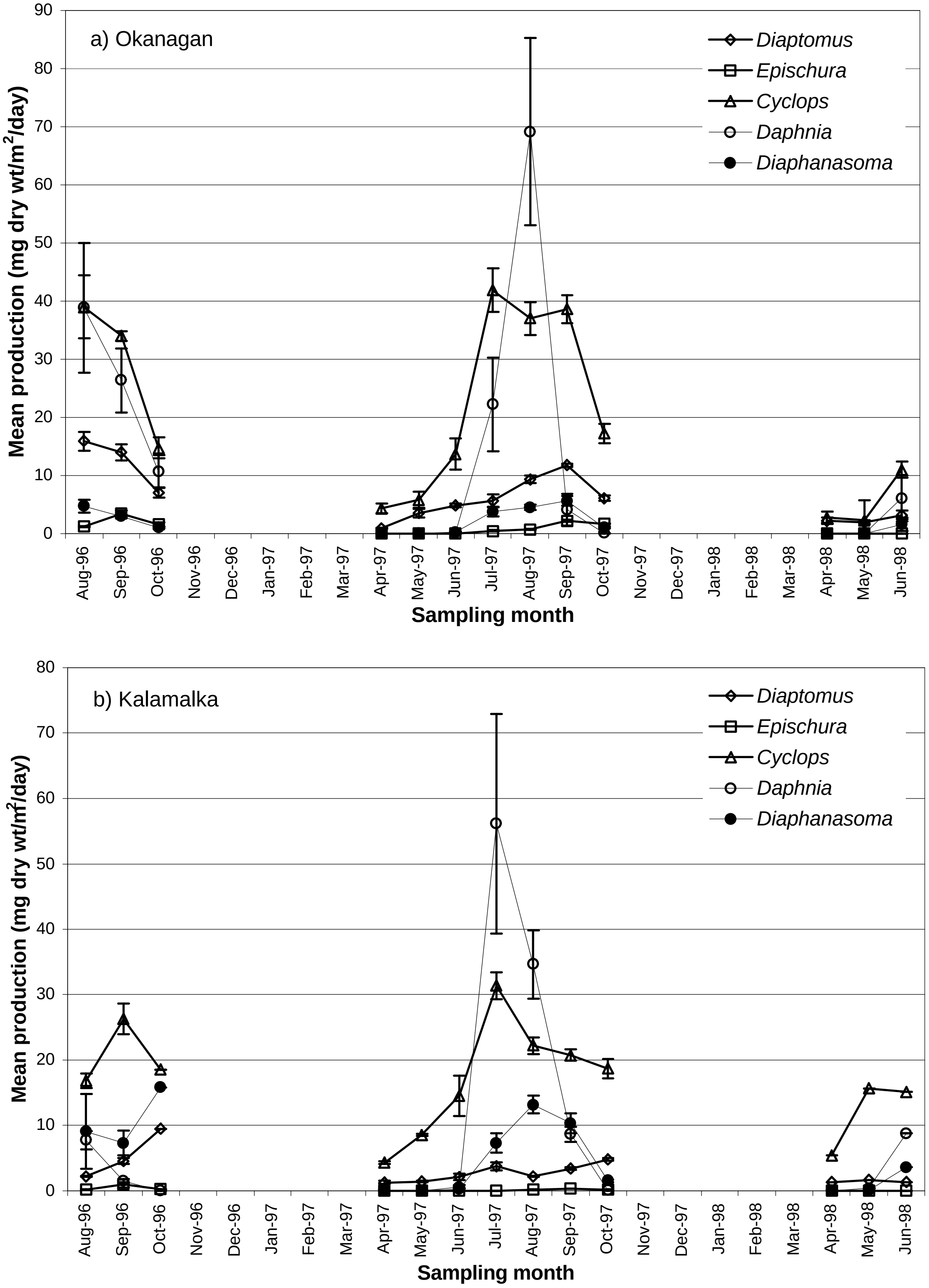
Thompson, L. and K. Ashley. 1997. Kootenay Lake Database: 1992 - 1996. Ministry of Environment, Lands and Parks. 2204 Main Hall, University of British Columbia, BC.

Vander Zanden, M.J., G. Cabana and J.B. Rasmussen. 1997. Comparing Trophic Position of Freshwater Fish Calculated Using Stable Nitrogen Isotope ratios (delta ^{15}N) and Literature Dietary Data. Can. J. Fish. Aquat. Sci. 54: 1142-1158.

Wada, E., Y. Kabaya and Y. Kurihara. 1993. Stable Isotopic Structure of Aquatic Systems. J. Biosci. 18: 483-499.

Whall, J.D. 2000. Comparison of the Trophic Role of the Freshwater Shrimp, *Mysis relicta*, in two Okanagan Valley Lakes, British Columbia. M.Sc. thesis, Trent University, Peterborough, Ont.

Yoshioka, T., E. Wada and H. Hayashi. 1994. A Stable Isotope Study on Seasonal Food Web Dynamics in a Eutrophic Lake. Ecology 75: 825-846.



Figures 1 a, b. Mean production estimates for a) Okanagan Lake and b) Kalamalka Lake zooplankton for periods between April and October 1996 to 1998 (bars represent ± 1 S.E.).

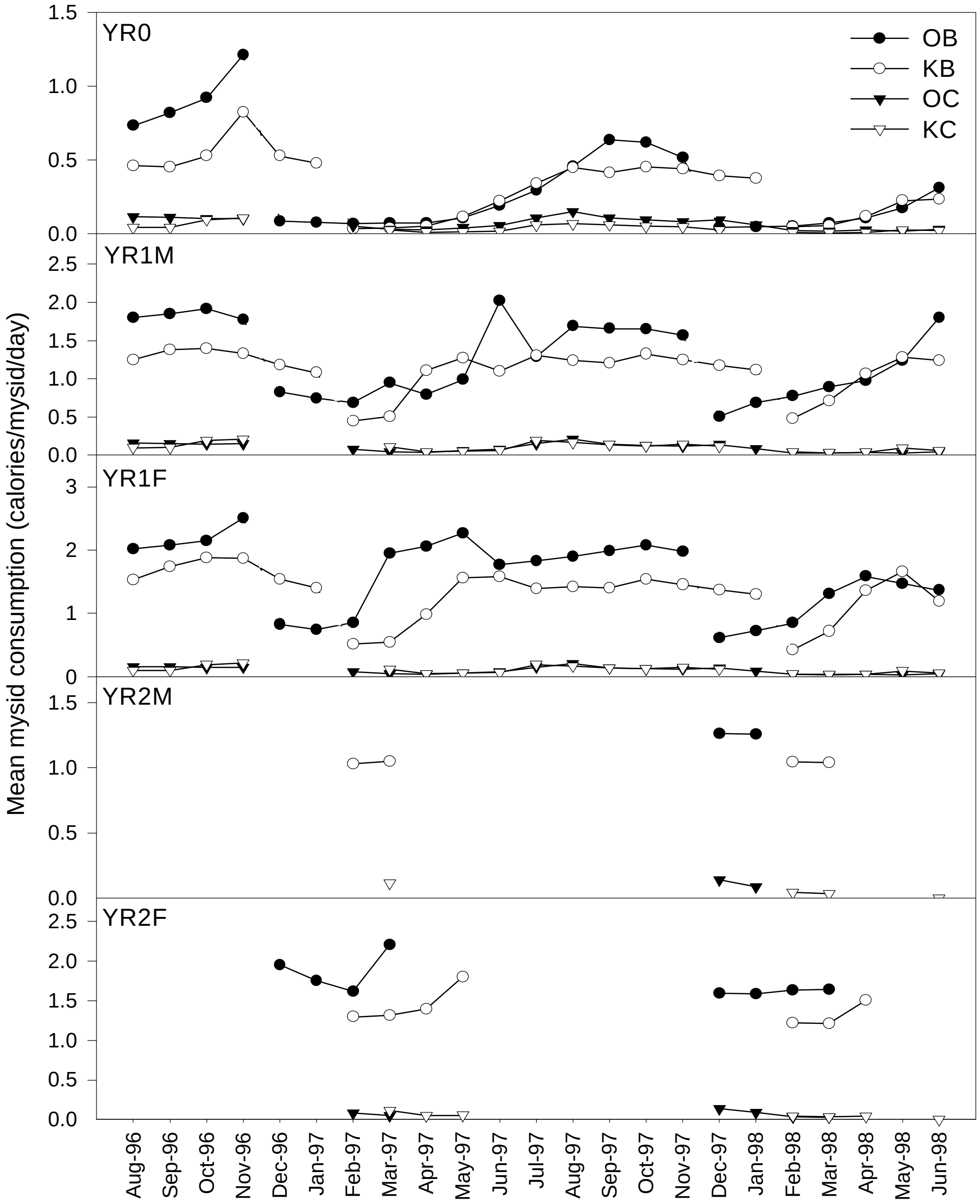


Figure 2. Average individual mysid daily caloric requirements for each sampling period in Okanagan and Kalamalka lakes as determined by bioenergetic modelling and clearance rate experiments. Abbreviations for methods of deriving caloric requirements: OB = Okanagan Lake bioenergetics, KB = Kalamalka Lake bioenergetics, OC = Okanagan Lake clearance rates, KC = Kalamalka Lake clearance rates.

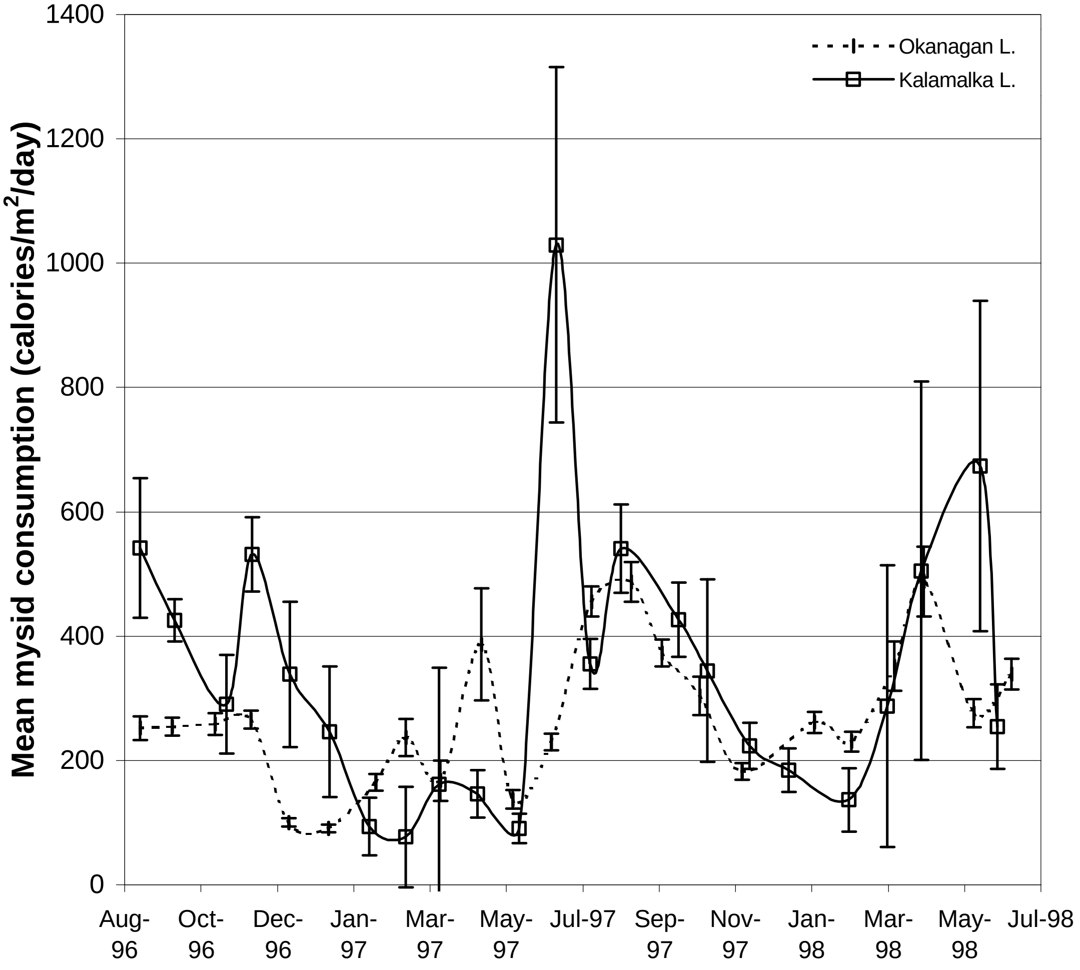


Figure 3. Mean daily caloric consumption per day by mysid populations for each sampling period in Okanagan and Kalamalka lakes as determined by bioenergetics modelling (bars rep. ± 1 S.E.).

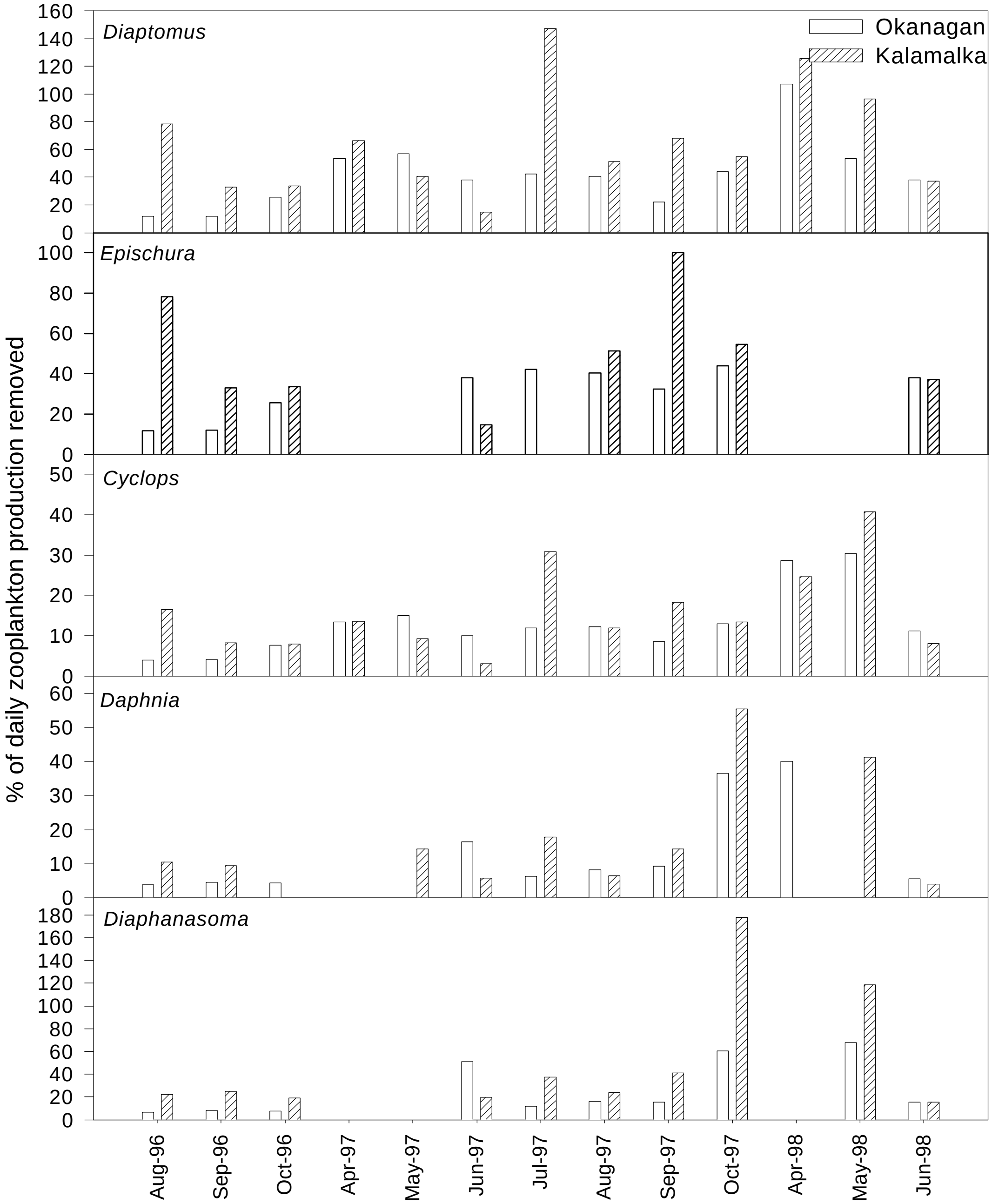


Figure 4. Estimated mysid population impact on daily zooplankton production removed using *in situ* clearance rate estimates and average whole-lake zooplankton and mysid densities.

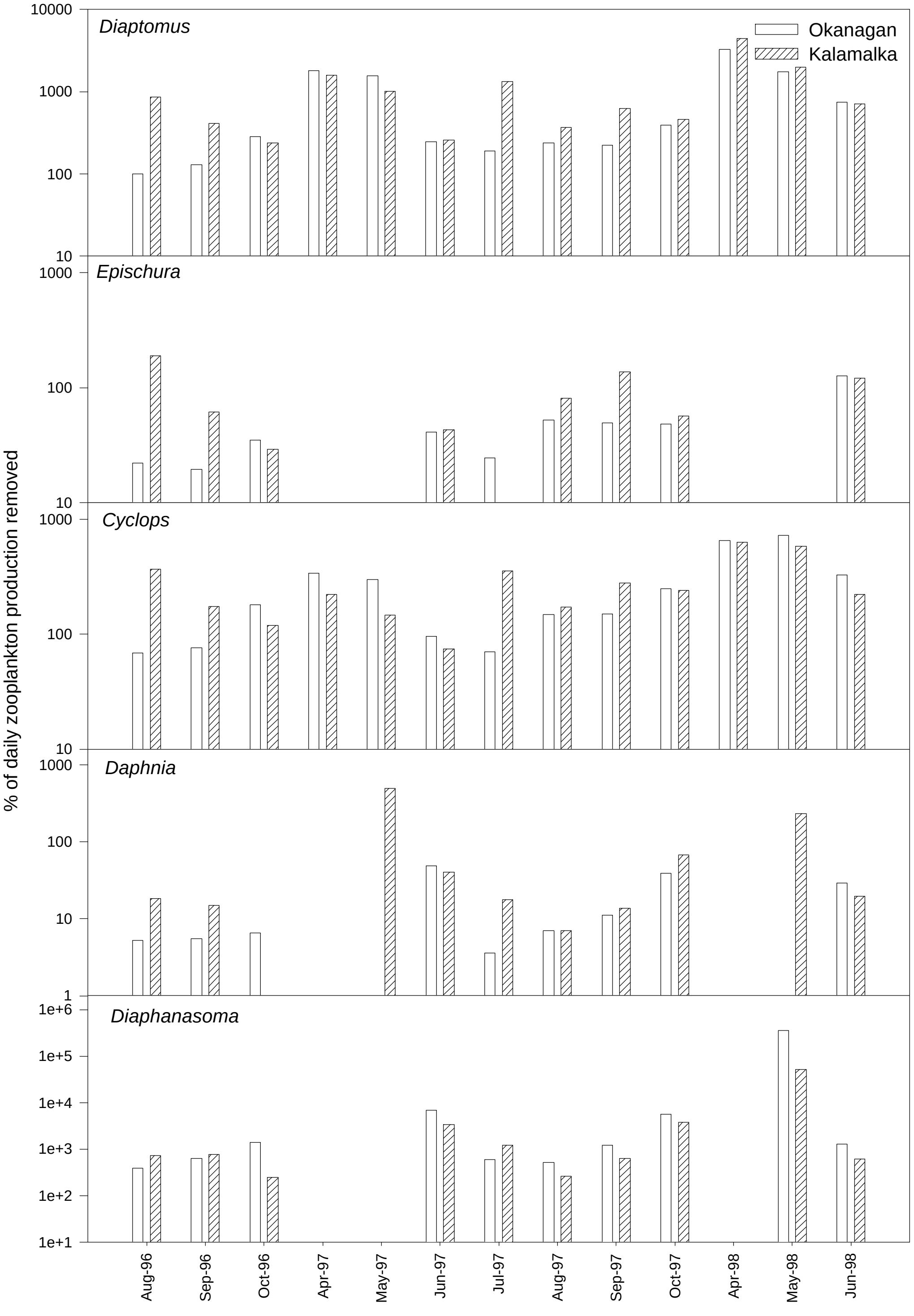


Figure 5. Estimated mysid population impact on daily zooplankton production removed using bioenergetically derived consumption estimates and average whole-lake zooplankton and mysid densities.

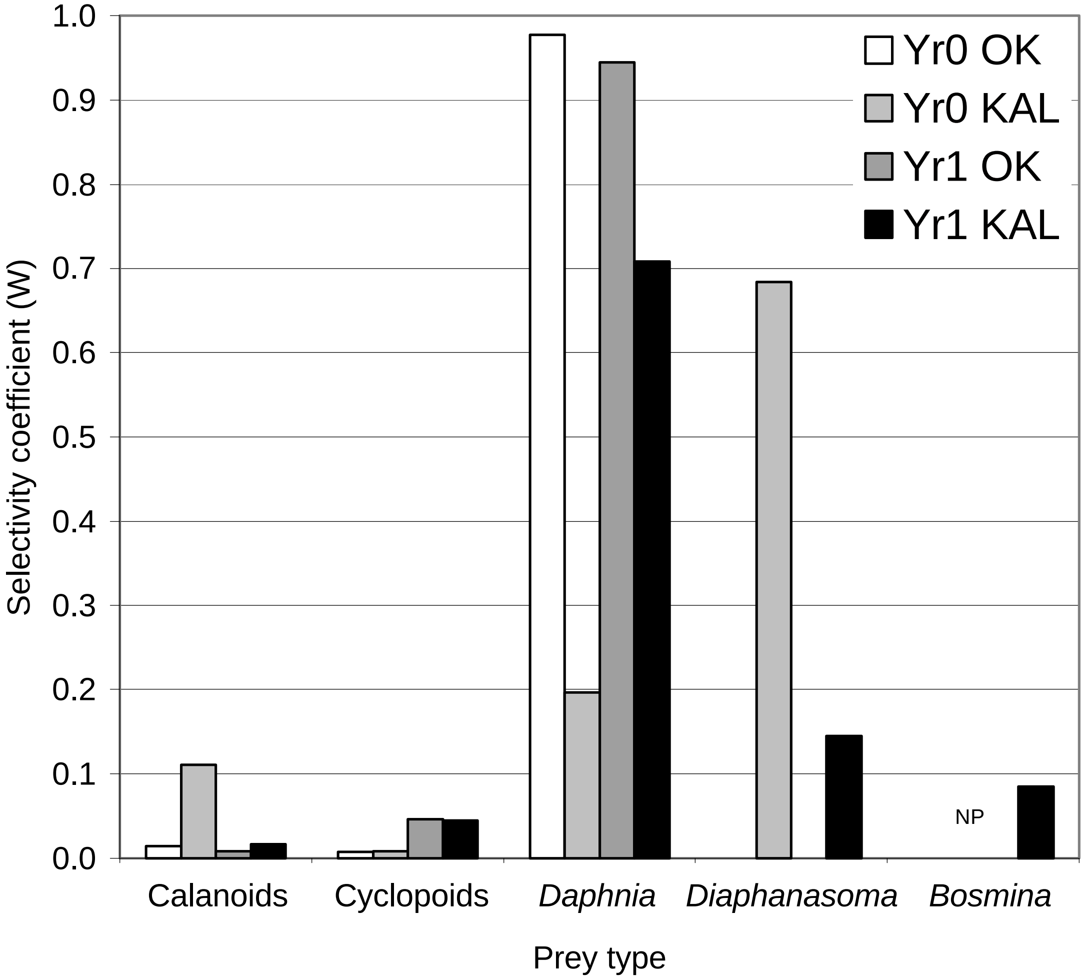
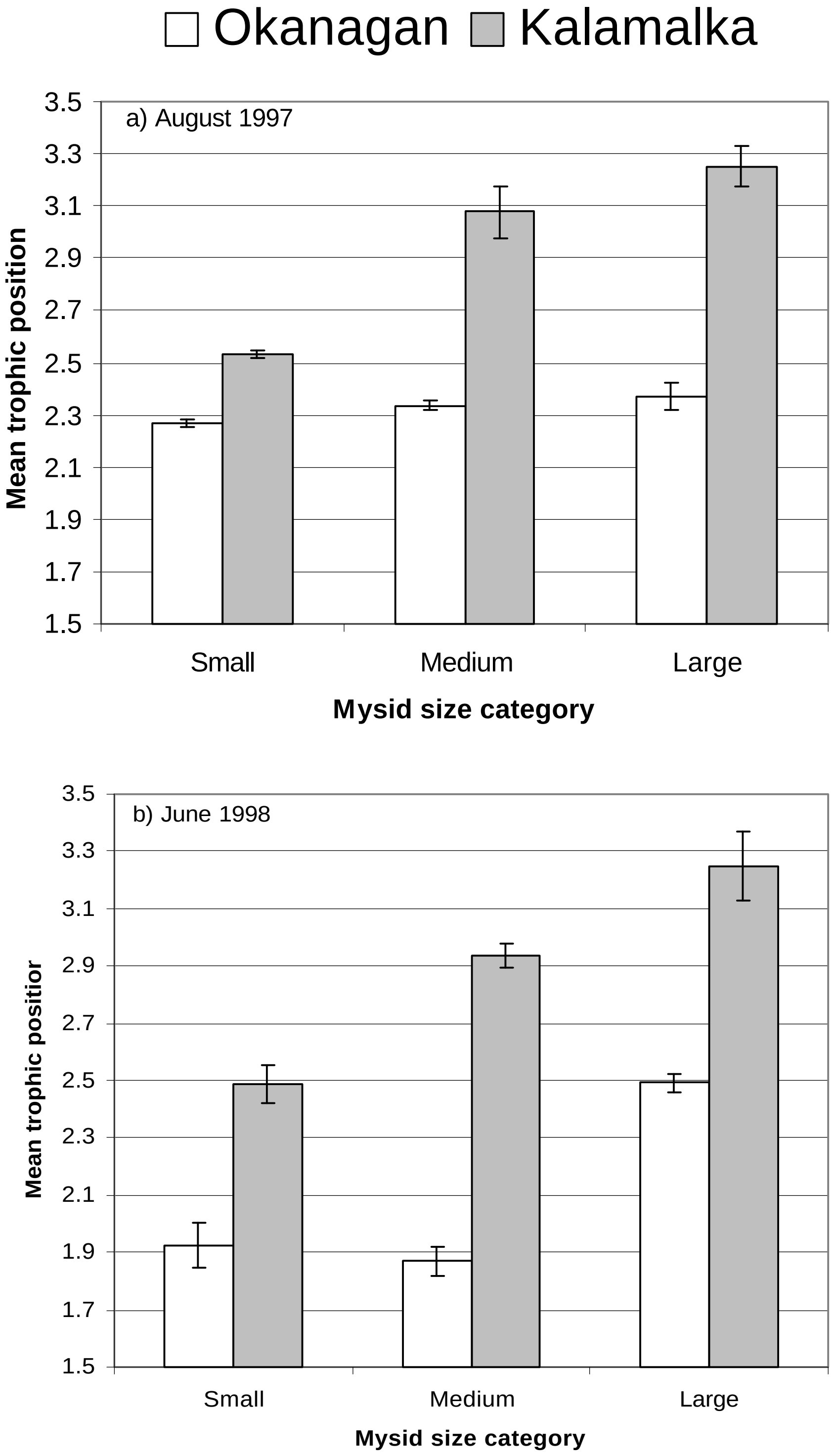


Figure 6. Selectivity coefficient index for Yr 0 and Yr 1 mysids in Okanagan and Kalamalka lakes in August 1997 based on gut content analysis. Possible values range from 0 to 1 with W < 0.2 indicating predator avoidance and W ≥ 0.2 indicating a feeding preference.



Figures 7 a, b. Comparison of mean trophic positions for small (3 to 7 mm), medium (8 to 13 mm) and large mysids (14 to 18 mm) as determined from nitrogen isotope ratios in Okanagan and Kalamalka lakes in August 1997 (n = 3 replicates from one composite sample of 10 animals) and June 1998 (n = 3 composite samples of 10–15 animals each per mysid size category; bars represent ± 1 S.E.).

MYSIS RELICTA IN OKANAGAN LAKE: A SUMMARY OF THEIR NUMBERS, DISTRIBUTION, AND RESULTS OF EXPERIMENTAL TRAWL FISHING, 1999

by

H. Andrusak[1]

INTRODUCTION

Mysis relicta introduction into Okanagan Lake in 1966 was intended to improve rainbow trout and kokanee growth by providing a macrozooplantor food source (Northcote 1991). By the late 1970s, there was some indication that the size of Okanagan Lake kokanee had increased, possibly as a result of mysid utilization (Smith 1978), but there was also a disturbing downward trend of total numbers (Bull 1987; Shepherd 1990). This downward trend in kokanee actually began in the mid 1970s, and has continued through the 1990s with record low escapements reported in 1998 by Matthews and Shepherd (*in* Ashley et al. 1999a). This decline led to establishment of the Okanagan Lake Action Plan (OLAP) with the most recent results described by Ashley et al. (1999a).

Formation of the OLAP occurred as a result of public and government concern for the conservation of Okanagan Lake kokanee. A workshop held in 1995 between fisheries experts, public representatives, engineers, and limnologists resulted in development of a comprehensive, long-term plan initially described by Ashley and Shepherd (1996) to address all the fish related problems. The workshop reviewed changes to the lakes' water quality, nutrients, plankton, kokanee and rainbow populations. A key finding was that most of the decline in kokanee numbers could be attributed to a reduction in nutrients, spawning habitat and or competition from mysids (Ashley et al. 1999a).

Fertilizing a part of Okanagan Lake or reducing the mysid population were the only two realistic options available that could possibly rectify the kokanee decline (Ashley et al. 1999a). During development of the OLAP, experimental fertilization of a portion of the North Arm of Kootenay Lake was underway (initiated in 1992) in an effort to reverse the dramatic decline in kokanee (Ashley et al. 1997). It was known that Kootenay Lake kokanee numbers increased immediately in response to fertilization, and therefore, this technology could have been transferred to Okanagan Lake.

It is worth noting that recent deliberate reduction of fertilizer loading to Kootenay Lake has resulted in decreases to kokanee numbers (Ashley, UBC Fisheries, pers comm.). This response confirms the influence of nutrient introduction at critical (low) levels and subsequent response in fish survival rates. Redfish Consulting Ltd. (1999) has identified poor fry-to-adult survival rates in Okanagan Lake kokanee similar to those recorded in Kootenay Lake where such low rates were known to be problematic.

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Despite the information on Kootenay Lake fertilization the option to reduce mysid numbers was chosen for Okanagan Lake since the lake does not appear to have declined below historical loading rates. The following report provides a summary to date of the understanding of mysid biology and the investigations into feasibility of reducing their numbers through fishing. Mysid reduction is one of the key strategies adopted by the OLAP. Further detail on the OLAP strategic objectives and planned activities can be found in Ashley et al. (1999a).

The objectives of this report are to:

- summarize Okanagan Lake mysid biology;
- summarize key kokanee distribution data;
- report on the experimental mysid fishery conducted in 1999; and
- recommend fishery strategy for early 2000 fishery.

BACKGROUND

Introduction of *Mysis relicta* into oligotrophic lakes has been touted as a means of improving fish growth for well over fifty years (Northcote 1991). Mysid biology has been the subject of numerous studies primarily in Sweden (Furst 1972), the Great Lakes (Beeton 1960), Lake Tahoe (Morgan et al. 1978) and British Columbia (Zyblut 1970; Lasenby et al. 1996). The success and failures of mysis transplants have been well documented by Lasenby et al. (1986) and Northcote (1991).

Clemens et al. (1939) was actually the first to suggest mysids introduction into Okanagan Lake to improve lake whitefish (*Coregonus clupeaformis*) growth. Most of the mysid introductions in British Columbia were initiated in reaction to the spectacular response of West Arm of Kootenay Lake kokanee that grew to a very large size as a result of heavy utilization of mysids (Sparrow et al. 1964; Lasenby et al. (1986). In the 1970s, West Arm kokanee exceeded a mean size of 30 cm at maturity and it was common for sport caught fish to exceed 2 kg (Martin and Northcote 1991; Redfish Consulting Ltd. 1999).

Lasenby et al. (1986) reported that 21 British Columbia lakes were subjects of mysid introductions, mostly due to the Kootenay Lake experience. At the time (1960s and 1970s) of these introductions there was a poor understanding of the unique flow dynamics associated with the West Arm, the outlet for Kootenay Lake water. A shallow sill located at the outlet causes (seasonally) deeper main lake water to rise upward and rapidly through the West Arm. Mysids from the main lake are displaced over the sill and due to the shallow depth cannot avoid predation by awaiting kokanee (see Thurber Consulting Ltd. 1981; Martin and Northcote 1991 for details). In the same lake, separate populations of North and South Arm kokanee (Vernon 1957) have not utilized mysids to any extent and their size (Redfish Consulting Ltd. 1999) has not varied in over thirty years despite the presence of *Mysis relicta*. In short, increased growth of West Arm kokanee was due to the unique physical features at the lake outlet. Interestingly, similar flow dynamics are present in the Arrow Reservoir, especially at the outlet, and large kokanee have been reported in this system.

Okanagan Lake is comparable to Kootenay Lake and Arrow Reservoir in many ways having similar size, north-south axis, depth and similar level of productivity i.e., oligotrophic. However, Okanagan Lake does not have a major outflow and surface water temperatures tend to be slightly higher than Kootenay or Arrow (see Ashley et al. 1999a; Pieters et al. 1998; and Ashley et al. 1999b, for limnological data). Mysids in Okanagan Lake appear to have possibly improved kokanee growth slightly (Andrusak in this report) but poor kokanee fry survival has been attributed to competition with mysids for the same food source - zooplankton.

Mysis relicta have been intriguing to fisheries biologists for decades since they have the potential of providing a great amount of energy to plankton feeding fish due to their large size. Northcote (1991) summarizes the rationale used by Larkin (1948) for introducing mysids to Kootenay Lake and Martin and Northcote (1991) explain why most introductions have indeed become a problem rather than a solution. In response to concerns of their impact on salmonids, and as a result of the numerous introductions, *Mysis relicta* research heightened in the late 1970s. British Columbia provincial fisheries have been fortunate to have had a long-term working relationship with a leading mysid expert, Dr. David Lasenby, who initially worked on Kootenay Lake mysid biology (Daley et al. 1981) in the late 1970s and more recently has worked on Okanagan Lake. Most of the results cited in this report are those of Dr. Lasenby and/or his students who were brought to Okanagan Lake as part of the team of researchers trying to understand and ultimately resolve the problem of declining numbers of kokanee. Fortunately, there has also been some minimal, routine monitoring of *Mysis relicta* in Okanagan Lake for over ten years by the provincial Ministry of Environment, Lands and Parks. This information provides some valuable insight into trends in mysid abundance.

Since the option to fertilize a portion of Okanagan Lake was not seen as viable due to conflicting public perceptions, (i.e., clean vs “polluted” water) reduction of mysids through fishing has been contemplated since 1996 (Ashley and Shepherd *in* Ashley et al. 1999a). Some local public interest in mysid harvesting has been present since the mid 1990s and one individual has done a considerable amount of experimenting including a catch of 2,100 kg in 1997 (Ashley and Shepherd *in* Ashley et al. 1999a). In 1998, the opportunity to fish for mysids on Okanagan Lake was expanded (including some financial incentives) to encourage commercial fishermen interest. Test net fishing using a small trawl net began in March 1998 to understand how to fish and where to fish for mysids (Ashley and Shepherd *in* Ashley et al. 1999a). In summer 1999, further experimental fishing commenced using a newly constructed, larger net.

SITE DESCRIPTION

Okanagan Lake is located in the southern interior of BC near the 49th parallel in a north-south axis between the Monashee and Cascade mountain ranges. The lake is located entirely within the warm, dry southern interior and it is approximately 135 km long, but only 4-5 km wide with a surface area of about 35,112 hectares. Despite a surface area of 351 km^2 the lake has a maximum depth of 242 m and a mean of only 76 m. Figure 1 illustrates the longitudinal profile of the lake that is divided into three basins created by underwater sills located at Squally Point and at the site of the Kelowna Bridge.

The lake is not fed by a major river system with inflow coming from very few tributary streams of any size. The Okanagan River flows out of the south end of the lake near Penticton, BC, into Skaha Lake, then south through Osoyoos Lake and eventually joins the Columbia River in northern Washington. At the outlet located near Penticton, BC, is a small dam that effectively regulates the lake between elevations 341 m to 342.5 m (see Ward et al. *in* Ashley et al. 1999a for more detail). The average throughflow of water is relatively small because of the dry climate of the Okanagan Valley and lake residence time has been calculated at 52 years (Shepherd 1990).

The lakes' physical and chemical attributes have been described by several authors in Ashley et al. (1999a). The lake is oligotrophic although the extreme north end is considered mesotrophic (Bryan 1990). Key limnological attributes (McEachern *in* Ashley et al. 1999a) relative to understanding *Mysis relicta* distribution and abundance include:

- thermal stratification is well established by July with surface temperatures exceeding 20º C and the thermocline usually @ 15-20 m;
- dissolved oxygen profiles are typical of oligotrophic lakes with hypolimnion water well oxygenated;
- Armstrong Arm located at the north end of the lake is very different limnologically from the remainder of the lake; this basin is shallow (maximum depth of 54 m) with the hypolimnetic waters having oxygen concentrations of <1 mg L^{-1} in the fall months (McEachern *in* Ashley et al. 1999a); and
- Secchi disk transparency readings range from 2-10 m with the lowest recordings in Armstrong Arm.

METHODS

Mysid Scientific Sampling

Mysis relicta have been the subject of intensive sampling in Okanagan Lake over the past 10 years. This sampling has provided considerable information on mysid densities and biology. Available data up to, and including 1998, is reviewed in the "Results" section of this report. Mysid sampling has varied to some degree over the years, but recently, there has been an effort to develop a standardized methodology in order to make comparisons not only between years but also with results from Kootenay Lake and Arrow Reservoir. Whall and Lasenby (*in* Ashley et al. 1999a) describe the methods in some detail while McEachern (*in* Ashley et al. 1999a) explains the changes in net(s) used and samples taken per station. Location of stations can be found in Figure 1.

Mysid Harvest Methods

Several nets and techniques have been employed in 1998 and 1999 in an effort to find effective means of harvesting *Mysis relicta.* The following briefly describes the nets used in 1999.

Prototype (1998) bottom trawl net

The net was 26 m long and 11 m wide with stretched mesh tapering from 8 mm to 6 mm. The net has an effective fishing open dimension of 11 m x 1.2 m (13.2 m^2). When fishing the net is held in position by a single cable with 10 m bridles leading from the cable and attached at each end of a 13.5 m aluminum beam. Four floats were attached to the top of the net to keep the net open during fishing. Two stakes (1.2 m) at each end of the beam also hold the net open when trawling (Photo 1). Weights varying from 40-120 kg were attached to the bottom of the stakes and/or to the cable bridle to achieve desired depth.

Modified ocean shrimp bottom trawl net

This net was a modified shrimp net typically used on the West Coast. The original mesh size was 508 mm but for fishing on Okanagan Lake an insert 10 m in length with mesh size tapering from 8 to 6 mm was sewn into the lower end of the net. When fished, the effective opening size of the net was 10 m x 1.3 m (13.0 m^2) since the larger mesh size of the original shrimp net (508 mm) would not capture any mysids.

Newly designed (1999) trawl net

This net was 44 m long and 20 m wide with stretched mesh size ranging from 8-6 mm. The net was towed by a 13 m commercial shrimp boat (Photo 2) using a single cable with two bridles fixed to a 16.4 m aluminum beam. When fishing, the net has an opening of 16 m by 7 m (114.8 m^2) with 8 floats (size 25 m) affixed to the top of the net (Photo 3) and the lead line weighted (depending upon depth fished) to keep the mouth open.

All three nets were deployed using a hydraulic winch and boom mounted on the drum (Photo 4) of the 13 m commercial fish boat. Net depth was determined from length and angle of cable. Trawl speed ranged from about 0.5 to 1.2 m·sec. Trawl time was set at 30 minutes. At the end of a trawl the cable and net were wound onto the net drum; the cod end of the net was lifted onto the deck using a side winch and boom. The catch was emptied into a plastic container and the mysids were scooped out using a kitchen sieve that was then shaken to remove excess water. After weighing the shrimp, the samples were frozen or held under ice for fresh samples used for marketing purposes. Any by-catch fish were recorded for species, length, and suspected age (kokanee only).

Experimental methods of fishing using the three nets were conducted from mid September to mid October 1999. A total of 40 successful bottom trawls and 36 mid water trawls were completed. Water layers fished were 50-70 m, 70-100 m, 100-130 m and >130 m. The depth actually fished varied considerably due to unfamiliarity with lake bottom contours, net deployment logistics, boat speed, and weights required to maintain the net within a depth layer.

It needs to be emphasized that the reported depths fished are approximate since the net could not be tracked accurately by a camera or sounder. A separate boat equipped with an echo sounder was utilized twice while fishing the mid water trawl net to determine net depth and provide a calibration factor using the cable angle for depth estimates. The area chosen for the test fishing was in the general vicinity of stations OK 6 (Whiskey Island) and OK 7 (Cameron Point) where mysid densities were known to be high and bottom water depths ranged from 100-200 m (Fig. 1).

Between net deployment, fishing time, net retrieval, and movement to and from the dock, a fishing day (usually eight hours) was usually restricted to four trawls, each 30 minutes long. The boat was equipped with a GPS to track location and direction as well as a depth recorder to ensure location of the trawl net relative to the lake bottom. Longitudinal and vertical transects were conducted at each station but some transects had to deviate in order to fish specific layers, i.e., some transects were not direct east-west or north-south due to wind and or lack of "room" to fish the deep layers.

During three days of mid water trawling some staged vertical plankton hauls were taken at the fishing sites to determine relative distribution of mysids within the water column. The methods described by McEachern (*in* Ashley et al. 1999a) were used although the samples were taken during day light hours.

An experimental surface trawl was operated by a local *mysis* Collection Permit holder who fished on September 19-20th and September 20-21th at night (~21:00-0:400) in the same areas as described for the daytime trawling experiment. This innovative operation consisted of a ~40 m long pipe (diameter ~20 cm) attached to the cod end of the 1999 mid water trawl net. The other end of the pipe was attached to a skiff at the surface with the skiff pulled by a motorized barge. When the net was towed the drag of the net would force water through the cod end hence the pipe to the surface and into the skiff. The water flowed into a trough located in the skiff that in turn held several angled, moveable screened collector plates (1.6mm holes). During actual fishing the mysids would collect on the screens that were lifted and cleaned repeatedly. This methodology allowed the net to fish continuously with net retrieval only necessary at the end of the night fishing period.

The mysid catch and by-catch were collected and information was recorded every 30 minutes to allow comparison with the daytime fishing operation. Two people were in the skiff with one person tending the pipe and flow while a second person pulled the screens and cleared them of mysids. The mysids were processed in the same manner as previously described. Any fish by-catch would swim freely in the trough and were released after being acclimated to lake surface water temperature in a bucket for several minutes.

Operationally, the only problem encountered with this near surface trawl was the pipe occasionally twisting due to excessive towing resistance from the barge and skiff. This twisting action would be transferred to the cod end, effectively blocking the flow of water through the pipe. Securing a towline from the trawl net to the barge, at a length slightly less than the pipe length reduced this problem. This transferred the towing resistance from the pipe to the towline, thereby reducing the twisting action of the pipe.

RESULTS

Data collected from various mysid sampling programs are analyzed below. In addition, a summary of Okanagan Lake kokanee data is included to provide a better understanding of kokanee/mysid interactions.

Analysis of Available *Mysis relicta* Data

Biology of *Mysis relicta*

Mysids are found in most large lakes in northeast Canada as well as in the Great Lakes (Edmondson 1963; Lasenby et al. 1986). They were not present in BC after the last glaciation but were introduced into numerous large lakes during the 1960s and 1970s (Northcote 1991; Martin and Northcote 1991). In Okanagan Lake, they are usually 12-18 mm long as adults while juveniles are usually 4-8 mm and immatures 8-15 mm (Whall and Lasenby *in* Ashley et al. 1999a).

During late summer there are three distinct size groups of *Mysis relicta* consisting of juveniles, immature, and adults. Juveniles are released from the female brood pouches from March-July. One year later these become immatures and during that winter the immatures become mature (Fig. 2) and are ready to release juveniles the following spring, i.e., two year life cycle. Sexually mature females examined in Kootenay Lake from 1992-1996 by Smokorowski (*in* Ashley et al. 1999b) suggest the average number of eggs per female was 18 in the North Arm and 17 in the South Arm.

Mysids are an unusual macrozooplanktor because they undergo a diurnal vertical migration that involves rising at dusk well over 100 m from the deep layers to surface waters and descending back to the deep water before dawn (Fig. 3). Whall and Lasenby (*in* Ashley et al. 1999a) found that from about 22:00 until about 04:00 hour all cohorts were found in the upper 50 m of the lake. Few *Mysis relicta* were found in the upper 50 m of water during the day and this was also the case in Kootenay Lake (Daley et al. 1981) and Kalamalka Lake (Whall and Lasenby *in* Ashley et al. 1999a). Levy (1991) suggests the diel vertical migration of mysids is an anti-predator strategy that results in minimal temporal and spatial exposure to predators such as adult kokanee. The presence of a thermal barrier to mysid vertical migration is discussed by Levy (1991) and Whall and Lasenby (*in* Ashley et al. 1999a) who noted few mysids in the upper 10 m during the summer when surface temperatures were >20° C.

Food habits of Kootenay Lake mysids have been studied by Smokorowski (*in* Ashley et al. 1997) and Okanagan Lake mysid gut samples have been analyzed by Whall and Lasenby (*in* Ashley et al. 1999a). They prey upon cladocerans, copepods, and rotifers and it has been demonstrated that they feed primarily at night when they move to the surface layers (0-30 m) where zooplankton densities are the highest. Unfortunately, mysids prefer the same food as kokanee fry especially Daphnia sp.; Diaptomus sp. and Cyclops sp. Considerable detailed food habit analysis of mysids can be found in Ashley et al. (1997).

Mysid densities in Okanagan Lake have been tracked for the last ten years and McEachern (*in* Ashley et al. 1999a) has summarized this data (all data collected at night). Figure 4 illustrates mean mysid densities from 1989-1998 that have ranged from a low of 154 m^2 to a high of 446 m^2. There has been a slight downward trend in the mean density over the ten year period. Mysid density data reported by McEachern (*in* Ashley et al. 1999a) indicates the greatest concentrations were found at Cameron Point (Fig. 1, Station OK7) ranging from a low of 245 m^2 in 1996 to a high of 914 m^2 in 1989 (Fig. 4). For most years, mysid densities have been lowest at Station OK4 (Mission Creek) ranging from 66 m^2 in 1994 to 230 m^2 in 1989. Whall and Lasenby (*in* Ashley et al. 1999a) point out that peak mysid abundance coincides with the deeper stations (Fig.1; Stations OK2, OK3, OK6) on Okanagan Lake while lower abundance(s) are associated with the shallower stations (Fig. 5). Smokorowski (*in* Ashley et al. 1999b) also observed that mysid densities are highest in deeper portions of Kootenay Lake.

Okanagan Lake averages increased from 284· m^2 in 1997 to 374· m^2 in 1998 (Whall and Lasenby *in* Ashley et al. 1999a). These densities are higher than those reported for Kootenay Lake during 1992-1996 where they ranged from a low of 98· m^2 to a high of 288· m^2 (Ashley et al. 1999b). Densities for Kootenay and Okanagan lakes are low compared to most other lakes that have been studied. Lasenby (1981; 1996 *in* Daley et al. 1981; *in* Ashley and Shepherd 1996) reported Kootenay Lake had 1,500· m^2 in the 1970s while the Great Lakes ranged from 800-1000 ·m^2. Kalamalka Lake densities ranged from 200-600 m^2 in 1996-1998 (Whall and Lasenby *in* Ashley et al. 1999a). In all lakes the numbers are greatest during the late summer months. All authors emphasize the high variability of mysid densities that exist from year to year.

Seasonally, the highest densities of mysids occur during the spring and summer months (Fig. 6) with numbers >400 ·m^2 at depths >100 m compared to <300 ·m^2 for the winter period for the same depth (Quirt and Lasenby *in* Ashley et al. 1999a). Based on the data shown in Figure 6 densities of about 500· m^2 could be expected at a depth of about 150 m in the spring and summer months but only about 250 ·m^2 in the winter months.

The question of horizontal distribution of mysids across the lake has also been examined on Okanagan Lake. Whall and Lasenby (*in* Ashley et al. 1999a) report that there was no consistent pattern to mysid abundance at the 40 m layer between the east, center, and west sides of the lake.

Mysid population estimates

Whall and Lasenby (*in* Ashley et al. 1999a) estimated that the biomass of mysids in Okanagan Lake from 1996-1998 ranged from a low of ~0.0005 kg m^2 in the winter months to a high of ~.003 kg m^2 in the summer months. The lake surface area is approximately 351 km^2. This means that the lake theoretically supports an estimated 175,000-1,050,000 kg of mysids. Since the shallow areas (<40 m) of the lake support few mysids the theoretical biomass is more likely to be ~105,000-630,000 kg depending on the actual contour chosen (Table 1).

Table 1. Theoretical estimates of mysid biomass for winter and summer using various contours delimiting zones which mysids inhabit.

Lake Contour	Area in Hectares	m^2	Winter Biomass @ 0.0005 kg m^2	Summer @ 0.003 kg m^2
Surface	35,000	$350 \cdot 10^6$	175,000 kg	1,050,000 kg
@ 20 m	24,829	$248 \cdot 10^6$	124,000 kg	744,000 kg
@ 40 m	20,982	$210 \cdot 10^6$	105,000 kg	630,000 kg
@ 60 m	16,614	$166 \cdot 10^6$	83,000 kg	498,000 kg
@ 80 m	13,081	$131 \cdot 10^6$	65,500 kg	393,000 kg
@100 m	9,678	$97\ 10^6$	48,500 kg	291,000 kg

<u>Summary of key information on mysids in Okanagan Lake</u>

- mysids are found in deep water (>50 m) during the day but vertically migrate to surface waters at night and are found in water <30 m until dawn;
- mysid densities have been slightly decreasing over the last ten years;
- mysid densities within Okanagan Lake are highly variable with the highest densities found at Cameron Point and Squally Point;
- mysids are abundant at deepwater sites during the day and they appear to be spread evenly across the lake at such sites; they are less abundant at sites associated with shelves;
- daytime mysid densities are highest at depths >100 m during the spring and summer months;
- water temperatures >20° C appear to be a thermal barrier to mysis movement, therefore, during the summer months they are not found in large numbers at the surface but high densities are found at night just below the thermocline; and
- annual biomass probably ranges from ~105,000-630,000 kg depending on the season.

Summary of Okanagan Lake Kokanee Data

A review of Okanagan Lake kokanee biology appears in the 1999-2000 version of the Okanagan Lake Action Plan (Redfish Consulting Ltd. 2000, in this report). Some key information about kokanee include:

- kokanee numbers in Okanagan Lake have declined appreciably over the last ten years;
- the majority spawn as age 3+ and it appears the greatest percentage are shore spawners;
- hydroacoustic estimates of total number have ranged from 5 - 14M with recent years estimates approximating only 5M;
- the highest densities of kokanee are found at Cameron Point, Squally Point and Gelately and these sites roughly coincide with the highest densities of mysids;
- kokanee inhabit the mid water area (10-30 m) of the lake during the day;
- kokanee undergo diel vertical movement during at least the summer months (Northcote et al. 1964);
- from echogram recordings Levy (1991) identified two groups of kokanee in Okanagan Lake with the adults remaining in 10-20 m of water during day while the juveniles were located at 50-80 m; the adults may possibly descend below 30 m at night;
- few kokanee were captured by trawling in less than 15 m at night Parkinson (1988);

- Levy (1991) recorded the juveniles undergoing diel vertical migration during the summer months from 80 m to 20 m at dusk and returning to 80 m at dawn. For this reason, Sebastian et al. (1995) trawl for kokanee in Arrow Reservoir, Kootenay and Okanagan lakes only at night in the upper 50 m of water since the vast majority are found in this layer associated with the thermocline. Few fish are found in less than 10 m of water; and
- depending upon depth layer fished, some age groups of kokanee are likely to become by-catch when trawling for mysids in the surface layers i.e., epilimnion.

Mysid and kokanee interactions

Evidently, mysids and kokanee do not inhabit the same layers of water during a 24 hour period for very long. Levy (1991) reports that Okanagan Lake adult kokanee prey upon mysids but presumably not for very long, otherwise their size would be much like those of West Arm of Kootenay Lake kokanee (see Redfish Consulting Ltd. 1999, for size comparisons). As mysids vertically migrate to the surface waters, kokanee are migrating downward and presumably they “pass” each other and occupy the same layer for only a short period of time. Conversely, as the mysids descend to the deeper depths the kokanee ascend towards the surface waters. Therefore, the kokanee and mysids are spatially separated during daylight hours and only intermix for a short period of time at night while they vertically migrate in opposite directions! Levy (1991) refers to the mysid movement to the deep water as “pelagic concealment”, i.e., predator avoidance.

To avoid kokanee by-catch while fishing for *Mysis relicta* the safest strategy is to fish for the shrimp during the day at the deeper depths. Fishing for mysids at night in water <30m will almost certainly result in kokanee by-catch. Unless kokanee by-catch can be addressed the mysid harvest strategy should be restricted to daytime fishing at deep depths. With this brief background on mysid-kokanee interactions, results of experimental fishing for *Mysis relicta* conducted in 1999 are now examined.

Results of 1999 Mysid Harvest Fishery

Note: reported mysid catches shown in Appendix 1 represent minimum weights (kg) since several hauls were observed to have lost portions of the catch due to small net holes or incomplete cleaning of the nets’ interior adjacent to the cod end.

Bottom Trawls

Bottom trawling was conducted using the 1998 prototype net and the West coast modified shrimp net in depths >75-100 m (n=14) and depths >100 m (n=28) depending on the bottom contour (Appendix 1). All trawls yielded some mysids although very few mysids (<1 kg) were caught in some of the initial trawl attempts using the modified West Coast shrimp net. Deepest minimum depth fished was 76 m while the greatest depth was 193 m. The highest yield was 41.1 kg when fishing the 1998 prototype net on the bottom at 90-104 m south of Whiteman Creek (Fig. 1, Station OK7).

Analysis of the catch data from both bottom trawl nets indicates that 14 shallow trawls (<100 m deepest depth) yielded an average catch of 1.98 kg (Table 2). On the other hand 26 trawls conducted in depths >100m yielded an average catch of 10.1 kg. This suggests that deeper depths fished produced higher catches and this is confirmed in Figure 7a,b where a weak trend of larger catch with increased depth is evident. However, eleven trawls at depths >130 m did not yield greater catches (x = 8.2 kg.) than trawls between 100-130 m (x =10.7 kg). Quality of catch was often poor due to the mysids being crushed and or mud and debris intermixed with them.

The by-catch for all 40 trawls totaled 16 fish (0.4 fish/haul) including 2 kokanee fry, 2 adult burbot, 8 sculpins, 1 yellow perch, and 3 sub adult sized mountain whitefish.

Table 2. Mysid catch using deep water bottom trawl nets (Sept. 10 - Oct. 4, 1999) at various depths determined by lake bottom. Note that all trawls were 30 minutes in duration.

	Shallow Trawls		**Deep Trawls**		**Deep Trawl Catch**	
	<100 m		**(>100 m)**		**<130 m**	**>130 m**
	Deepest Depth	**Catch (kg)**	**Deepest Depth**	**Catch (kg)**	**Catch (kg)**	**Catch (kg)**
	76	3.2	102	12.5	12.5	10.4
	80	0.9	103	8.7	8.7	6.3
	80	0.0	103	20.4	20.4	11.5
	83	0.2	104	41.1	41.1	13.7
	85	1.0	104	12.7	12.7	2.8
	86	0.4	105	21.6	21.6	5.6
	88	0.5	109	3.8	3.8	9.9
	90	0.8	113	2.2	2.2	7.2
	91	5.3	114	1.3	1.3	22.6
	92	12.5	115	3.0	3.0	8.7
	93	0.1	117	13.6	13.6	3.3
	93	2.0	117	2.8	2.8	
	95	0.1	120	6.2	6.2	
	97	0.8	124	7.6	7.6	
			128	3.6	3.6	
			132	10.4		
			132	6.3		
			134	11.5		
			135	13.7		
			139	2.8		
			140	5.6		
			144	9.9		
			144	7.2		
			151	22.6		
			168	8.7		
			193	3.3		
# Trawls		**(14)**		**(26)**	**(15)**	**(11)**
Total (kg)		**27.8**		**263.0**	**161.0**	**102.0**
Mean catch		**1.98 kg**		**10.1 kg**	**10.7 kg**	**8.2 kg**

Mid Water Trawls

Mid water trawls were actually fished at depth intervals of approximately 60-110 m (17), 120-135 m (16) and 3 trawls at 130-166 m (Appendix 1). The shallowest depth layer (47-63 m) was only fished once producing no mysids while the other 35 mid water trawls caught at least some mysids. The largest single catch was 87.1 kg in a layer 102-22 m just south of Cameron Point. At first glance, the data in Table 3 suggests that average catch at the deeper depths was greater than that for shallow layers, i.e., mean catch of 11.1 kg (shallow depths of 63-109 m) compared to 16.1 kg caught in the deeper layers. However, the single catch of 87.1 kg @ 102-122 m greatly skews the average and without that single catch the average is only 12.1 kg which is almost the same level of catch as the shallow(er) trawls. This explains why the trend line in Figure 8 is virtually flat, i.e., no trend of catch vs depth. What Figure 8 does show is that several of the trawls in the 100-130 layer often yielded catches of 20-30 kg per haul and that deeper depths fished often produced much smaller catches. The three deepest hauls (>130 m) only yielded 3.1, 2.6 and 4.1 kg respectively, while two hauls at 122 and 128 m resulted in the highest single catches (87.1 and 48.2 kg respectively see Appendix 1).

A significant feature of the mid water trawl catch(s) was the difference in mean catch at Station OK6 (Whiskey Point) and Station OK7 (Cameron Point). The mean catch at Whiskey Point for 18 hauls was 5.4 kg compared to 23.6 kg for 16 hauls at Cameron Point. The difference (~4X) in catch rate between the two stations is even greater than what was expected based on the data shown in Figure 2.

Table 3. Mysid catch using mid water trawl net (September 14-29, 1999) and deepest level fished per trawl. Note that all trawls were 30 minutes in duration and the depth layer fished was usually 30 m.

Maximum depth range	**Trawls 63-109 m**	**Catch (kg)**	**Trawls 119-166 m**	**Catch (kg)**
	63	0.0	119	21.7
	89	23.6	122	87.1
	95	6.6	122	11.9
	96	4.6	122	18.3
	96	12.0	122	23.0
	99	2.9	126	4.2
	100	0.2	128	48.2
	102	7.3	128	16.9
	102	28.3	129	13.6
	102	24.0	129	6.9
	102	6.7	129	6.3
	102	4.7	129	7.6
	102	5.6	129	6.1
	102	1.7	129	7.9
	102	21.3	129	7.0
	105	6.6	135	8.1
	109	32.9	162	3.1
			166	2.6
			166	4.1
#Trawls	**(14)**		**(19)**	
Total catch (kg)		**188.9**		**304.6**
Mean catch		**11.1 kg**		**16.1 kg***

Figure 9 is instructive for future fisheries. A plot of catch from all mid water trawls vs lake bottom depth at the trawl transects indicates that catch actually decreased slightly with increasing depth of the lake bottom. This is somewhat surprising since Whall and Lasenby (1999, *in* Ashley et al. 1999a) found that mysids tend to be found in greatest densities at the deep sites of the lake. However, the single staged daytime plankton hauls conducted during three days of the fishery (Figs. 10a, 10b) tend to support the mid water trawl catch data. That is, the numbers at depths >150 m were equal or less than numbers <140 m.

The total by-catch for all mid water trawls was comprised of only four kokanee (three fry and one 1+) and one sculpin.

Experimental surface trawl

In mid September the surface trawl operation conducted 14 hauls at approximately 30 minute intervals in the area of Cameron Point. The depth fished ranged from ~10-20 m. On the night of September 19th the total catch was 254 kg while the following night it was 207 kg. One observation worth noting is that the captured mysids were usually alive and this could be significant depending upon market demand.

Not surprisingly, there was a considerable by-catch of 96 kokanee the first night and 32 on September 20th. The fish ranged in age from 0-2+ and combining the two nights catch results in an average by-catch of about 10 fish per haul. The fish were reportedly all released in good condition.

Total Catch and Exploitation Rate

Net performance

Summary of catch by net type is shown in Table 4. All mid water and bottom trawls were conducted for ~30 minutes while individual surface trawl numbers and time were more variable, therefore, total time fishing per night was deemed the more accurate and comparable measurement of surface fishing time. Since the nets had different opening sizes, all catch has been converted to catch·hour·m^2 (Table 4). Clearly, the most effective method of capturing mysids was by means of the bottom trawl. The least effective method was the mid water trawl and bottom trawl while the modified West Coast shrimp net and surface trawl were intermediate. The bottom trawl using the 1998 prototype net, despite some initial start up problems, was quite effective with a catch rate six times that of the mid water trawl net.

Table 4. Comparative analysis of different net types used in 1999 experimental mysid fishery.

Trawl Method	Net Type	Sample Size	Total Fishing Time	Catch (kg)	Catch (kg)·Hour	Net Opening Size	Catch Hour·m^2
Bottom	1998 prototype	25 hauls	12.5 hours	242.0	19.4	13.2 m^2	1.47
Bottom	West Coast	15 hauls	7.5 hours	48.7	6.5	13.0 m^2	0.50
mid water	1999 new net	36 hauls	18.0 hours	493.6	27.4	114.8 m^2	0.24
surface	Modified trawl	n/a	8.0 hours	461.3	51.3	114.8 m^2	0.45
Total			**46.0 hours[1]**	**1245.6**	**26.5**		

[1] This represents actual net fishing time not number of days fished.

Assuming the total mysid biomass was at the summer high of 630,000 kg (Table 1) then the experimental fishery (bottom and mid water) in total (784 kg) caught about 0.1% of the biomass in about 18 days of fishing. Taking into account the two nights of surface trawling raises the total catch by 461 kg, to a grand total of 1246 kg. Inclusion of this data raises the estimate to ~0.2% of the biomass for 20 days of fishing.

The purpose of this fishery was to test various methods, techniques, and gear types at variable depth layers. It should be emphasized that the 1999 test fishery was not an attempt to maximize catch. Nonetheless, it is worth considering the extent of fishing that would need to be applied to this mysid population before any impact might be felt.

At first glance the theoretical numbers of required boats and/or days to fish to impact the mysid population (1-10% biomass harvest) appear to be out of the realm of possibility. However, the experimental nature of the 1999 fishery needs to be taken into account and the potential for capture improvement should not be readily discounted. Effective fishing time can be greatly increased per day by simply fishing longer between net retrievals. As well, fishing only the depth layers where the mysid densities are highest would result in greatly improved catch rates. Certainly, the catch rates experienced by the near surface experimental fishing in September 1999, illustrates that large catches are possible and even two such operations potentially could exert a significant impact (5%) on mysid biomass if fishing occurred for about 2-3 months (Table 5).

Table 5. Theoretical estimates of fishing days required based on 1999 catch rates to achieve variable biomass harvest rates (assumes summer biomass of 630,000 kg).

1999 Method (Trawl)	1999 Catch Rate	~Catch (kg)	Fishing Days Required	Number of Boats Required	% of Biomass
Bottom and midwater	43.5 kg·day	784	18	1	0.1
Bottom and midwater	43.5 kg·day	6,300	145	1	1.0
Bottom and midwater	43.5 kg·day	63,000	1,448	1	10.0
Bottom and midwater	43.5 kg·day	63,000	290	5	10.0
Bottom and midwater	43.5 kg·day	63,000	145	10	10.0
Mid and surface	62.3 kg·day	1,246	20	2	0.2
Mid and surface	62.3 kg·day	6,230	100	2	1.0
Mid and surface	62.3 kg·day	62,300	1,000	2	10.0
Mid and surface	62.3 kg·day	62,300	100	10	10.0
Surface	230.5 kg·day	461	2	1	0.07
Surface	230.5 kg·day	6,300	27	1	1.0
Surface	230.5 kg·day	63,000	273	1	10.0
Surface	230.5 kg·day	63,000	137	2	10.0
Surface	230.5 kg·day	31,500	68	2	5.0
Surface	230.5 kg·day	63,000	27	10	10.0

Finally, if a market is identified and developed then the number of boats wanting to enter this fishery may well increase rapidly. Continuation of the experimental mysid harvest on Okanagan Lake is warranted with more emphasis on maximizing catch using a high frequency sounder to locate the highest density layer(s).

DISCUSSION

Mysid densities in Okanagan Lake have varied considerably over the ten-year period for which there is comparable data. McEachern (*in* Ashley et al. 1999a) illustrated that mysid abundance has ranged from just over 900 mysids ·m^2 to as low as approximately 150· m^2 with recent years approximating 250 ·m^2. However, Okanagan Lake data also indicates that their abundance is greatest at deeper sites (>100 m), especially during the spring and summer months with densities typically >300-500 ·m^2. Another important feature of mysid biology is their diel nocturnal vertical migration behavior that results in movement from depths >100 m during the day to surface waters at night to feed and then return to deep water by dawn. Similarly, juvenile kokanee are found in deeper water (50-80 m) during the day and migrate to the surface waters at night and then return to the deeper water by dawn. Because the mysids occupy different layers (deeper) of water than juvenile kokanee there is only a short period of time when they are together. Adult size kokanee remain in the surface waters during the day and do not vertically migrate to the same extent, therefore, mysids are available for food for very short period of time. Okanagan Lake kokanee in fact do prey on mysids (Smith 1978) but evidently not to any great extent as suggested by their size. There has been no recent detailed analysis of their food habits.

Levy (1991) noted that Okanagan Lake mysids were suppressed from moving to the very shallow surface layer when the temperature exceeded 20º C and this probably results in some mysid predation by adult kokanee. Kokanee in the main part of Kootenay Lake also prey on mysids (Thompson 1999) but their overall contribution must be small since their size at maturity, remain small. For example, <23 cm, Levy (1991) discusses an anti-predation strategy that mysids appear to have developed to minimize predation but there is still much to be learned about the dynamics of mysid and kokanee interactions.

The average catch (1.98 kg) from the shallow bottom trawls (<100 m) was much lower compared to the deep bottom trawl catch (10.1 kg). There was a slight difference between mean catch >130 m than <130 m, i.e., 10.7 kg/haul vs 8.2 kg/haul. However, there was a considerable difference in the performance of the two bottom trawl nets with the 1998 prototype experiencing far higher catch rates compared to the West Coast shrimp net. The prototype net, when adjusted for difference in opening size, yielded far higher catch rates compared to the mid water trawls (Table 4) and the by-catch was very low. There was a weak positive trend towards larger catches at greater depths but catch was not greater once depths >130 m were exceeded. The single largest catch was 41.1 kg. The by-catch was 0.38 fish/haul with 5 different species caught. At approximately the same sites the bottom trawl catch per effort was consistently higher than the mid water trawl results.

The bottom trawl catch results reflects the mysid distribution data (Fig. 5) of Whall and Lasenby (*in* Ashley et al. 1999a). The shallower bottom trawls caught fewer mysids compared to the deeper trawls. Net performance between the two nets used for bottom trawling appeared to be significant. Fishing the very deepest layers did not result in much greater catches and these results are generally consistent with the density data (Fig. 6) of Quirt and Lasenby (*in* Ashley et al. 1999a) for the summer period.

Mid water trawl catch in the ~70-100m layer (11.1 kg·haul) was similar to that in the ~100-130 m layer (12.1 kg·haul) if the largest single catch of 87.1 kg is removed from the latter data set. There was no trend evident for greater catch in the deepest layers as might be expected. Indeed, mid water trawl catch appeared to decline slightly when fishing in the deeper parts of the lake (Fig. 9). This is an important point for future commercial fishing interests. Net deployment and retrieval time is a major consideration for a commercial venture, therefore, if catch per unit of effort is the same or similar at the shallower layers then there is little point to fishing the deepest layers. Further emphasizing this point is the fact that the three largest single catches (87.1, 48.2 and 32.9 kg·haul) were made while fishing the net variably within a layer ~62-128 m where the lake bottom was only 140-148 m.

The mid water trawl by-catch was very low at 0.14 fish/haul with kokanee representing four of the five fish caught. This by-catch rate is low but it has to be noted that the kokanee density in lake is also at a record low (Sebastian and Scholten *in* Ashley et al. 1999a).

Results from the experimental fishing conducted by bottom and mid water trawls in 1999 provide some useful insights into the potential for reducing mysid numbers, thereby, theoretically providing more food for kokanee. The fishing sites were chosen because of known high densities of mysids but it should be noted that the fishery was experimental with testing of net types, different water layers and net deployment techniques.

It should be noted that there was a significant difference in quality of product between the bottom trawl catch and mid water and or surface catch. Debris, mud, and crushed mysids were commonly observed in the bottom trawl samples rendering them much less attractive for most markets. For this reason alone, the bottom trawl method is not recommended for future fisheries unless it becomes apparent that such a product would have value.

Although the estimated exploitation rate was an insignificant ~0.1-0.2% the prospect of actually fishing down mysids to increase kokanee fry survival rates should not be discounted or dismissed. A cursory analysis of various combinations of net types and number of fishing boats directed at mysids suggest that it may be possible to impact the population especially if a market is identified. Mature mysids carry a very small number of eggs (~18/female in Kootenay Lake), therefore, it is most likely that a modest (5-10%) amount of fishing would significantly impact *mysis relicta* survival.

A great deal of useful information was generated from the 1999 fishery and the results of this test fishery should be used to specifically focus future fisheries to maximize the catch.

RECOMMENDATIONS

1. Interview the skipper of the mid water trawl boat to determine any required changes in gear type and methods for future fisheries.

2. Proceed with a full scale fishery in February 2000, specifically targeted at mature mysids with young still in the brood pouches.

3. Direct the February fishery to mid water trawling at depths of 90-120 m and 120-140 m employing stepped-oblique trawls to ensure representative sampling within the depth strata fished.

4. Bottom trawling should be deferred for the proposed February fishery.

5. Area to be fished should remain the same as the test fishery (Stations OK6 and OK7).

6. Secure a high frequency sounder to locate the mysid layer.

7. Proceed with increased effort for a spring-summer 2000 fishery.

8. A short-term (1-3 years) objective of future fisheries should be to achieve an exploitation rate of 1-2%.

9. Continue to closely monitor the kokanee by-catch especially if any night fishing is permitted. If night fishing is permitted then the by-catch should be held in a live box for a period of 24 hours.

LITERATURE CITED

Ashley, K., and B. Shepherd. 1996. Okanagan Lake Workshop Report and Action Plan. Fish. Proj. Rep. No. RD - 45, Univ. BC, Vancouver, BC.

Ashley, Ken, Lisa C. Thompson, David C. Lasenby, Laurie McEachern, Karen E. Smokorowski and Dale Sebastian. 1997. Restoration of an Interior Lake Ecosystem: the Kootenay Lake Fertilization Experiment. Water Qual. Res. J. Canada. Volume 32, No. 295-323.

Ashley, K., I. McGregor, B. Shepherd, D. Sebastian, S. Matthews, L. Vidmanic, P. Ward, H. Yassien, L. McEachern, H. Andrusak, D. Lasenby, J. Quirt, J. Whall, E. Taylor, A. Kuiper, P.M. Troffe, C. Wong, G. Scholten, M. Zimmerman, P. Epp, V. Jensen, R. Finnegan. 1999a. Okanagan Lake Action Plan Year 3 (1998-99) Report. Fisheries Project Report No. RD 78. Province of British Columbia, Ministry of Fisheries, Fisheries Management Branch, Victoria BC.

Ashley, K., L. Thompson, D. P. Lombard, J.R. Yang, F.R. Pick, P.B. Hamilton, D.C. Lasenby, K.E. Smokorowski, L. McEachern, Sebastian D.C. and G. Scholten. 1999b. Kootenay Lake Fertilization Experiment - Year 5 (1996/97) Report. Fisheries Project Report No. 65. Province of BC, Ministry of Fisheries, Fisheries Management Branch.

Beeton, A.M. 1960. The Vertical Migration of *Mysis relicta* in Lakes Huron and Michigan J. Fish. Res. Bd. Canada 17 (4) 1960.

Bryan, J.E. 1990. Water Quality of Okanagan, Kalamalka and Woods Lakes. B.C. Ministry of Environment, 69 pp.

Bull, C. J. 1987. Okanagan Lake Plan. Draft Rept., BC Min. Env., Penticton, BC.

Clemens, W.A., D.S. Rawson and J.L. McHugh. 1939. A Biological Survey of Okanagan Lake, British Columbia. Bull. Fish. Res. Bd. Canada 56: 70p

Daley, R.J., E.C. Carmack, C.B.J. Gray, C.H. Pharo, S. Jasper, and R.C. Wiegand. 1981. The Effects of Upstream Impoundments on Kootenay Lake, B.C. Canada Inland Waters Directorate, Research Institute, Scientific Series, West Vancouver, British Columbia.

Edmondson, W. T. 1963. Freshwater Biology. 2nd Edition John Wiley & Sons Inc.

Furst, M. 1972. Experiments on the Transplantation of New Fish-food Organisms into Swedish Impounded Lakes. The Feeding Habits of Brown Trout and Char in Lake Blasjon. Verh. Internat. Verein. Limnol. (18) 114-1121.

Larkin, P.A. 1948. *Pontopereia* and *Mysis* in Athabaska, Great Bear and Great Slave Lakes. Fisheries Research Board of Canada Bulletin 78.

Levy, D.A. 1991. Acoustic Analysis of Diel Vertical Migration Behavior of *Mysis relicta* and Kokanee (*Oncorhynchus nerka*) within Okanagan Lake, British Columbia. Can. J. Aquat. Sci. Vol 48, 1991.

Lasenby, D.C., T.G. Northcote and M. Furst. 1986. Theory, Practice, and Effects of *Mysis relicta* Introductions to North American and Scandinavian Lakes. Can. J. Fish. Aquatic Sci., Vol. 43.

Lasenby, D.C., K.E. Smokorowski, and L.J. McEachern. 1996. Distribution, Abundance, Growth, Life History and Feeding Habits of *Mysis relicta* in Kootenay Lake, BC Following Experimental Fertilization Year 4 (1994/95). Contract report prepared for BC Ministry of Environment, Lands and Parks, Fisheries Branch.

Martin, A.D. and T.G. Northcote. 1991. Kootenay Lake: An Inappropriate Model for Mysis relicta Introduction in North Temperate Lakes. American Fisheries Society Symposium 9:23-29.

Morgan, M. D., Threlkeld, S.T., and C.R. Goldman. 1978. Impact of the Introduction of Kokanee (*Oncorhynchus nerka*) and Opossum Shrimp (*Mysis relicta*) on a Subalpine Lake. J. Fish. Res. Bd. Can. 35: 1572-1579.

Northcote, T.G. 1991. Success, Problems and Control of Introduced Mysid Populations in Lake and Reservoirs. American Fisheries Society Symposium 9:5-16, 1991.

Northcote, T.G., H.W.Lorz and J.C. Macleod. 1964. Studies on Diel Movement of Fishes in a British Columbia Lake. Veh. Internat. Verein. Limnol. XV 940-946.

Parkinson, E. A. 1988. Long-term Data Collection on Kokanee from Large Lakes: Does it Make Sense? Fish. Tech. Circ. No. 83, BC Min. Env., Rec. Fish. Progr., Univ. BC, Vancouver, BC.

Pieters, R., L.C. Thompson, L. Vidmanic, S. Pond, J. Stockner, P. Hamblin, M. Young, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian, G. Scholten and D.L. Lombard. 1998. Arrow Reservoir Limnology and Trophic Status - Year 1 (1997/98) Report. Fisheries Project Report No. RD 67. Ministry of Environment, Lands and Parks, Province of British Columbia.

Redfish Consulting Ltd. 1999. Performance Evaluation of Six Kokanee Spawning Channels in British Columbia. Unpubl. Ministry of Fisheries, Province of British Columbia, Victoria, BC.

Sebastian, D., G. Scholten, D. Addison and D. Green. 1995. Results of the 1985-94 Acoustic and Trawl Surveys on Okanagan Lake, Unpubl. Stock Management Unit Report No. 2. Fisheries Branch, Ministry of Environment, Lands and Parks, Victoria, BC, 54 p.

Shepherd, B.G. 1990. Okanagan Lake Management Plan, 1990 - 1995. BC Min. Env., Recreational Fish. Progr., Penticton, BC.

Smith, D. R. 1978. A Summary of Existing Data on Kokanee (O. nerka) in Okanagan Lake. Unpubl. BC Government Ministry of Environment 34 p.

Sparrow, R.A.H., P.A. Larkin and R.A. Rutherglen. 1964. Successful Introduction of *Mysis relicta* into Kootenay Lake, British Columbia. J. Fish. Res. Bd. Canada, 21 (5): 1325-1327.

Thompson, L.C. 1999. Abundance and Production of Zooplankton and Kokanee Salmon (*Oncorhynchus nerka*) in Kootenay Lake, British Columbia During Artificial Fertilization. PHD Thesis University of British Columbia Vancouver BC. 252 p.

Thurber Consultants. 1981. *Mysis relicta* in the West Arm of Kootenay Lake. Unpulished report prepared by B.C. Research, Project 1-12-338, Vancouver, British Columbia.

Vernon, E. H. 1957. Morphometric Comparison of Three Races of Kokanee (*Oncorhynchus nerka*) Within a Large British Columbia Lake. Journal of the Fisheries Research Board of Canada 27: 1239-1250.

Zyblut, E.R. 1970. Long-term Changes in the Limnology and Macrozooplankton of a Large British Columbia Lake. Journal of the Fisheries Research Board of Canada 27: 1239-1250.

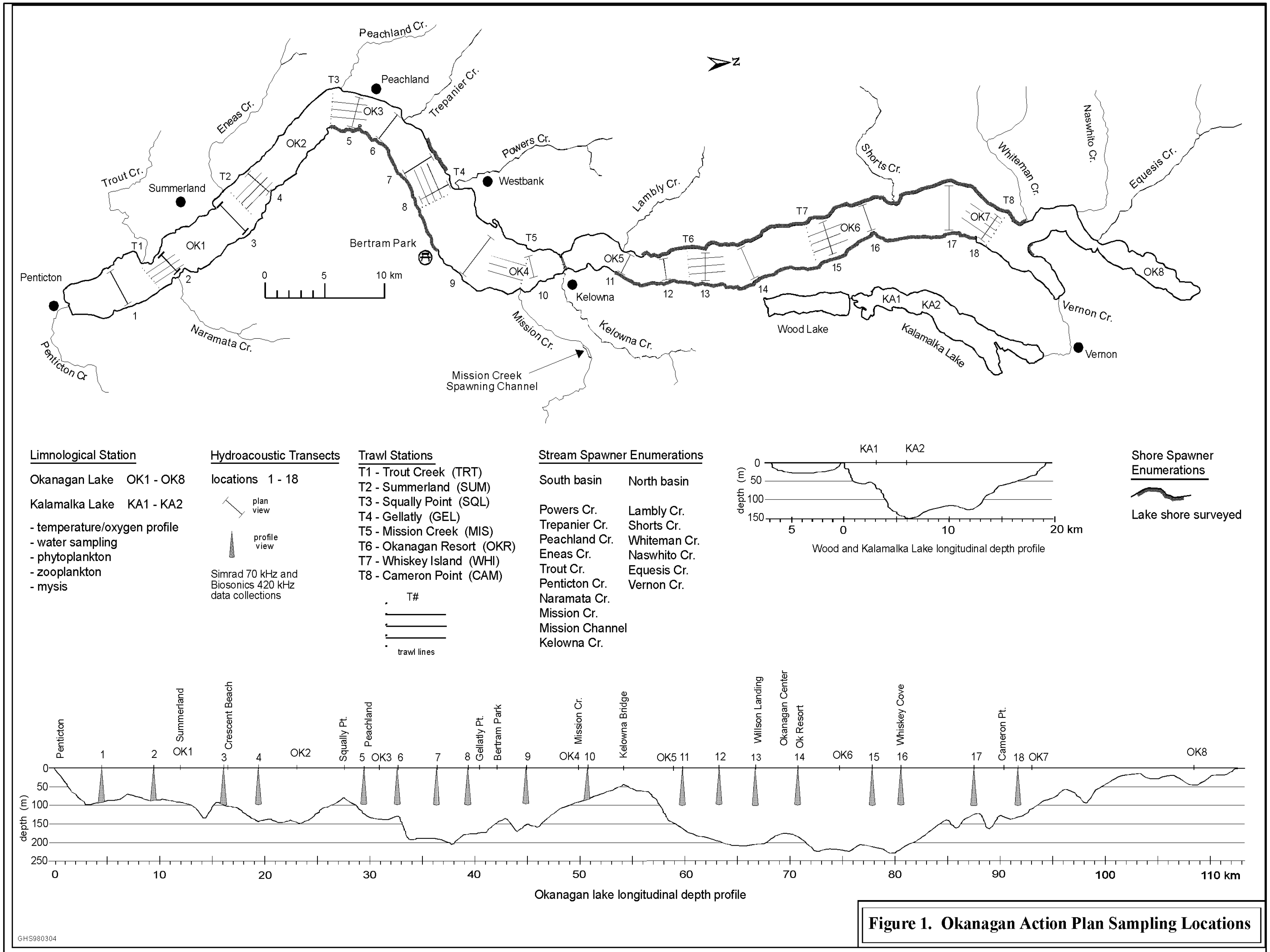

Figure 1. Okanagan Action Plan Sampling Locations

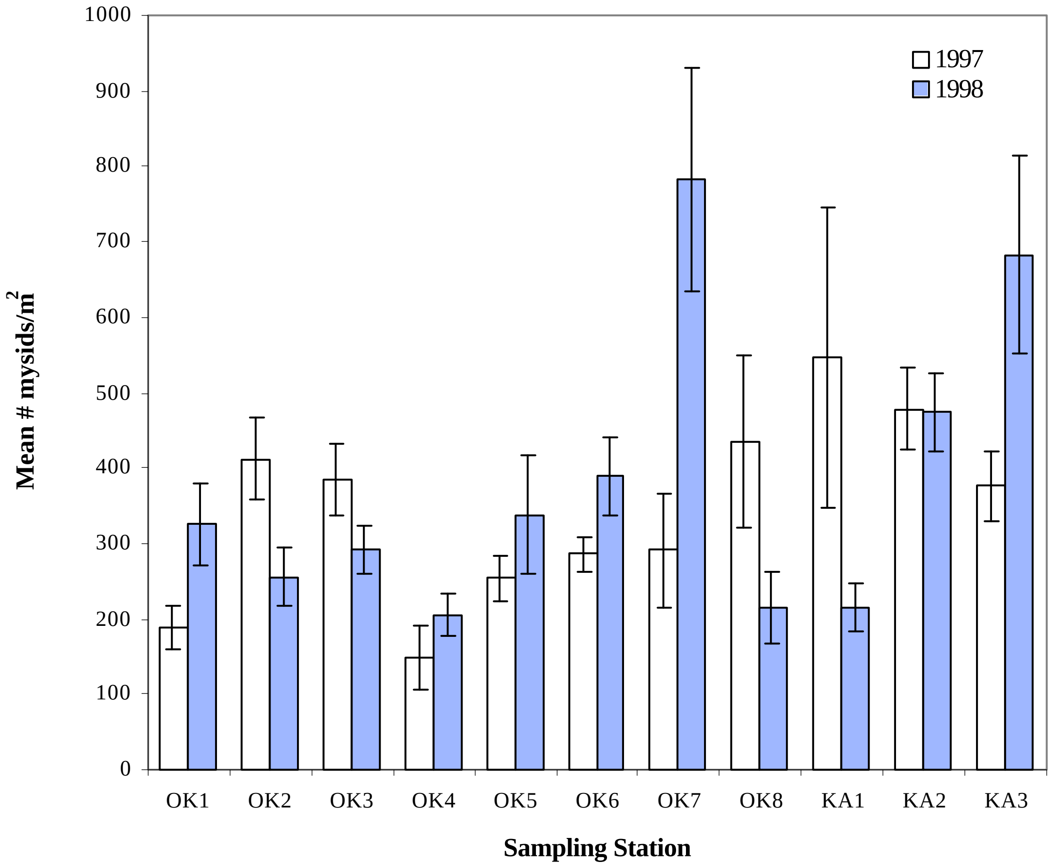

Figure 2. Mean annual mysid distribution by station for Okanagan Lake (Station #OK1-8) and Kalamalka Lake (Station #KA1-3) (data from Whall and Lasenby *in* Ashley et al. 1999).

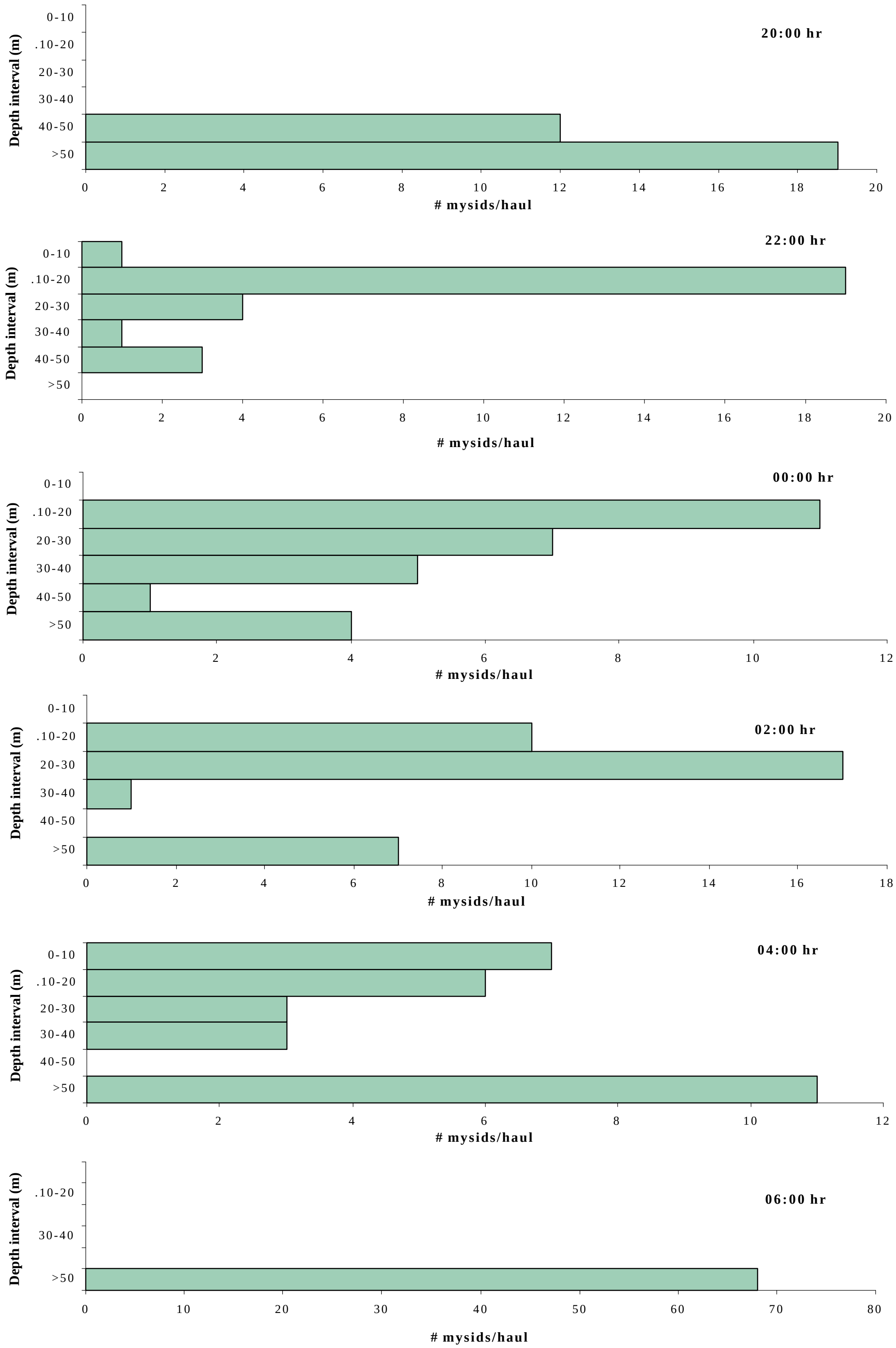

Figure 3. Mysid nocturnal vertical distribution in Okanagan Lake August 1997 (data from Whall and Lasenby *in* Ashley et al. 1998).

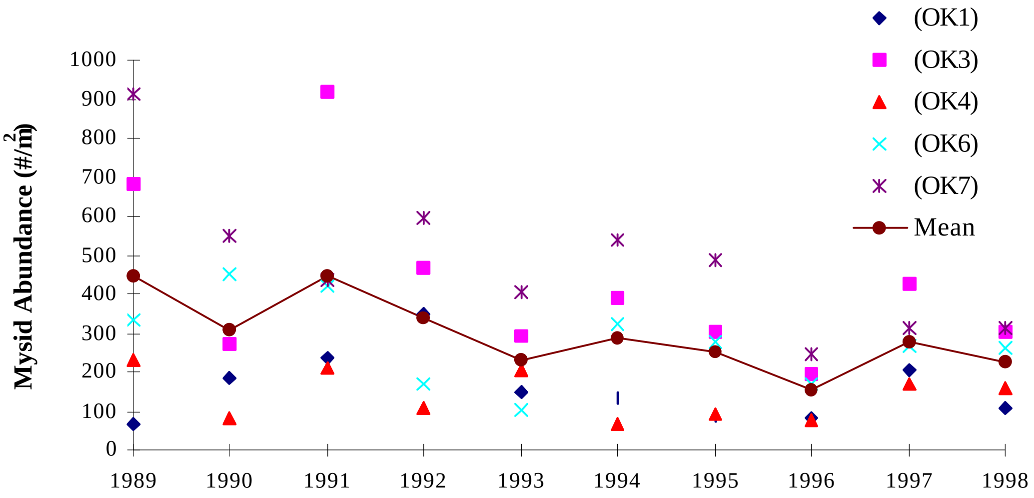

Figure 4. Abundance of *Mysis relicta* in Okanagan Lake from 1989 through 1998 inclusive, vertical hauls from September and October only (data from McEachren *in* Ashley et al. 1999).

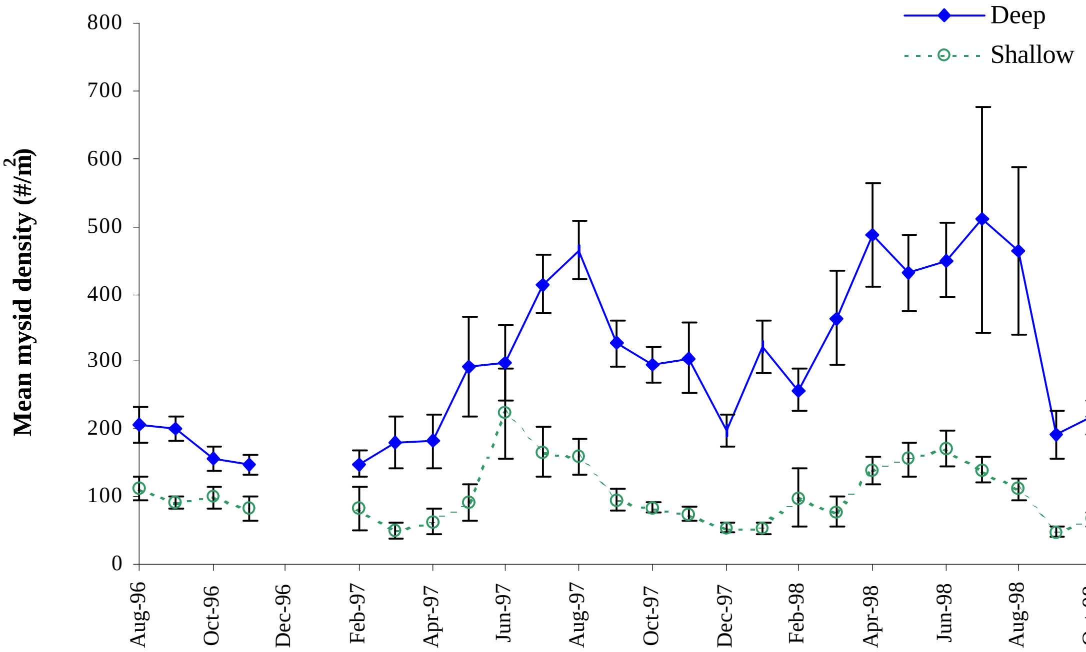

Figure 5. Whole-lake mean mysid densities for a) Okanagan Lake (Station #OK 8 excl.; n=7 stations) and b) Kalamalka Lake (n=2-3 stations) (bars rep. +/- 1 S.E.). (data from Whall and Lasenby *in* Ashley et al. 1998).

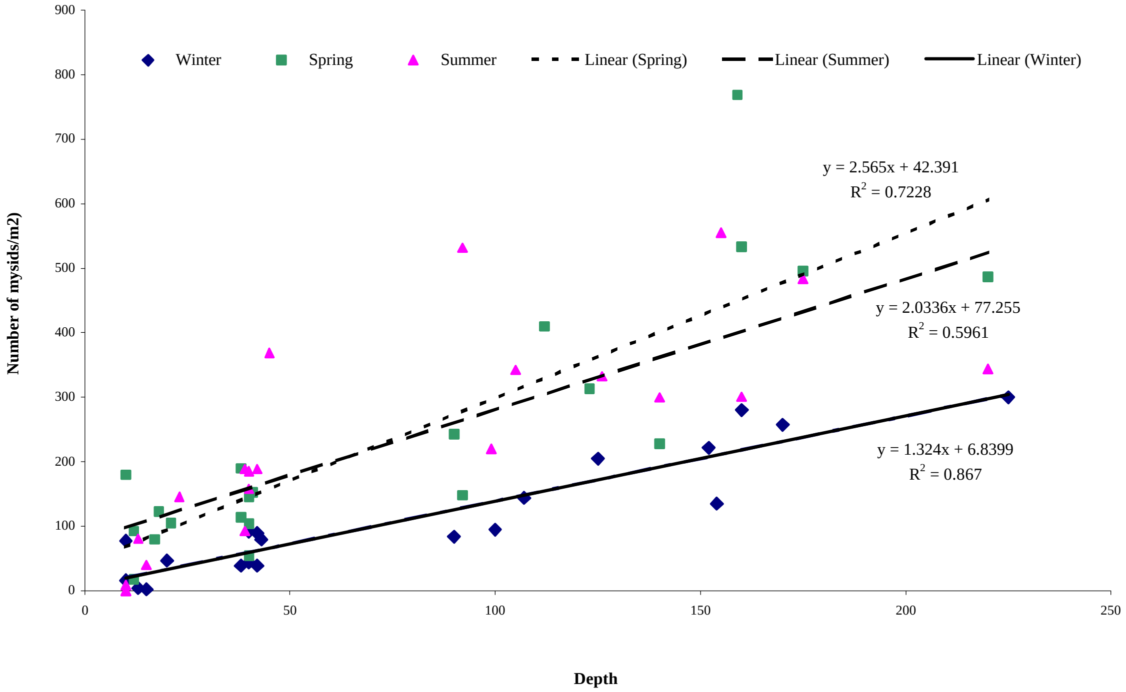

Figure 6. The # of mysids (/m^2) vs depth for three pooled sites (OK 6, OK 5, OK 2) for three different seasons (data from Quirt and Lasenby *in* Ashley et al. 1999).

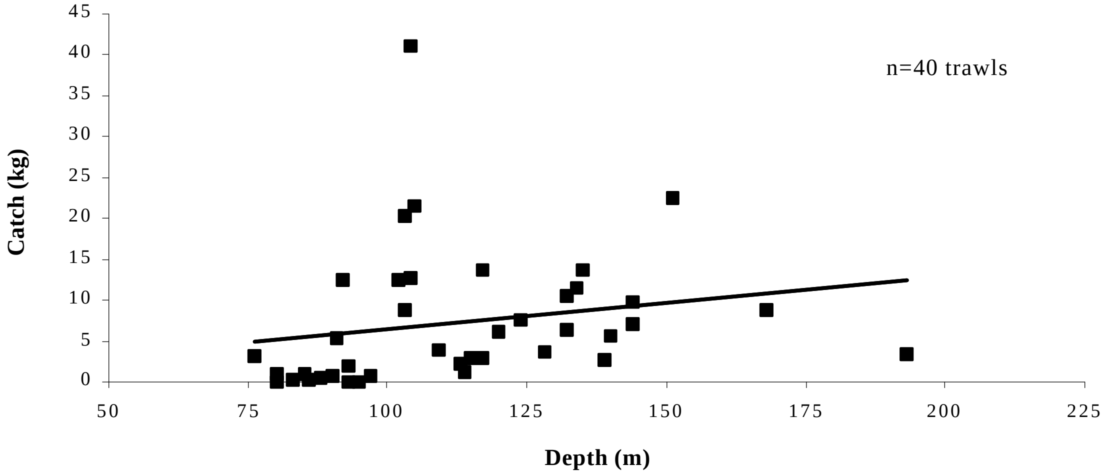

Figure 7a. Catch in kilograms of mysids at variable depths utilizing both bottom trawls. Note that the weak trendline illustrating catch increases at deeper depths.

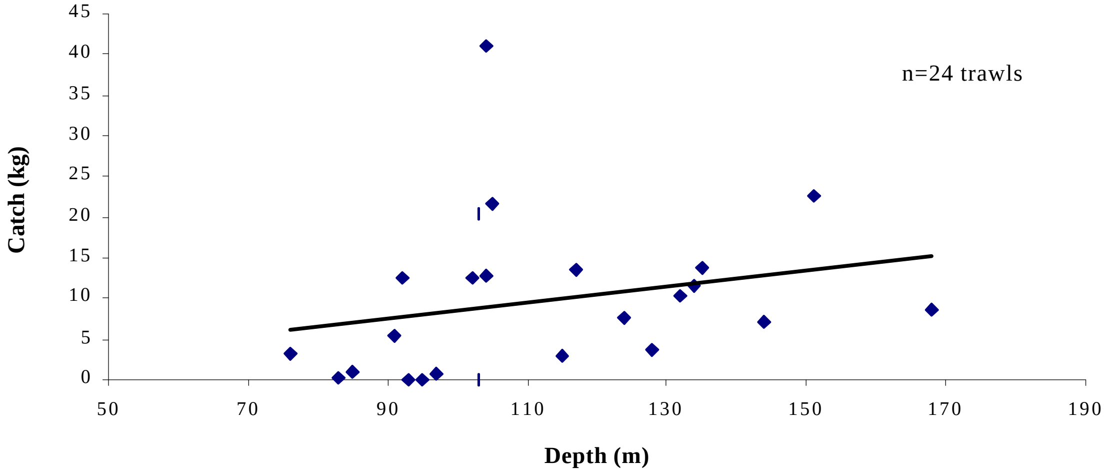

Figure 7b. Catch in kilograms of mysids at variable depths using the 1998 prototype bottom trawl. Note that the weak trendline illustrating catch increases at deeper depths.

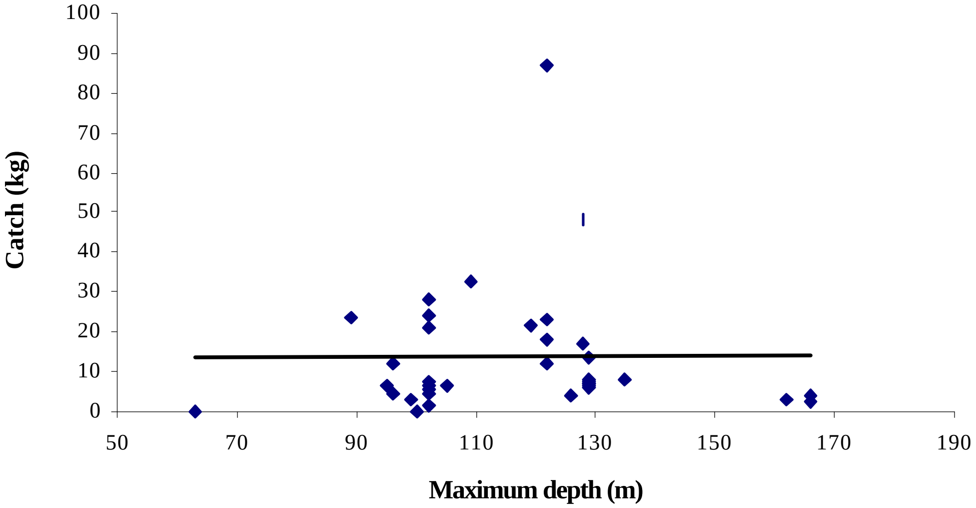

Figure 8. Mysid catch vs maximum depth fished by mid water trawls (depth layers were approximately 50-100 m and 100-150 m). Note: there is no trend evident.

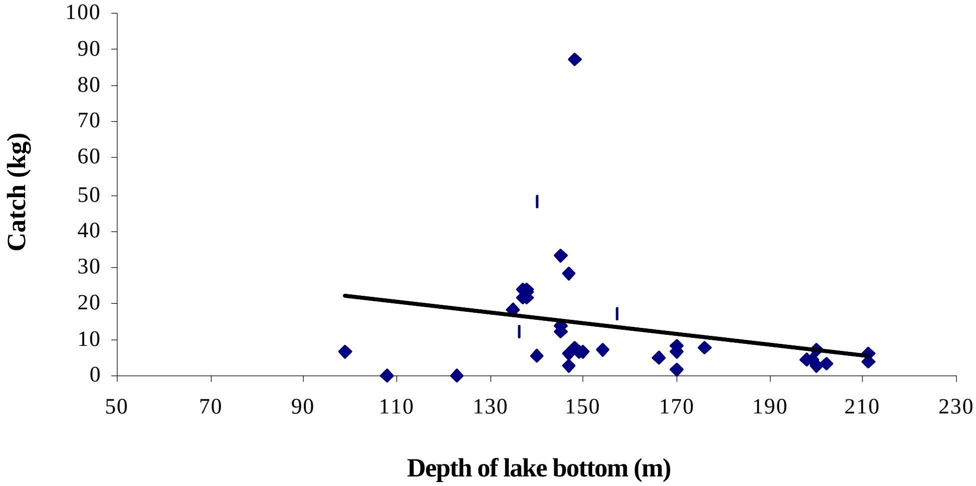

Figure 9. Mid water trawl catches compared to depth of lake bottom at trawl sites. Note: Trend line suggests slight negative trend of catch vs increasing depth of lake.

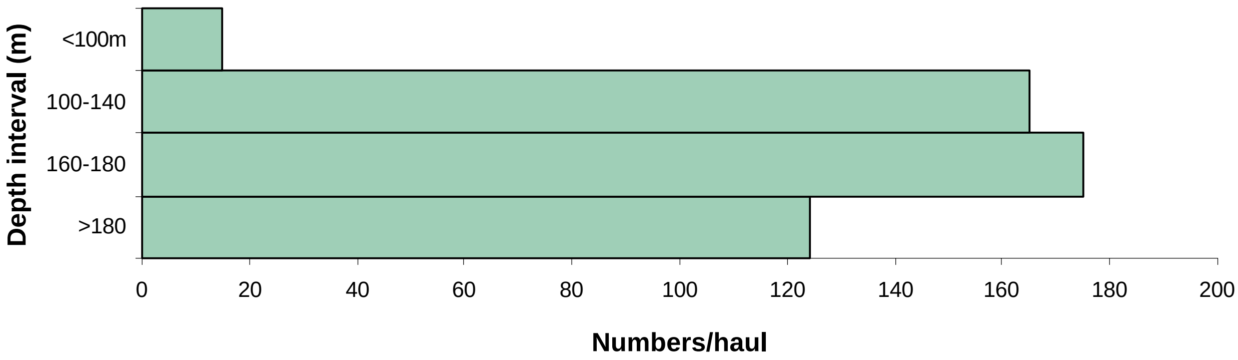

Figure 10a. Mean numbers of mysids per depth interval determined from staged single vertical hauls Sept. 16, 24 and October 1 @ Station OK 6 at mid day (12:00-15:00 hr.) Note: lake depth approximately 200 m.

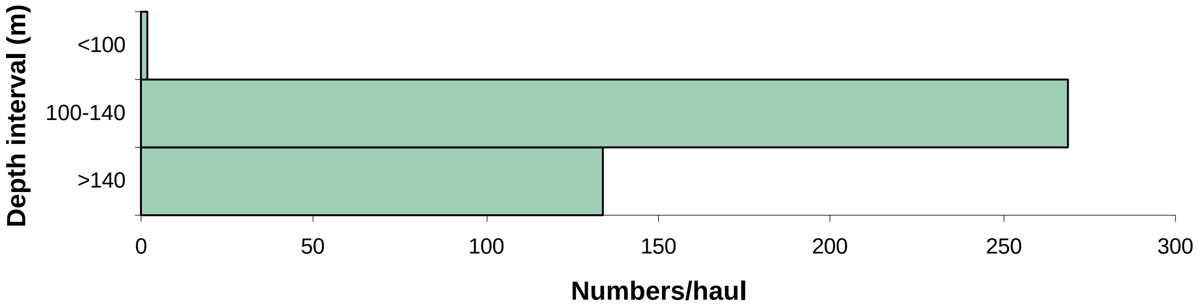

Figure 10b. Mean numbers of mysids per depth interval determined from staged single vertical hauls Sept. 16 and 24 @ Station OK 6 at mid day (12:00-15:00 hr.) Note: lake depth approximately 150 m.

Photo 1. Deployment of 1998 prototype net illustrating 1.2 m stake, 13.5 m beam and bridle attached to single cable mounted on the boats net drum.

Photo 2. 13 m Trident Isle commercial fish boat with 16.5 m aluminum beam stored atop of wheelhouse and net drum (aft).

Photo 3. Retrieval of net with cable being winched into net drum.

Photo 4. Two bridles attached to the ends of the 16.4 beam. Bridles attached to single cable. Note: floats atop of beam and net.

Appendix 1 1999 mysis trawl data summary - Trident Isle, Okanagan Lake

Trawl	Net	Date	Zone*	Location /	%	Wind	Trawl	Net Depth Range (m)		Bottom Depth Range (m)		Mysis	Bycatch					RPM	Tow Line	
No.		**d/m/y**		**Direction of Tow**	**Cloud**	**kph**	**(Minutes)**	**(m, shallow)**	**(m, deep)**	**(m, shallow)**	**(m, deep)**	**Catch (kg)**	**# fish**	**Size (mm)**	**Wt (g)**	**Species**	**Stomach**	**Range**	**Used (FM)**	**Other Notes**
58	**1**	30/9/99		Whiteman Creek	10	5	15	91	94	same because bottom trawl		0.0	0					725	175	80 lbs weight
58	**1**	30/9/99	1	Whiteman Cr / S	10	5	33	90	92	same because bottom trawl		12.5	0					650	200	80 lbs weight
58	**1**	30/9/99		Whiteman Cr / S	10	5	33	90	92	same because bottom trawl		12.5	0					650	200	80 lbs weight
59	**1**	30/9/99	1	Whiteman Cr / S	10	5	32	60	85	same because bottom trawl		1.0	0					650	200	80 lbs weight
59	**1**	30/9/99		Whiteman Cr / S	10	5	32	60	85	same because bottom trawl		1.0	0					650	200	80 lbs weight
60	**1**	30/9/99	1	Whiteman Cr / S	10	5	30	90	104	same because bottom trawl		41.1	0					650	200	80 lbs weight
60	**1**	30/9/99		Whiteman Cr / S	10	5	30	90	104	same because bottom trawl		41.1	0					650	200	80 lbs weight
61	**1**	1/10/99	1	Whiteman Cr / S	0	10	30	90	103	same because bottom trawl		8.7*	0					625-650	200	230 lbs wt, suspected much of catch lost (mysis
61	**1**	1/10/99		Whiteman Cr / S	0	10	30	90	103	same because bottom trawl		8.7*	0					625-650	200	230 lbs wt, suspected much of catch lost (mysis
62	**1**	1/10/99	2	Cameron / S	0	10	30	108	134	same because bottom trawl		11.5*	0					650	225	230 lbs wt, noticed hole in net @ rings, tracking
62	**1**	1/10/99		Cameron / S	0	10	30	108	134	same because bottom trawl		11.5*	0					650	225	230 lbs wt, noticed hole in net @ rings, tracking
63	**1**	1/10/99	2	S of Cameron / S	0	10	30	89	102	same because bottom trawl		12.5	0					650	250	230 lbs weight
63	**1**	1/10/99		S of Cameron / S	0	10	30	89	102	same because bottom trawl		12.5	0					650	250	230 lbs weight
64	**1**	1/10/99	2	Ellison / N	0	10	30	62	76	same because bottom trawl		3.2	0					650	200	230 lbs wt, milfoil, pine needles
64	**1**	1/10/99		Ellison / N	0	10	30	62	76	same because bottom trawl		3.2	0					650	200	230 lbs wt, milfoil, pine needles
65	**1**	1/10/99	1	Whiteman Cr/ S	10	15	30	90	93	same because bottom trawl		blown	1	710	1700	LC	empty w/ worms	650	200	230 lbs, klinkers and tree debris in net, net
65	**1**	1/10/99		Whiteman Cr/ S	10	15	30	90	93	same because bottom trawl		blown	1	710	1700	LC	empty w/ worms	650	200	230 lbs, klinkers and tree debris in net, net
66	**1**	2/10/99	2	Cameron Pt / S	0	5	30	114	132	same because bottom trawl		10.4	0					675	250	230 lbs, pine needles milfoil, replicate of 62
66	**1**	2/10/99		Cameron Pt / S	0	5	30	114	132	same because bottom trawl		10.4	0					675	250	230 lbs, pine needles milfoil, replicate of 62
67	**1**	2/10/99	2	S of Cameron / S	0	5	30	87	93	same because bottom trawl		< 50 g*	0					650	250	230 lbs, towed over v steep cliff, jumped into
67	**1**	2/10/99		S of Cameron / S	0	5	30	87	93	same because bottom trawl		< 50 g*	0					650	250	230 lbs, towed over v steep cliff, jumped into
68	**1**	2/10/99	2	S Cameron on W /	0	5	30	100	117	same because bottom trawl		13.6	0					650	250	230 lbs, near trawl 63
68	**1**	2/10/99		S Cameron on W /	0	5	30	100	117	same because bottom trawl		13.6	0					650	250	230 lbs, near trawl 63
69	**1**	2/10/99	2	S Cameron on W /	0	5	30	61	91	same because bottom trawl		5.3	0					550	200	230 lbs, floats on bottom middle removed to
69	**1**	2/10/99		S Cameron on W /	0	5	30	61	91	same because bottom trawl		5.3	0					550	200	230 lbs, floats on bottom middle removed to
70	**1**	2/10/99	2	S Cameron on W /	0	0	30	90	105	same because bottom trawl		21.6*	0					550-650	250	230 lbs, bottom ripped out of net, large
70	**1**	2/10/99		S Cameron on W /	0	0	30	90	105	same because bottom trawl		21.6*	0					550-650	250	230 lbs, bottom ripped out of net, large
71	**1**	3/10/99	1	Whiteman Cr / S	0	<5	30	90	104	same because bottom trawl		12.7	0					550-650	200	230 lbs, repl't tows 58, 60 @ different time of
71	**1**	3/10/99		Whiteman Cr / S	0	<5	30	90	104	same because bottom trawl		12.7	0					550-650	200	230 lbs, repl't tows 58, 60 @ different time of
72	**1**	3/10/99	2	Cameron Pt / S	0	<5	30	88	103	same because bottom trawl		20.4	2	35, 31	released alive			650	250	230 lbs
72	**1**	3/10/99		Cameron Pt / S	0	<5	30	88	103	same because bottom trawl		20.4	2	35, 31	released alive			650	250	230 lbs
73	**1**	3/10/99	2	S Cameron Pt / S	0	<5	30	55	83	same because bottom trawl		0.2	0					650	200	230 lbs, had bobble sewn to bag to prevent
73	**1**	3/10/99		S Cameron Pt / S	0	<5	30	55	83	same because bottom trawl		0.2	0					650	200	230 lbs, had bobble sewn to bag to prevent
74	**1**	4/10/99	4	N Whiskey Isl / S	0	5	30	65	95	same because bottom trawl		50 g	0					650	200	230 lbs, bobble on
74	**1**	4/10/99		N Whiskey Isl / S	0	5	30	65	95	same because bottom trawl		50 g	0					650	200	230 lbs, bobble on
75	**1**	4/10/99	4	Whiskey Isl / N	0	5	30	93	115	same because bottom trawl		3.0	0					650	250	230 lbs, some pine needles
75	**1**	4/10/99		Whiskey Isl / N	0	5	30	93	115	same because bottom trawl		3.0	0					650	250	230 lbs, some pine needles
76	**1**	4/10/99	4	Whiskey Isl / S	0	5	30	121	168	same because bottom trawl		8.7	0					650	250	230 lbs
76	**1**	4/10/99		Whiskey Isl / S	0	5	30	121	168	same because bottom trawl		8.7	0					650	250	230 lbs
77	**1**	4/10/99	4	N of Whiskey Isl / N	0	5	30	91	124	same because bottom trawl		7.6	3	18, 33, 34	released	SC		650	250	230 lbs, some sticks, milfoil
77	**1**	4/10/99		N of Whiskey Isl / N	0	5	30	91	124	same because bottom trawl		7.6	3	18, 33, 34	released	SC		650	250	230 lbs, some sticks, milfoil
78	**1**	4/10/99	4	N Whiskey W side /	0	<5	30	130	144	same because bottom trawl		7.2	0					650	250	230 lbs
78	**1**	4/10/99		N Whiskey W side /	0	<5	30	130	144	same because bottom trawl		7.2	0					650	250	230 lbs
79	**1**	5/10/99	4	N Whiskey Isl / S	10	<5	30	61	97	same because bottom trawl		0.8	2	15,16	released	SC		650	200	230 lbs, milfoil, clay
79	**1**	5/10/99		N Whiskey Isl / S	10	<5	30	61	97	same because bottom trawl		0.8	2	15,16	released	SC		650	200	230 lbs, milfoil, clay
80	**1**	5/10/99	4	N Whiskey Isl / S	10	<5	30	91	128	same because bottom trawl		3.6	0					800	250	230 lbs, milfoil, clay
80	**1**	5/10/99		N Whiskey Isl / S	10	<5	30	91	128	same because bottom trawl		3.6	0					800	250	230 lbs, milfoil, clay
81	**1**	5/10/99	4	N of Whiskey Isl / N	10	<5	30	117	135	same because bottom trawl		13.7	0					650	250	230 lbs
81	**1**	5/10/99		N of Whiskey Isl / N	10	<5	30	117	135	same because bottom trawl		13.7	0					650	250	230 lbs
82	**1**	5/10/99	2	(@ Cameron Pt) /S	10	<5	22	134	151	same because bottom trawl		22.6	0					650	250	230 lbs
82	**1**	5/10/99		(@ Cameron Pt) /S	10	<5	22	134	151	same because bottom trawl		22.6	0					650	250	230 lbs

Trawl No.	Net	Date d/m/y	Zone*	Location / Direction of Tow	% Cloud	Wind kph	Trawl (Minutes)	Net Depth Range (m) (m, shallow)	(m, deep)	Bottom Depth Range (m) (m, shallow)	(m, deep)	Mysis Catch (kg)	Bycatch # fish	Size (mm)	Wt (g)	Species	Stomach	RPM Range	Tow Line Used (FM)	Other Notes
1	**2**	10/9/99	2	S of Ellison	80	5 to 15	30	63	80	same because bottom trawl		0.880	2	35, 42		SC, SC		600	200	10 min drop time allowed for net
2	**2**	10/9/99	2	S of Ellison	80	6 to 15	30	62	80	same because bottom trawl		0.020	0							some clay chunks
3	**2**	10/9/99	2	S of Ellison	0	7 to 15	30	75	90	same because bottom trawl		0.804	0							some clay chunks
4	**2**	10/9/99	3	Cedar Cove	0	8 to 15	30	73	86	same because bottom trawl		0.363	1	140	24	MW	stomach full, no	650	200	
5	**2**	10/9/99	3	S of Cedar Cove	0	9 to 15	30	80	88	same because bottom trawl		0.520	0					650	200	some problems with liner twisting, outer net left
6	**2**	10/9/99	3	N of Cedar Cove	0	10 to 15	30	82	93	same because bottom trawl		1.977	2	153, 152	37, 36	MW, MW	1) mysis present,	650	200	
7	**2**	11/9/99	2	S of Cameron Pt/ S	0	5	30	92	117	same because bottom trawl		2.814	0					650	225	
8	**2**	11/9/99	2	Ellison	0	5	30	91	132	same because bottom trawl		6.288	1	36	1	SC	stomach no mysis,	650	225	
9	**2**	11/9/99	3	N of Cedar Cove /	0	5	30	102	114	same because bottom trawl		1.251	0					650	225	
10	**2**	11/9/99	3	Cedar Cove / N	0	5	30	110	113	same because bottom trawl		2.210	1	115	15	YP	mysis only in	650	225	
11	**2**	11/9/99	2	S of Ellison / N	0	5	30	96	109	same because bottom trawl		3.802	0					650	225	
12	**2**	11/9/99	2	S of Ellison / N	0	5	30	109	120	same because bottom trawl		6.160	0					650	225	mysis on outside of big mesh bag
13	**2**	12/9/99	2	Cameron Pt / S	0	<5	31	120	144	same because bottom trawl		9.880	0					650	250	left to tow Outrageous
14	**2**	12/9/99	4	Whiskey Isl / N	0	<6	30	127	139	same because bottom trawl		2.806	0					650	250	switched to spring scale
15	**2**	12/9/99	3	N of Carrs Landing /	0	<7	30	123	140	same because bottom trawl		5.629	0					650	250	wood in sample, leaves in net
16	**2**	12/9/99	2	S of Ellison Pk / N	0	<8	30	137	193	same because bottom trawl		3.306	1	730	2510	LC	empty	625	250	some milfoil bits

Appendix 1 1999 mysis trawl data summary - Trident Isle, Okanagan Lake

Trawl	Net	Date	Zone*	Location /	%	Wind	Trawl	Net Depth Range (m)		Bottom Depth Range (m)		Mysis	Bycatch					RPM	Tow Line	
No.		**d/m/y**		**Direction of Tow**	**Cloud**	**kph**	**(Minutes)**	**(m, shallow)**	**(m, deep)**	**(m, shallow)**	**(m, deep)**	**Catch (kg)**	**# fish**	**Size (mm)**	**Wt (g)**	**Species**	**Stomach**	**Range**	**Used (FM)**	**Other Notes**
17	**3**	14/9/99	2	S of Cameron Pt/ S-	0	5	30	47	63	104	108	0.000	0					650-750	116	TEST MIDWATER ~80 lbs weight
18	**3**	14/9/99	2	S of Cameron Pt /	0	5	31	66	100	123	123	0.159	0					650-750	140	had to stop letting out FM because of sounder
19	**3**	14/9/99	2	S of Camerion Pt	0	5	SCRATCHED due to lack of depth													
20	**3**	14/9/99	2	Ellison / S	0	5	28	67	128	136	140	48.2	0					750	216	
21	**3**	15/9/99	2	Cameron Pt / S	0	<5	30	68	102	113	138	24.0	0					825	216	drop @650 rpm until down
22	**3**	15/9/99	2	S of Cameron / N	0	<5	30	62	102	115	147	28.3	0					800	216	brought up to 825 to bring net up
23	**3**	15/9/99	2	Ellison Pk / S	0	<5	30	62	109	120	145	32.9	1	released Kokanee				850	216	90 lbs bridle weight
24	**3**	15/9/99	2	S of Ellison / N	0	<5	30	102	122	124	148	87.1	0					700-850	216	slowed 850 down, 90 lbs wt
25	**3**	15/9/99	3	S of Fintry/S testing	0	5	120	60	102	174	200	7.3	0					750	216	fathom chg from 216-191
26	**3**	16/9/99	4	N of Whiskey Isl / S	30	<5	30	84	126	194	198	4.2	0					750	266	90 lbs wt, sounder shows bottom of net @ cal'd
27	**3**	16/9/99	4	Whiskey Isl / N	30	<5	30	126	166	189	200	2.6	0					800	266	160 lbs bridle wt
28	**3**	16/9/99	3	Carrs Landing / N	10	0	30	102	122	128	136	11.9	0					825	216	160 lbs wt, try to repl't 24
32	**3**	22/9/99	2	S of Ellison / S	0	<5	30	102	119	128	138	21.7 kg	1-0+	released Kokanee in good shape				800-850	216	240 lbs bridle wt
33	**3**	22/9/99	2	S of Ellison / N	0	<5	30	105	122	123	135	18	0					800-950	196-216	240 lbs bridle wt
34	**3**	22/9/99	2	S of Ellison / N	0	<5	30	105	122	129	138	23.0	0					800-850	216	150 lbs bridle wt
35	**3**	22/9/99	2	S of Ellison / N	0	<5	30	68	89	122	137	23.6	0					800-850	216	150 lbs bridle wt
36	**3**	23/9/99	2	Cameron Pt / S	80	<5	30	102	128	149	157	16.9	0					700-750	216	180 lbs bridle wt
37	**3**	23/9/99	2	Ellison / W to E	50	5	30	68	84	84	96	blown	1- 1+	139	37	Kokanee	no mysis, empty	750-850	191-216	boat hooked on tether, woody debris
38	**3**	23/9/99	2	Cameron Pt / S	80	20	30	75	102	110	137	21.3	1- 0+	released Kokanee in good shape				700-825	216	wind up to 20 kph
39	**3**	24/9/99	2	Cameron Pt / E to	30	5	30	75	96	119	145	12.0	0					600-850	216	80 lbs weight
40	**3**	24/9/99	2	Ellison W to E to S	30	5	30	68	95	90	99	6.6	0					800-1100	216	80 lbs weight
41	**3**	24/9/99	4	Whiskey Isl / S	70	5	30	68	102	160	166	4.7	0					750-850	216	80 lbs weight
42	**3**	24/9/99	4	Whiskey Isl / N	70	5	30	68	105	163	170	6.6	1	37	10	SC	indiscernable	700-800	216	80 lbs weight
43	**3**	25/9/99	4	Whiskey Isl / S	100	<5	30	68	96	190	199	4.6	0					650-900	216	80 lbs weight
44	**3**	25/9/99	4	Whiskey Isl / S	100	<5	30	102	129	198	211	6.3	0					600-800	216	150 lbs bridle wt
45	**3**	25/9/99	4	Whiskey Isl / S	80	<5	30	134	162	198	202	3.1	0					700-750	266	150 lbs bridle wt
46	**3**	25/9/99	4	Whiskey Isl / N	80	<5	30	134	166	181	211	4.1	0					700-825	266	150 lbs bridle wt
47	**3**	27/9/99	4	Whiskey Isl / S	30	<5	30	102	129	172	176	7.6	0					725-800	216	150 lbs bridle wt
48	**3**	27/9/99	4	Whiskey Isl / S	30	<5	30	102	129	123	147	6.1	0					750-800	216	150 lbs bridle wt
49	**3**	27/9/99	4	Whiskey Isl / S	30	<5	30	102	129	141	148	7.9	0					750	216	150 lbs bridle wt
50	**3**	27/9/99	4	Whiskey Isl / N	30	<5	30	102	129	143	149	6.9	0					750	216	150 lbs bridle wt
51	**3**	28/9/99	4	Whiskey Isl / S	30	<5	30	68	99	139	147	2.9	0					750-800	216	80 lbs weight
52	**3**	28/9/99	4	Whiskey Island	30	<5	15	68	102	161	170	1.7	0					800	216	150 lbs bridle wt
53	**3**	28/9/99	4	Whiskey Isl / S	90	<5	30	68	102	135	140	5.6	0					750	216	80 lbs weight
54	**3**	28/9/99	4	Whiskey Isl / N	90	<5	30	68	102	140	150	6.7	0					750-800	216	80 lbs weight
54	**3**	28/9/99		Whiskey Isl / N	90	<5	30	68	102	140	150	6.7	0					750-800	216	80 lbs weight
55	**3**	29/9/99	2	S of Ellison / S	20	10	30	102	129	132	145	13.6	0					700	216	150 lbs bridle wt
55	**3**	29/9/99		S of Ellison / S	20	10	30	102	129	132	145	13.6	0					700	216	150 lbs bridle wt
56	**3**	29/9/99	4	Whiskey Isl, W side	20	10	30	102	129	137	154	7.0	0					725	216	150 lbs bridle wt
56	**3**	29/9/99		Whiskey Isl, W side	20	10	30	102	129	137	154	7.0	0					725	216	150 lbs bridle wt
57	**3**	29/9/99	4	Whiskey Isl / S	50	5	30	102	135	154	170	8.1	0					750-850	216	150 lbs bridle wt
57	**3**	29/9/99		Whiskey Isl / S	50	5	30	102	135	154	170	8.1	0					750-850	216	150 lbs bridle wt

Trawl	Net	Date	Zone*	Location /	%	Wind	Trawl	Net Depth Range (m)		Bottom Depth Range (m)		Mysis	Bycatch					RPM	Tow Line	
No.		**d/m/y**		**Direction of Tow**	**Cloud**	**kph**	**(Minutes)**	**(m, shallow)**	**(m, deep)**	**(m, shallow)**	**(m, deep)**	**Catch (kg)**	**# fish**	**Size (mm)**	**Wt (g)**	**Species**	**Stomach**	**Range**	**Used (FM)**	**Other Notes**
29	**4**	19/9/99		Cameron Pt / S	clr night	<5	10 57 pm	13	13	64	72	65.0	7 - 0+	released Kokanee in good shape				825-900	36	240 bridle wt
											NOTE IN POUNDS!!		1- 1+	released Kokanee in good shape						
							12:02 AM					65.0	4 - 0+	released Kokanee in good shape						
													2 - 2+	released Kokanee in good shape						
							12:32 AM					60.0	2- 2+	released Kokanee in good shape						
													2- 1+	released Kokanee in good shape						
				65 lbs			1:04 AM	14.3				51.0	3- 0+	released Kokanee in good shape				1000	36	0.8 knots
													2- 1+	released Kokanee in good shape						
													3- 2+	released Kokanee in good shape						
							1:37 AM	10.7				50.0	4- 0+	released Kokanee in good shape				1000	36	bicatch went up but not flow
													5- 1+	released Kokanee in good shape						
													8- 2+	released Kokanee in good shape						
							2:12 AM	11	19	159	167	80.0	6- 0+	released Kokanee in good shape				1000	46	let out more line
													2- 1+	released Kokanee in good shape						
													2- 2+	released Kokanee in good shape						
							2:44 AM	17		119		100.0	3-0+	released Kokanee in good shape				1000	46	
													6- 1+	released Kokanee in good shape						
													10- 2+	released Kokanee in good shape						
							3:20 AM	14		100		45.0	2- 0+	released Kokanee in good shape				1000	41	
													6- 1+	released Kokanee in good shape						
													3- 2+	released Kokanee in good shape						
							3:55 AM	16		102		45.0	7- 0+	released Kokanee in good shape						
										AVERAGE:	**62.3**	**lbs**	6-2+	released Kokanee in good shape						
30	**4**	20/9/99		Cameron Pt / S	clr night	<5	8:18 PM	16	18	118		85.0	2- 0+	released Kokanee in good shape				1000	46	240 lbs bridle wt
													1- 1+	released Kokanee in good shape						
													2- 2+	released Kokanee in good shape						
							8:54 PM	16		107		81.0	1- 0+	released Kokanee in good shape						
													2- 1+	released Kokanee in good shape						
													2- 2+	released Kokanee in good shape						
							9:26 PM transition					15.0	2- 0+	released Kokanee in good shape						
													1- 2+	released Kokanee in good shape						
							9:35 PM	13	14	114	121	75.0	0					1000	40	brought up 6 FM
							10:05 PM transition	pulled up camera/ pole to boat				13.0	2- 1+	released Kokanee in good shape						
31	**4**	20/9/99		going N	clr night	<5	PM - 11:32	17		115	est on 2 tows:	187.0	7- 0+	released Kokanee in good shape						
													2- 1+	released Kokanee in good shape						
										AVERAGE:	**53.8**	**lbs**	7- 2+	released Kokanee in good shape						

CHAPTER 4

PUBLIC COMMUNICATIONS

This component of the Action Plan involves communication with the public and private interest groups regarding implementation of all the activities associated with the OLAP. A few examples of media coverage in 1999 are shown to emphasize the importance the public places on the work conducted by fisheries personnel.

1999 MEDIA COVERAGE OF OKANAGAN LAKE FISHERIES ISSUES

Throughout 1999, local newspaper media and television provided considerable coverage on fisheries related issues associated with the OLAP. The most prominent issue was the extensive coverage of the experimental mysid fishery that is reported in Chapter 3 of this report. A Westland Series documentary on the mysid fishery funded by the HCTF was aired on local television throughout British Columbia several times in 1999. This documentary plus the extensive newspaper articles have been invaluable to the OLAP since they have provided numerous opportunities for messaging the public about the serious ecological state that Okanagan Lake is in. The local newspapers have been very cooperative and done a good job of explaining the story of Okanagan Lake.

Local fisheries staff queried about the mysid fishery were able to explain the problems of declining kokanee numbers and what the OLAP was attempting to do to remedy the situation. The public has begun to grasp the complexity of problems associated with Okanagan Lake and have shown strong support for the work of the OLAP. The news coverage has also refocused attention on the critical problems of water supply for fish.

The somewhat unusual attempt to commercially fish for freshwater shrimp is quite novel in North America and has attracted a great deal of interest not only locally but also internationally as well. Researchers have contacted local fisheries staff as well as market analysts and inventive individuals who all want to know how the fishery is developing.

With the heightened extent of public interest and near completion of Phase 1 of the OLAP plans are underway for a major conference on Okanagan Lake in 2001. This event will provide the public, private groups and government officials with details of progress of the OLAP and will be a good opportunity for public input into the direction of Phase 2 (see Appendix 1).