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TROPHIC CHANGES IN LAKES OKANAGAN, SKAHA AND OSOYOOS, B. C., FOLLOWING IMPLEMENTATION OF TERTIARY MUNICIPAL WASTE TREATMENT

Prepared by

S. J. Truscott

B. W. Kelso

Department of Environment

Environmental Protection Service

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N O T I C E

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Office of the Program Coordinator
P. O. Box 458
Penticton, B. C.
V2A 6K6

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Author	S. J. Truscott
Project Design and Direction	B. W. Kelso
Field Studies	S. J. Truscott G. Derksen A. B. Guest M. Ferguson

ABSTRACT

As part of the Canada - British Columbia Okanagan Basin Implementation Program, a water quality monitoring study was conducted on lakes Okanagan, Skaha, and Osoyoos in British Columbia during June to October, 1976, and April to October, 1977 and 1978. The purpose of the study was to determine if and to what degree the lakes were responding to reduced nutrient loadings from tertiary treatment facilities.

Samples were collected at selected shallow stations to determine physical, chemical, and biological parameters in order to monitor the impact of sewage disposal in littoral areas. Deep water samples were also taken to determine the effects of nutrient loading on the biological production of the lakes as a whole.

Lakes Skaha and Osoyoos were of major interest during the study as they are located downstream of a tertiary sewage treatment plant located at Penticton, where considerable amounts of phosphorus have been removed from the sewage since 1971.

Skaha Lake appears to have responded to this measure in terms of reduced phosphorus levels and reduced algal production since 1971.

Algal production has also decreased significantly in Osoyoos Lake, but it was not possible to detect if any change in phosphorus levels had occurred since 1971.

No reduction in biological production was observed in Okanagan Lake, except in Vernon Arm where there has been a diversion of the Vernon sewage discharge from the Okanagan Lake system. Nutrient concentrations and the production of algal biomass have both been reduced in the Vernon Arm area.

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SUMMARY AND CONCLUSIONS

As part of the Okanagan Basin Implementation Study of water quality, the federal Environmental Protection Service (EPS) carried out a limnological monitoring program in lakes Okanagan, Skaha, and Osoyoos over three separate periods, one of five months (1976) and two of seven months (1977 and 1978). The objective of the study was to monitor and assess the changes in each lake since implementation of tertiary municipal waste treatment measures in 1972 and subsequent years.

Lakes Skaha and Osoyoos were of principal concern because they are situated downstream from the tertiary treatment plant at Penticton, where, since 1972, phosphorus has been removed from the sewage. Prior to implementation of Penticton tertiary treatment, these two lakes were responding to unacceptable phosphorus loadings with accelerated eutrophication (Canada - British Columbia Okanagan Basin Agreement, Technical Supplement V, 1974). Okanagan Lake was of secondary importance as only a few new treatment measures had been implemented in this area since 1972, one of which was the partial diversion of Vernon sewage from the system each year during the spring through fall periods. In August 1977, the Vernon sewage discharge was completely diverted from the lake system.

Physical, chemical and biological data were collected during the three-year program primarily at shallow sampling stations within the zone of direct nutrient influence and also at deep water stations. In order to determine if there had been a change in the trophic status of the lake system, the 1976 to 1978 data were compared with similar data obtained in 1971 during the Okanagan Basin Limnology Study (Canada - British Columbia Okanagan Basin Agreement, Technical Supplement V, 1974), and during other studies in 1969, 1970 and 1971 (Stein and Coulthard, 1971 and Patalas and Salki, 1973).

The E.P.S. field studies did not include the assessment of nutrient loadings to the lakes. That information was obtained and should soon be reported by the Inland Waters Directorate (I.W.D.). Such information will be absolutely necessary for the final water quality report to substantiate indication in this report of trends from 1971 to 1978. There are two reasons for this:

(1) Nutrient levels in lakes are affected by a complex of interacting factors including biological fluctuation, climate, hydrology, urbanization, and rural development. This fact was evidenced by a variation in limnological measurements between the years 1976, 1977 and 1978 which were known to be climatologically and hydrologically different from each other. All of these factors should of course be considered in the final report. However, the objective of this portion of the water quality program was to compare the present conditions of these lakes with conditions prevalent in 1971, rather than to unequivocally identify the source of those conditions.

(2) There were severe limitations with some of the 1971 limnology data (especially the chemical parameters) in terms of their representativeness and comparability to recent data, thereby disallowing firm conclusions concerning chemical changes since 1971.

The algal and zooplankton data, however, provided the firmest basis for conclusions because the organisms in an environment are an excellent reflection of the complex of environmental factors surrounding them, and because more comparable biology data from previous years were available than was the case for chemistry data.

Various limnological researchers, including Vollenweider, Birge, and Juday have identified trophic categories and other well known characteristics of lake waters. Some of these characteristics are presented in Table 1 (modified from Wetzel, 1975), which provide a basis for the trophic classification of the three lakes of concern in this study.

Okanagan Lake. Since 1971, there has been no obvious change in spring or seasonal total phosphorus concentrations at any of the deep stations. What small variability occurred could be easily attributed to climatic and hydrological variability (Table 2).

April total nitrogen values have not clearly changed since 1971 in all the above three sections of Okanagan Lake.

Some increases in concentration were noted at OK-1, but were possibly due to analytical variations from one year to another (section 4.2.2.4), or simply annual variation.

No obvious changes in trend were noticed for the other nutrients since 1971.

At the shallow stations in 1976, 1977 and 1978, the highest nutrient concentrations, as expected, were found at the stations most subject to nutrient loadings. The stations effected were OK-S1 at the end of the North Arm, OK-S2 at the end of the Vernon Arm, and OK-S5 near the Kelowna sewage outfall south of the floating bridge. Total P concentrations were generally quite high at those stations. A significant drop in all nutrients was noted at OK-S2 between the 1977 and 1978 sampling seasons. The cause of this was most likely the diversion of all Vernon sewage from the lake system. Nutrient values remained quite low throughout 1976, 1977 and 1978 at OK-S3, at Okanagan Centre, and at OK-S10 located at the south end of the lake. No nutrient samples were taken at the shallow stations in 1971 and therefore no basis for comparison to recent nutrient studies in these areas exists.

TABLE 1 GENERAL RANGES OF VARIOUS LIMNOLOGICAL CHARACTERISTICS OF LAKES OF DIFFERENT TROPHIC CATEGORIES

Trophic Type	Phyto-plankton Biovolume (cm^3/m^3)	Chlorophyll-a (mg/m^3)	Dominant Phytoplankton	Total P (ug/l)	Total N (ug/l)
Ultra-oligotrophic	1	0.01-0.05		1-5	1-250
Oligotrophic		0.3-3	Chrysophyceae		
			Cryptophyceae		
Oligo-mesotrophic	1-3		Dinophyceae	5-10	250-600
			Bacillariophyceae		
Mesotrophic		2-15			
Meso-eutrophic	3-5			10-30	500-1100
Eutrophic		10-500	Bacillariophycea		
			Cyanophyceae		
Hyper-eutrophic	10		Chlorophyceae	30- 5000	500- 15000
			Euglenophyceae		
Dystrophic		0.1-10		1-10	1-500

Modified from Wetzel (1975), after many authors and sources.

TABLE 2 A COMPARISON OF SOME MAJOR 1976/1977/78 OKANAGAN LAKE DATA WITH THOSE FROM STUDIES IN 1969/70 AND 1971 (SEASONAL MEAN VALUES UNLESS OTHERWISE SPECIFIED)*

Station	Parameter	Year 1969/70		1971		1976		1977		1978		Trophic Status 1969/71	1976/77/78
OK-1	Total P (μg/l)	-	-	16.8	(8.7)	20.0	-	8.0	(9.5)	10.3	(8.5)	Oligotrophic tending to Mesotrophic	Oligotrophic tending to Mesotrophic
	Total N (μg/l)	-	-	129.0	(160.0)	-	-	199.0	(190.0)	210.0	(201.0)		
	Phyto. Chl-a + Pheo. (μg/l)	-	-	5.63	-	1.45	1.26^{S}	1.72	-	2.09	1.44^{S}		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	1.53	3.24^{P}	0.42	0.70^{P}	1.04	1.27^{P}		
	Oct. Bottom D.O. (mg/l)	-	-	-	-	10.8	90%	10.5	91%	9.5	80%		
	Zooplankton (mm^3/cm^2)	-	2.1^{Se}	-	12.0^{A}	14.5	18.3^{Se}	19.3	-	15.3	23.8^{A}		
OK-2	Total P (μg/l)	10.4	(7.6)	12.0	(10.8)	7.0	-	7.6	(8.5)	7.3	(4.5)	Oligotrophic tending to Mesotrophic	Oligotrophic tending to Mesotrophic
	Total N (μg/l)	-	-	148.0	(196.6)	-	-	246.0	(384.0)	187.0	(202.0)		
	Phyto. Chl-a + Pheo. (μg/l)	-	-	3.78	-	0.97	0.95^{S}	1.22	-	2.39	2.20^{S}		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	1.25	2.65^{P}	0.45	0.77^{P}	0.78	1.05^{P}		
	Oct Bottom D.O. (mg/l)	-	-	-	-	11.2	96%	10.5	90%	10.8	94%		
	Zooplankton (mm^3/cm^2)	-	8.9^{Se}	-	12.0^{A}	14.1	20.5^{Se}	10.6	-	19.6	33.2^{A}		
OK-3	Total P (μg/l)	-	-	13.9	(9.78)	9.0	-	7.0	(7.5)	5.8	(6.0)	Oligotrophic tending to Mesotrophic	Oligotrophic tending to Mesotrophic
	Total N (μg/l)	-	-	162.0	(190.0)	-	-	216.0	(295.0)	183.0	(199.0)		
	Phyto. Chl-a + Pheo. (μg/l)	-	-	4.01	-	1.05	0.79^{S}	0.67	-	1.33	1.16^{S}		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	1.32	2.54^{P}	0.28	0.39^{P}	0.58	0.94^{P}		
	Oct. Bottom D.O. (mg/l)	-	-	-	-	10.6	90%	10.7	93%	10.7	93%		
	Zooplankton (mm^3/cm^2)	-	17.0^{Se}	-	-	14.8	13.9^{Se}	10.6	-	12.1	21.3^{A}		
OK-S1	Total P (μg/l)	-	-	-	-	21.3	-	16.0	-	16.5	-	-	-
	Phyto. Chl-a (μg/l)	-	-	-	-	5.56	-	2.25	-	2.99	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	9.98	15.69^{P}		
	Peri. Chl-a ($\mu g/cm^2$)	-	-	0.8	-	-	-	0.42	-	0.40	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	1.56	6.91^{P}	0.40	1.36^{P}		
OK-S2	Total P (μg/l)	-	-	-	-	42.0	-	50.0	-	13.6	-	-	-
	Phyto. Chl-a (μg/l)	-	-	-	-	4.97	-	4.16	-	2.50	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	5.23	15.52^{P}		
	Peri. Chl-a ($\mu g/cm^2$)	-	-	8.5	-	-	-	1.87	-	0.58	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	1.72	7.07^{P}	0.26	1.04^{P}		
OK-S3	Total P (μg/l)	-	-	-	-	7.0	-	9.0	-	8.0	-	-	-
	Phyto. Chl-a (μg/l)	-	-	-	-	1.38	-	1.03	-	2.30	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	1.91	3.03^{P}		
	Peri. Chl-a ($\mu g/cm^2$)	-	-	-	-	-	-	0.05	-	0.07	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	0.16	0.57^{P}	0.05	0.16^{P}		
OK-S5	Total P (μg/l)	-	-	-	-	100.0	-	12.0	-	13.8	-	-	-
	Phyto. Chl-a (μg/l)	-	-	-	-	3.27	-	1.43	-	2.08	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	1.23	2.96^{P}		
	Peri. Chl-a ($\mu g/cm^2$)	-	-	0.6	-	-	-	0.24	-	0.21	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	0.56	1.15^{P}	0.16	0.46^{P}		
OK-S10	Total P (μg/l)	-	-	-	-	5.0	-	7.0	-	7.8	-	-	-
	Phyto. Chl-a (μg/l)	-	-	-	-	0.89	-	0.77	-	2.05	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	0.84	2.05^{P}		
	Peri. Chl-a ($\mu g/cm^2$)	-	-	0.5	-	-	-	0.04	-	0.03	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	0.09	0.28^{P}	0.03	0.11^{P}		

* Values in brackets are Spring overturn or soon after values.
P Peak value
S Mean for summer months
% Percent Saturation
C Value comparable to the 1969 and/or 1971 value
A August value
Se September value

Dissolved oxygen concentrations in the hypolimnion at the deep stations remained at high levels of saturation throughout each season, and exhibited no significant depletion. In some cases concentrations increased immediately below the metalimnion due to deep photosynthesis, which is not uncommon for relatively clear lakes, such as Okanagan Lake (Secchi values were as high as 8.5 m).

Biological production levels were relatively low for the main body of the lake (Table 2). The phytoplankton biomass measurements in terms of chlorophyll-a values were slightly lower in 1976, 1977 and 1978 than in 1971. However, all values compared were very small and could have been due to annual variation or simply variations in analytical techniques between the old and new studies. Zooplankton production appeared to have increased since 1969 and 1971 at all stations; however, this could have been due to a reduction in both the Kokanee population and its predation on the zooplankton. Therefore, no conclusions regarding a change in trophic status could be determined on the basis of standing crop of zooplankton measurements alone.

Station OK-S2 was the only shallow station in Okanagan Lake where a clearly defined change in production had occurred since 1971. The 1977 periphyton standing crop biomass production in terms of chlorophyll-a concentration was 1.87 ug/cm^2 compared to the 1971 value of 8.5 ug/cm^2. This 80% reduction was probably largely due to the partial diversion of Vernon sewage from the system. A further reduction of 70% to 0.58 ug/cm^2 was noted in 1978, which corresponded with a drop in all nutrients measured, undoubtedly a response to the complete diversion of the Vernon sewage discharge. Phytoplankton chlorophyll-a as well as the biovolume of both phytoplankton and periphyton also reflected this drop in biological production. From these data it was apparent that algae tended to respond quite rapidly to the reduction of nutrient loadings in zones of direct influence. Monitoring in this area is continuing in 1979 and the results of that program should help to confirm this observation.

It can therefore be concluded that Okanagan Lake as a whole is in an oligotrophic state but has some characteristics of a mesotrophic lake. There are a few areas on the lake such as the tip of the North Arm and the Vernon Arm, which exhibit a eutrophic character. The Vernon Arm has shown a very favourable response to the sewage diversion, and continued monitoring of the area would help to provide indication of any further response. The littoral area south of the Kelowna bridge near the sewage discharge is apparently in a meso-eutrophic state. Possibly the eutrophication of this area has been mitigated to some extent by wind or current mixing. Some dye and drogue studies carried out by the Water Investigations Branch in May 1978 (unpublished data), indicated extensive wind mixing in the foreshore surface waters of this area. The water quality of the other stations at Okanagan Centre and at the south end of the lake was very good and is considered to be in an oligotrophic state.

Skaha Lake. Of all the nutrients available in the water column, nitrogen and phosphorus are usually the ones which can limit the growth of algae. Most commonly, P is the limiting nutrient except in unusual circumstances such as where P loading from sewage or other discharges is high. The 1971 report indicated a nitrogen limiting condition in Skaha Lake, and concluded that the lake was eutrophic or exhibiting excess and nuisance algal growth due to excess phosphorus loadings.

Phosphorus is the most logical nutrient to reduce loadings for two reasons. Firstly, the reduction of nitrogen loadings would be ineffective in controlling growth of those species of Blue-green algae which can fix atmospheric nitrogen. Secondly, for technical reasons, phosphorus is easier to control than nitrogen. The Canada - British Columbia Okanagan Basin Agreement report (1974) recommended that loadings of phosphorus from sewage to the Okanagan system be reduced to control eutrophication of the lake. As a result, Penticton has been removing at least 80% of the phosphorus from its municipal sewage since 1972.

As Table 3 shows, there has been an apparent decrease in spring and mean seasonal total phosphorus concentrations since 1969, 1970 and 1971. The decrease in spring phosphorus concentrations has been between 4% and 65%, and the decrease in seasonal phosphorus has been between 19% and 56%. These percentage values do not include 1976 samples which were taken at only one depth in the epilimnion.

The spring dissolved P level in 1978 was lower than the 1971 spring orthophosphorus level, and the 1977 value was very similar to that of 1971. From this it seems possible that there has also been a reduction in orthophosphorus since 1971. Total nitrogen concentrations may have increased since 1971. The result of studies by the Pollution Control Branch (P.C.B.) on Okanagan sewage treatment plants and I.W.D. on basin loadings should more clearly indicate total nitrogen trends, if there were any.

Spring nitrogen-phosphorus ratios have risen from 9:1 in 1971, which was indicative of nitrogen limitation, to 20:1 and 14:1 in 1977 and 1978, which are indicative of phosphorus limitation (Dillon and Rigler, 1974). These results were supported by an in situ algal bioassay completed in 1977 on Skaha Lake by the B.C. Water Investigation Branch (Nordin, 1978).

The declines in seasonal total phosphorus since 1971 at the deep station were reflected by the northernmost shallow station S-S1. No nutrient samples were collected at the other two stations, SS-3 and SS-2, in 1971; but the 1976, 1977 and 1978 values at those stations were similar to values found at S-S1 and the deep station in the same years - averaging about 13 ug/l.

Phytoplankton data for the deep station indicated a marked reduction in biomass since 1971, as well as a shift in species of predominant algae during the summer months. In 1971, seasonal chlorophyll-a and pheopigment values averaged 13.19 ug/l compared to

TABLE 3 A COMPARISON OF SOME MAJOR 1976/1977/78 SKAHA LAKE DATA WITH THOSE FROM STUDIES IN 1969/70 AND 1971 (SEASONAL MEAN VALUES UNLESS OTHERWISE SPECIFIED)*

Station	Parameter	Year										Trophic Status	
		1969/70		1971		1976		1977		1978		1969/71	1976/77/78
S-1	Total P (μg/l)	18.8	(31.0)	29.5	(20.7)	10.0	-	13.1	(11.0)	15.3	(18.0)		
	Total N (μg/l)	-	-	234.0	(196.6)	-	-	265.0	(217.0)	255.0	(243.0)		Mesotrophicc but close to Eutrophic
	Phyto. Chl-a + Pheo. (μg/l)	-	-	13.19	15.65^{S}	2.96	3.15^{S}	3.22	3.33^{S}	4.16	5.05^{S}	Eutrophic	
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	4.44	7.83^{P}	0.84	1.30^{P}	2.55	4.35^{P}		
	Hypolimnetic O_2 Depletion Rate (mg/cm^2/day)	.076	-	-	0.077	-	-	0.149	0.125^{C}	0.136	0.139^{C}		
	Oct. Bottom D.O. (mg/l)	-	-	-	-	-	-	2.1	18.3%	0.8	7.3%		
	Zooplankton (mm^3/cm^2)	-	23.2^{Se}	-	24.1^{A}	9.7	9.7^{Se}	9.0	16.1^{A}	23.6	30.0^{A}		
S-S1	Total P (μg/l)	-	-	38.0	-	10.7	-	13.0	-	13.1	-		
	Phyto. Chl-a (μg/l)	-	-	17.25	-	2.35	-	2.70	-	3.32	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	3.40	12.86^{P}	-	-
	Peri. Chl-a (μg/cm^2)	-	-	15.28	-	-	-	0.59	-	1.08	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	0.97	5.71^{P}	0.35	1.05^{P}		
S-S3	Total P (μg/l)	-	-	-	-	-	-	13.0	-	13.0	-		
	Phyto. Chl-a (μg/l)	-	-	-	-	-	-	2.08	-	3.27	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	2.48	4.19^{P}	-	-
	Peri. Chl-a (μg/cm^2)	-	-	-	-	-	-	0.12	-	0.12	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	0.26	0.97^{P}	0.13	0.49^{P}		
S-S2	Total P (μg/l)	-	-	-	-	12.0	-	12.0	-	13.5	-		
	Phyto. Chl-a (μg/l)	-	-	-	-	2.57	-	2.22	-	2.95	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	3.68	13.15^{P}	-	-
	Peri. Chl-a (μg/cm^2)	-	-	1.1	-	-	-	0.06	-	0.09	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	0.33	1.55^{P}	0.10	0.23^{P}		

* Values in brackets are Spring overturn or soon after values.
P Peak value
S Mean for summer months
% Percent saturation

C Value comparable to the 1971 value
A August value
Se September value

1976, 1977 and 1978 values which ranged from 3.96 to 5.80 ug/l. This represented a drop of at least 57%. The 1969 August period was characterized by large blooms of Blue-green algae which at 574 cells/ml made up 80% to 90% of the total number. The algal assemblage was dominated by Aphanizomenon flos-aquae, Aphanothece nidulans, and Oscillatoria sp. In 1976, 1977 and 1978 Blue-green algae remained relatively low in number throughout each season, reaching a maximum of only 296 cells/ml in August which was 17% of the total number at that time. At the same time diatoms dominated the algal assemblage instead of Blue-green algae. These were key data in identifying a decreasing trend in production since 1971, and suggested a present state of meso-eutrophy compared to marked eutrophy in 1971.

Zooplankton data, especially the identification and enumeration data, indicated a general decrease in secondary production. In most cases, 1976, 1977 and 1978 settled volumes were less than in 1969 and 1971 (Table 3), and in all cases the total population of crustacean zooplankton was significantly less than in 1969 and 1971. This showed that the decreased primary standing crop had probably not resulted from increased zooplankton grazing.

Shallow station algal production, in terms of periphyton, has also decreased at stations S-S1 and S-S2 which were the only stations sampled in 1971. The greatest decrease was noted at the north end of Skaha Lake (S-S1) where the 1971 periphyton chlorophyll-a value was 15.8 ug/cm^2 compared to the 1977 and 1978 values of 0.59 and 1.08 ug/cm^2. At the south end of the lake at S-S2, the 1971 value was 1.1 ug/cm^2 compared to 0.06 and 0.09 ug/cm^2 during 1977 and 1978. This fact pointed towards decreased nutrient loadings from the Okanagan River at Penticton as the cause of lowered algal biomass. Therefore, the biological data allowed fairly firm conclusions that there has been a decrease in algal and zooplankton standing crop production in Skaha Lake since 1971. Phosphorus levels also seem to have decreased. Nutrient levels, however, are controlled by a variety of factors and a marked change could have gone unnoticed due to fluctuations in values.

Dissolved oxygen measurements showed an increase in the hypolimnetic depletion rate since 1971. More importantly hypolimnetic dissolved oxygen concentrations at the bottom of the lake had approached a value of 0 mg/l by October 1977 and 1978 (Table 3). It is not known if this was the case in 1971 because no October data were collected that year. It is evident that such a dissolved oxygen depletion presents an existing problem regarding harm to fish.

Though these data indicated a severe problem, they do not necessarily contradict other indicators of reduced eutrophication since 1971. An excess oxygen demand on this hypolimnion could have arisen due to some influence from outside the lake.

The severity of this situation is cause for concern, because if this trend continues, an anaerobic hypolimnion would result. The net effect of this would probably be a sudden increase of rapid eutrophication due to an internal and possibly irreversible loading of nutrients from the sediments (Wetzel, 1975).

It is therefore urgent that this problem be studied much more intensively to identify its source and potential duration. It is important that such an investigation include an intensive physical limnological survey to clearly determine current and mixing patterns as well as flushing tendencies in Skaha Lake, which presently cannot be understood from the data available.

Also noteworthy is the fact that the City of Penticton has recently been considering Skaha Lake as a potential receiving environment for a deep water sewage outfall. The hypolimnion of this lake, however, should be considered unsuitable for sewage disposal, because any further oxygen demand placed on this system could only intensify the oxygen depletion problem.

An important point to note is that despite the reduction in phytoplankton and periphyton production in this lake, a large problem still exists with regard to the well known littoral infestations of the aquatic weed Myriophyllum spicatum (Eurasian Milfoil). It is therefore necessary to differentiate between excess algal production and excess weed production in terms of their response to reduced nutrient loadings for the following reasons:

(1) Secondary treated sewage discharges tend to load a relatively large amount of dissolved phosphorus into the water column. This dissolved P is immediately available for assimilation by periphyton and phytoplankton. The amount of phosphorus taken up by algae is to a large degree removed from the system through flushing out or sedimentation of algal cells. However, if there is a reduction in nutrient loading to the lake, as in the case of Skaha Lake in 1971, dissolved nutrients are made less available for algal assimilation. The net effect of this is likely to be reduced algal production as was verified by the 1976, 1977 and 1978 data for Skaha Lake.

(2) Even though present discharges of sewage to Skaha Lake contain fewer nutrients and should result in lower algal production, a reduced production of macrophytes in littoral areas might not occur very rapidly. Nichols and Keeney (1973) found that up to 90% of the phosphate in Myriophyllum stems can come from the roots, indicating that the main source of phosphorus for M. spicatum depend more on sediments for a nutrient source than the water column, and reduced external loadings of nutrients to a lake would have little effect in reducing existing sediment nutrient concentrations or M. spicatum growth.

During the 1976, 1977 and 1978 study the potential role that nitrogen played on the macrophyte population in the littoral zone was not investigated because the study's primary concern was to evaluate the algal production changes since 1971. Of course, it is very likely that other factors, in addition to nutrients, played an important part in affecting *M. spicatum* infestations.

Whether or not the reduction of algal production in Skaha Lake is permanent can only be determined by continued monitoring on a long-term basis and by nutrient budgeting. The nutrient budgeting information can only be based on the combination of the data from the E.P.S. project with that of the Inland Waters Directorate loading survey and the waste loading study being conducted by the British Columbia Pollution Control Branch.

Okanagan River at Penticton. In 1977, chemical samples and benthic macroinvertebrate samples were taken in the Okanagan River upstream and downstream of the sewage treatment plant discharge. Analyses of these samples from the brief (May to October) monitoring program indicated that 26% of the total phosphorus at station OK-R2, just downstream from the mouth of Shingle Creek, had come from Okanagan Lake, and that the remaining 74% was from the sewage discharge and other sources located between the mouth of the creek and the sampling station. During the same period only about 19% of the dissolved phosphorus (20 ug/l) came from Okanagan Lake; the remaining 81% came from the sewage treatment plant and other sources downstream of the plant.

Eighty-six percent of the nitrate-nitrogen (36.0 ug/l) at OK-R2 came from the sewage treatment plant and downstream sources. Ammonia levels were very high (averaging 715 ug/l) at station OK-R2, with most of the ammonia originating at the sewage treatment plant. This also undoubtedly contributed to the higher than usual ammonia levels at Skaha Lake shallow stations. This parameter should be investigated as a potential contributor to the Skaha Lake oxygen demand problem. These trends were likely to be different during the winter months when minimum discharges occurred from the sewage treatment plant.

Benthic macroinvertebrate data indicated no negative biological impact due to sewage or other discharges on the river downstream of the sewage treatment plant. Although there were good degrees of secondary production at both stations, diversity and evenness values were usually quite acceptable. As well, there was generally a good distribution of tolerant, facultative and intolerant organisms throughout most of the season at both stations.

Osoyoos Lake. As in the case of Skaha Lake, the 1971 Canada - British Columbia Okanagan Basin Agreement concluded that nitrogen limitation caused by excess phosphorus loadings had occurred in Osoyoos Lake.

Spring total phosphorus levels in 1976, 1977 and 1978 were not appreciably different from those of 1969, 1970 and 1971, but were slightly less than the 1970 concentration. The seasonal mean values did not indicate any trend changes (Table 4). There may have been a reduction but the available data did not clearly identify one.

Spring and seasonal nitrate and total nitrogen concentrations appear, as in the case of Skaha Lake, to have substantially increased since 1971. The cause was unclear and could have been either differences in analytic methods between the years, increased external loadings, or reduced algal uptake in response to possibly reduced phosphorus levels. The I.W.D. and P.C.B. studies should help to isolate which of these factors, singly or together, were operative. The result of increased total N values was a shift of the N:P ratio from a nitrogen limiting character in 1971 to a phosphorus limiting character in 1977 and 1978.

TABLE 4 A COMPARISON OF SOME MAJOR 1976/1977/78 OSOYOOS LAKE DATA WITH THOSE FROM STUDIES IN 1969/70 AND 1971 (SEASONAL MEAN VALUES UNLESS OTHERWISE SPECIFIED)*

Station	Parameter	Year										Trophic Status	
		1969/70		1971		1976		1977		1978		1969/71	1976/77/78
O-1	Total P (μg/l)	15.4	(26.9)	17.4	(22.8)	12.0	-	18.0	(21.0)	17.3	(23.5)		
	Total N (μg/l)	-	-	169.0	(226.0)	-	-	360.0	(300.0)	288.0	(309.0)		
	Phyto. Chl-a + Pheo. (μg/l)	-	-	19.59	22.93^S	4.08	4.71^S	4.98	4.79^S	5.64	4.55^S	Eutrophic	Eutrophic but close to Mesotrophic
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	7.01	7.82^P	2.52	6.54^P	4.50	15.54^P		
	Hypolimnetic O_2 Depletion Rate ($mg/cm^2/day$)	.086	-	-	0.061	-	-	0.098	0.105^C	0.091	0.090^C		
	Oct. Bottom D.O. (mg/l)	-	-	-	-	-	-	1.4	13%	0.7	7%		
	Zooplankton (mm^3/cm^2)	-	25.9^Se	-	10.9^A	23.8	6.1^Se	31.9	16.8^A	31.9	27.0^A		
O-S1	Total P (μg/l)	-	-	17.3	-	15.0	-	18.0	-	17.5	-		
	Phyto. Chl-a (μg/l)	-	-	-	-	3.73	-	5.40	-	3.55	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	2.40	15.55^P	-	-
	Peri. Chl-a ($\mu g/cm^2$)	-	-	6.3	-	-	-	0.32	-	1.18	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	0.47	1.50^P	0.60	2.63^P		
O-S2	Total P (μg/l)	-	-	-	-	18.0	-	12.5	-	13.1	-		
	Phyto. Chl-a (μg/l)	-	-	9.81	-	4.29	-	4.64	-	3.67	-		
	Phyto. Biovol. (cm^3/m^3)	-	-	-	-	-	-	-	-	3.44	23.49^P	-	-
	Peri. Chl-a ($\mu g/cm^2$)	-	-	1.9	-	-	-	0.15	-	0.09	-		
	Peri. Biovol. (mm^3/cm^2)	-	-	-	-	-	-	0.14	0.30^P	0.19	0.97^P		

* Values in brackets are Spring overturn (or soon after) values.
P Peak value
S Mean for summer months
% Percent saturation
C Value comparable to 1971 value
A August value
Se September value

Algal biomass production, despite the lack of apparent change in phosphorus levels, has decreased since 1969 and 1971. Seasonal deep station chlorophyll-a and pheopigment values in 1971 averaged 19.59 ug/l, and in 1976 through 1978 averaged 4.64 to 6.95 ug/l. This represented at least a 65% reduction, and was supported by phytoplankton identification and enumeration data. In 1969, there were larger summer blooms of Blue-green algae which, with 1162 cells/ml in August, made up 71% of the total number of cells present at that time. The assemblage was dominated by *Lyngbya limnetica*, *Aphanizomenon flos-aquae* and *Aphanothece nidulans*. In 1976, 1977 and 1978, the numbers of Blue-green algae were much less than in 1969, although a summer bloom did occur.

Blue-green algae numbers varied from 53 cells/ml (11.8% of total) in August 1976, to 486 cells/ml (36% of total) in August 1978 with diatoms dominating the assemblage. This change was less marked than the one on Skaha Lake.

Zooplankton settled volumes did not indicate any clear changes in the trends of secondary biomass production. Identification and enumeration data indicated perhaps a slight drop in numbers since 1969 and 1971. There were less total Crustacea in the September months of 1977 and 1978 than in September 1969. However, there were about the same number of total Crustacea during the August months of 1977 and 1978 as there were in August 1971.

Periphyton data from the shallow stations indicated a considerable drop in biomass between 1971, and the years 1977 and 1978. At the northernmost station, 0-S1, near the mouth of the Okanagan River, chlorophyll-a production dropped from 6.3 ug/cm^2 in 1971 to 0.32 and 1.18 ug/cm^2 in 1977 and 1978, respectively. At the other shallow station, 0-S2, there was also a drop from 1.9 ug/cm^2 in 1971 to 0.15 and 0.09 ug/cm^2 in 1977 and 1978.

These declines were a key factor in evaluating the trophic state of this lake but were surprising in view of the apparent lack of change in phosphorus concentrations. The biomass figures found, however, were not unexpected from the total phosphorus values found in 1977 and 1978. What was unexplainable was the large discrepancy between present chlorophyll-a data and those of 1971, which were much higher than expected from the phosphorus levels found in the latter year. This was not the case for lakes Okanagan and Skaha in 1971.

The dissolved oxygen data, like those of Skaha Lake, indicated poor water quality. Oxygen depletion rates in 1977 and 1978 were 0.105 and 0.090 $mg/cm^2/day$. These rates were slightly higher than the 1969 and 1971 values of .086 and 0.061 $mg/cm^2/day$, and such variation could have been due to annual fluctuations. Therefore, no conclusions are possible regarding change in areal depletion rates from 1969 to 1971.

Of greater significance, however, were the low hypolimnetic dissolved oxygen concentrations found in 1977 and 1978, which were close to 0 mg/l near the bottom. This is a cause of concern for the same reasons as those outlined above for Skaha Lake. The potential eutrophication of Skaha Lake adds to this concern because Osoyoos Lake could ill-afford increased nutrient loadings from Skaha Lake. The I.W.D. survey should shed more light on this subject in terms of what quantities of nutrients from Skaha Lake reach Osoyoos Lake under present conditions.

Of marked importance here is the fact that oxygen depletion rates and concentrations have not gone down since 1971, even though algal production has decreased. Further study is therefore necessary to identify the source of this problem.

On the basis of the 1976, 1977 and 1978 data, it was therefore concluded that the main body of the north basin of Osoyoos Lake was in a eutrophic state tending to mesotrophy. The north end littoral area exhibited a eutrophic character, but the shallow area in the Central Basin was in slightly better condition, being mesotrophic tending to eutrophy.

The above comparison of present and past data leads to less clearly defined conclusions concerning changes in Osoyoos Lake than were possible in the case of Skaha Lake. Osoyoos Lake has become less productive since 1971 in terms of algae, but it is not clear whether or not the concentration of total phosphorus has changed. It is also not known if there has been a decrease in soluble orthophosphate since 1971, but a reduction of this fraction is suspected as having been the cause of reduced algal production. The questions concerning the actuality of a phosphorus reduction and whether it pertains to point or non-point nutrient sources will hopefully be answered by the I.W.D. and P.C.B. studies.

1 HISTORICAL BACKGROUND

Various studies have been conducted throughout the years on the Okanagan Basin Lakes in British Columbia. The most recent and comprehensive of these was the multi-disciplinary water resource management study from 1969 to 1973 resulting from the Canada - British Columbia Okanagan Basin Agreement. The limnology portion of this study was conducted during April to October in 1971. Out of this study arose a "...comprehensive framework plan for the development and management of water resources" in the Okanagan Basin. The Canada - British Columbia Okanagan Basin Implementation Agreement signed in 1976 provides for the implementation of the 45 recommendations of the above framework plan.

Recommendations of the comprehensive framework plan which addressed the problem of water quality were in the form of waste management policies for the various communities in the Okanagan Valley. All had the goal of achieving at least 80% reduction of point source phosphorus loadings to the basin streams and lakes.

As a result of these recommendations, local governments in some areas for several years have been pursuing improved waste treatment. Since 1972, the City of Penticton has been treating its secondary treated sewage with a precipitation technique to remove initially 70% of the phosphorus in 1972 and up to 90% in 1976, 1977 and 1978. The City of Vernon, since 1970, had been operating a pilot spray irrigation system where, during the forage crop season, up to half of the city's secondary treated sewage was being discharged to the land. Since August, 1977, 100% of the discharge from the Vernon Sewage Treatment Plant has been going to the land, or a winter holding lagoon system. In 1972, three industries in Kelowna - American Can of Canada Ltd., Sun-Rype Ltd., and Calona Wines Ltd. - began secondary treatment of plant waste prior to discharge to Brandt's Creek in Kelowna.

To date, no new treatment measures have been implemented at the Armstrong, Kelowna, and Oliver sewage treatment systems, where major point source discharges have also occurred into the basin water courses.

The Okanagan Basin Implementation Board, in addressing the subject of water quality, has a particular interest in the use of monitoring as a tool to assess the success of local waste management programs. As a result, three monitoring programs were initiated:

(1) Monitor nutrient loadings from major municipal outfalls - B.C. Pollution Control Branch;
(2) Monitor river flows at selected sites and, in conjunction with this, monitor basin loadings to lakes Skaha and Osoyoos
  - Inland Waters Directorate, Environment Canada;
(3) Monitor the response of the main valley lakes to reduced nutrient loadings
  - Environmental Protection Service, Environment Canada.

The subject of this report is the third of these - a study of the response of the lakes. More clearly defined, the program goal was to conduct an integrated limnological survey of the major Okanagan Basin Lakes for a period of three years. The main emphasis was to be directed toward lakes Skaha and Osoyoos, which are downstream of the Penticton tertiary sewage treatment plant. A lesser emphasis was placed on Okanagan Lake where fewer nutrient removal measures had been implemented. The results were to be compared with those of the original 1971 Okanagan Basin limnology study to determine if the lakes had experienced increased or decreased biological production, or had not noticeably changed. Some data gathered by Stein and Coulthard (1971) in 1969 and 1970 were also available for use in this comparison.

This report, therefore, relates the findings from limnological monitoring in the Okanagan Valley during the spring to fall periods of 1976, 1977, and 1978.

2 STUDY AREA

A most thorough description of geological, geographical, and morphometric features of the Okanagan Valley can be found in Technical Supplement V to the final Okanagan Basin Study report (1974). Therefore, only a brief summary of these features will be given in this report.

The Okanagan Basin Extends in a north-south direction for 204 kilometers in Canada and 118 kilometers in the United States. It is located in the south-central interior portion of British Columbia. Flow of water is in a southerly direction through the Okanagan River which interconnects lakes Okanagan, Skaha, Vaseux, and Osoyoos.

The Okanagan Valley is U-shaped with the valley sides being from 1220 to 2134 meters high. The sunny, warm, summer weather, coupled with flat terraces and basin water available for irrigation creates a situation conducive to fruit growing. In addition to fruit growing, there is considerable dairy and vegetable farming. The area is also under heavy use by tourists in the summer season.

As Table 5 shows, the area generally is quite dry. Most of the water input to the system occurs from April to June, up to 1/3 of which is lost by evaporation and transpiration from Okanagan Lake. According to the results in Table 5 the hydrology of 1978, though wetter, was comparable to that of 1971 whereas 1977 was a considerably drier year than both 1971 and 1978. Precipitation records for the valley in 1971, 1976 and 1977 are presented in Appendix I, and indicate that 1976 was a wetter year than 1971, whereas 1977 was a drier year than 1971.

The three main population centres in the Canadian portion of the valley are Vernon, Kelowna, and Penticton (Figure 1). In addition to industries associated with the agricultural and tourist trades, the forest industry also has a large interest in the area.

TABLE 5 BASIC OKANAGAN BASIN DATA*

Okanagan Basin Watershed (in British Columbia)	
Total Drainage Area	8 073 m^2
Potentially irrigable lands (below 1800 ft. elev.)	408 854 m^2
Irrigated Lands	156 250 m^2
Tree Fruits	88 542 m^2
Vegetables	11 718 m^2
Grapes	6 510 m^2
Forage Crops	49 479 m^2
Climate	
Mean Annual Temperature	46°F (7.8°C)
Average Annual Precipitation - Armstrong	7.2" 18.0 cm
Average Annual Precipitation - Kelowna	12.2" 30.5 cm
Average Annual Precipitation - Penticton	11.3" 28.8 cm
Average Annual Precipitation - Oliver	10.8" 27.4 cm
Hydrology	
Average net inflow to Okanagan Lake	4.83×10^8 m^3
Minimum net inflow to Okanagan Lake	9.86×10^7 m^3 (1931)
Maximum net inflow to Okanagan Lake	9.41×10^8 m^3 (1948)
1971 net inflow to Okanagan Lake**	5.33×10^8 m^3
1977 net inflow to Okanagan Lake**	1.84×10^8 m^3
1978 net inflow to Okanagan Lake**	5.94×10^8 m^3 (Est.)

* Modified from Technical Supplement V to the Okanagan Basin Study Report (1974)

** Personal communication (Robin McNeil, Water Investigations Branch, Victoria, B.C.)

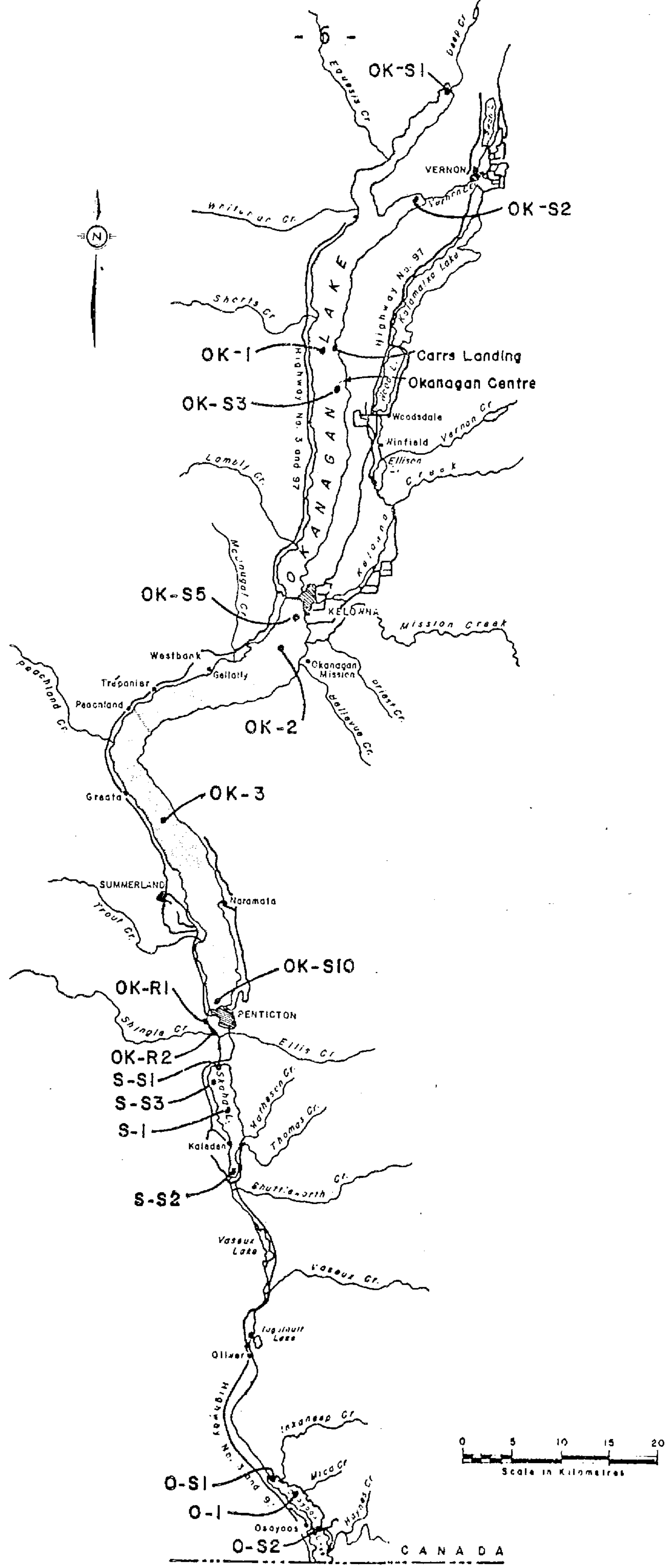

FIGURE 1 MAP OF OKANAGAN MAIN STEM LAKES WITH 1976-77-78 SAMPLE STATIONS (S-S3, OK-R1, OK-R2 New Stations in 1977)

3 METHODS

Sampling was initiated in June of 1976 and continued on a regular basis until October. In 1977 and 1978, sampling started in April and proceeded again until October. (See Tables 6, 7 and 8 for sampling dates). Two kinds of sampling stations existed during each year - deep stations and shallow stations. (See Figure 1 for station locations.) The shallow stations have a prefix "S" between the hyphen and the numerical value (e.g. S-S1 for Skaha Shallow-1) to distinguish them from the deep stations (e.g. S-1 for Skaha Deep-1). During each year, shallow stations were sampled every two weeks and deep stations monthly, except for Okanagan Lake deep stations which were only sampled three times in 1977 and four times in 1978 due to budget restrictions and a lesser emphasis of study for that lake. In 1977, two river stations OK-R-1 and OK-R-2 (Figure 1) were added above and below the sewage discharge to assist in the monitoring of biological response to nutrient loadings. Table 7 also depicts the approximate sampling periodicity of the 1971 limnology study.

Different criteria accounted for the existence of each of the two types of stations. Deep stations were designed to gain some representation of the trophic status of the main body of the lake under study, whereas, shallow stations were designed and located to gain knowledge about the more localized zones likely to receive a more direct impact from the inflow of nutrients or other materials. These more localized areas were therefore expected to show earlier and more obvious signs of lake response to reduced nutrient loadings than the main body of the lake.

Sampling over a number of years has an inherent advantage over sampling for one year, in that information gained from the first year can lead to improvements in the program during the following years. Such improvements can, and in the case of this study did, result in a higher yield of data in 1977 and 1978 than in 1976. In addition, trends over a few years may provide clearer insight into the limnology of the lake being studied.

TABLE 6 APPROXIMATE SAMPLING DATES 1976 SEASON

Station	Beginning of Each Two-Week Sampling Period								
	June 22	July 7	July 20	Aug. 4	Aug. 17	Sept. 1	Sept. 14	Sept. 28	Oct. 13
OK-1	x		x		x		x		x
OK-2	x		x		x		x		x
OK-3	x		x		x		x		x
OK-S1	x	x	x	x	x	x	x	x	x
OK-S2	x	x	x	x	x	x	x	x	x
OK-S3	x	x	x	x	x	x	x	x	x
OK-S5	x	x	x	x	x	x	x	x	x
OK-S10	x	x	x	x	x	x	x	x	x
S-1	x		x		x		x		x
S-S1	x	x	x	x	x	x	x	x	x
S-S2	x	x	x	x	x	x	x	x	x
O-1	x		x		x		x		x
O-S1	x	x	x	x	x	x	x	x	x
O-S2	x	x	x	x	x	x	x	x	x

TABLE 7 APPROXIMATE SAMPLING DATES 1971 AND 1977 SEASONS

Station	Beginning of Each Two-Week Sampling Period													
	April 20	May 9	May 25	June 7	June 21	July 4	July 18	July 25	Aug. 15	Aug. 29	Sept 12	Sept 26	Oct. 11	Oct. 24
OK-1	x,o				o			x		o			x,o	
OK-2	x,o				o			x		o			x,o	
OK-3	x,o				o			x		o			x,o	
OK-S1	p	x,p	x,p	x,p	x,p	x,p	x,p	p	x,p	x,p	x	x	x	x
OK-S2		x,p	x,p	x,p	x,p	x,p	x,p	p	x,p	x,p	x	x	x	x
OK-S3		x	x	x	x	x	x		x	x	x	x	x	x
OK-S5	p	x,p	x,p	x,p	x,p	x,p	x,p	p	x,p	x,p	x	x	x	x
OK-S10	p	x,p	x,p	x,p	x,p	x,p	x,p	p	x,p	x,p	x	x	x	x
S-1	x,o		x		x,o		x			x,o		x	o	x
S-S1	p	x,p	x,p	x,p	x,p	x,p	p	x,p	x,p	x,p	x,p	x	x	x
S-S3		x	x	x	x	x		x	x	x	x	x	x	x
S-S2	p	x,p	x,p	x,p	x,p	x,p	p	x,p	x,p	x,p	x,p	x	x	x
O-1	x,o		x		x,o		x			x,o		x	o	x
O-S1		x,p	x,p	x,p	x,p	x,p	p	x,p	x,p	x,p	x,p	x	x	x
O-S2		x,p	x,p	x,p	x,p	x,p	p	x,p	x,p	x,p	x,p	x	x	x

x = 1977 physical, chemical and biological samples.
o = 1971 physical, chemical and biological samples.
p = 1971 periphyton samples.

TABLE 8 APPROXIMATE SAMPLING DATES 1978 SEASON

Station	Beginning of Each Two-Week Sampling Period													
	April 2	May 7	May 14	May 28	June 11	June 25	July 9	July 23	Aug. 6	Aug. 20	Sept 4	Sept 17	Oct. 1	Oct. 15
OK-1	x					x		x					x	
OK-2	x					x		x					x	
OK-3	x					x		x					x	
OK-S1		x	x	x	x	x	x	x	x	x	x	x	x	x
OK-S2		x	x	x	x	x	x	x	x	x	x	x	x	x
OK-S3		x	x	x	x	x	x	x	x	x	x	x	x	x
OK-S5		x	x	x	x	x	x	x	x	x	x	x	x	x
OK-S10		x	x	x	x	x	x	x	x	x	x	x	x	x
S-1	x		x		x		x		x		x			x
S-S1			x	x	x	x	x	x	x	x	x	x	x	x
S-S3			x	x	x	x	x	x	x	x	x	x	x	x
S-S2			x	x	x	x	x	x	x	x	x	x	x	x
0-1	x		x		x		x		x		x			x
0-S1			x	x	x	x	x	x	x	x	x	x	x	x
0-S2			x	x	x	x	x	x	x	x	x	x	x	x

During the 1976 through 1978 field seasons, physical, chemical, and biological samples were taken. There were some differences between the sampling methodologies and parameters sampled during the three years, as described in the following sections 3.1 and 3.2.

3.1 Deep Stations

Sampling began by locating the station using geographical markers and a Model FM-21 Furuno Echo Sounder. Secchi measurements were taken with the aid of a viewing box. Surface temperatures were then taken using a field thermometer. Next, depth-temperature profiles from the surface to the bottom were obtained using a Kahl Scientific Instrument Corporation Bathythermograph.

By deploying six-litre Van-Dorn water bottles, chemistry samples were taken in 1976 at two depths - one metre below the surface and below the thermocline - approximately in the middle of the hypolimnion. Following the 1976 field season, it was felt that the vertical sampling frequency should be increased in order to obtain more representative samples from each stratum. Therefore, in 1977 and 1978, chemistry samples were taken at four depths - one metre below the surface, just above the thermocline, just below the thermocline and within a few metres of the bottom. See Table 9 for details concerning parameters sampled in each year, the field methods of sample preparation and analysis, and the laboratories to which samples were shipped for analyses.

The next procedure was to estimate the depth of the photic zone using the formula D = 2.5 x Secchi Depth. Phytoplankon identification and chlorophyll-a samples were taken using 6-litre Van Dorn water bottles at 2, 4, and 10 metres and at the depth of the photic zone. The chlorophyll-a samples were filtered at the field laboratory through a Whatman GFC glass fiber filter and shipped frozen to the laboratory. (See Table 9 for details of analysis). Phytoplankton identification samples were preserved with Lugol's solution and shipped to the laboratory.

TABLE 9 SUMMARY OF PARAMETERS SAMPLED IN 1976/77/78 AND LOCATIONS AND METHODS OF DETERMINATION

Parameter	Field Preparation and Location of Sample Analyses	1976		1977/78	
		Deep	Shallow	Deep	Shallow
Total Phosphorus	IWD Lab	x	x	x	x
Total Dissolved Phosphorus	Filtered through .45 micron sartorius membrane filter in field and sent to IWD Lab	x	x	x	x
Nitrite-Nitrate	IWD Lab	x	x	x	x
Ammonia	IWD Lab	x	x	x	x
Total Dissolved Nitrogen	IWD Lab	x	x	x	x
Particulate Nitrogen) Particulate Carbon)	Filtered through roasted GF-F Whatman glass fiber filter and sent to IWD Lab			x	
Reactive Silica	IWD Lab	x	x	x	x
pH	IWD and Field Lab - pH meter	x	x	x	x
Turbidity	IWD Lab	x	x	x	x
Conductivity	IWD Lab	x	x	x	x
Temperature	Field Lab - thermometer Field using bathythermograph	x	x	x	x
Dissolved Oxygen	In boat added manganous sulphate solution and alkaline - iodide azide solution. In field lab did titrations within 48 hours, according to Winkler method.	x	x	x	
Phytoplankton Chlorophyll-a and Pheopigments	Filtered through Watman GFC filter paper in field lab, filters frozen, and sent to EC Lab*	x		x	x
Phytoplankton and Periphyton	Preserved with Lugol's solution and sent to EPS Biology Lab for identification and enumeration of 1976 and 1978 data. IWD biology lab did the 1977 analyses. (See Appendix VIII for details on algal analytical procedures.)	x	x	x	x
Periphyton Chlorophyll-a and Pheopigments	Filtered through Whatman GFC filter paper, filters frozen, and sent to EC Lab*		xx		x
Periphyton Dry Wt.) Periphyton Ash Free Dry Wt.)	Preserved with a few drops of Lugol's solution and sent to EC Lab		xx		x
Zooplankton	Settled volumes done in field lab and identification and enumeration contracted to Dr. Charles Low, Nanaimo	x		x	
Benthic Macroinvertebrates from the River	Identification and enumeration contracted to Dr. Charles Low				

x - samples taken (No SiO_2 samples taken in 1977)
xx - attempts were made to collect periphyton in 1976 but most results were lost through vandalism or inclement weather
IWD - Inland Waters Directorate in North Vancouver (See Inland Waters Directorate, 1974, for methods of determination.) IWD Biology Lab also is in North Vancouver.
EC - Fisheries and Environment Canada Laboratory in West Vancouver (See Environment Canada, 1976, for methods of determination.)
* - Filters were macerated in acetone using a polytron ultrasonic disrupter and centrifuged; absorbancies were determined spectrophotometrically, and calculations were done according to Lorenzen (1967).
EPS - Environmental Protection Service, Biology Lab in North Vancouver, B.C.

In 1976, duplicate dissolved oxygen samples were taken; in 1977/78, triplicate samples were taken.

At each deep station, four 50-metre vertical hauls for zooplankton were undertaken using a #20 Wisconsin plankton net with a 25 cm diameter opening. Samples were preserved with 5% formalin solution. Settled volumes were determined in the field laboratory using Imhoff graduated cones, and identification and enumeration was completed by Dr. Charles Low.

3.2 <u>Shallow Stations</u>

As outlined in Table 9, periphyton samples were taken in addition to the chemical and physical samples. In 1976, periphyton samples were attempted at a depth of 1.5 metres using microscope glass slide artificial substrate samplers patterned after those used by Stockner et al (1972). There were a few problems associated with use of this type of sampler. Firstly the delicate structure of the sampler, coupled with very inclement weather in 1976, resulted in frequent breakage and loss of slides and samplers. Secondly, the ready discovery and accessibility of the samplers due to surface marker identification resulted in considerable vandalism and subsequent loss of data. Thirdly, it was felt that some interference with samples was being caused by material sluffing off the slides during their retrieval. The first two problems caused so many lost samples that those which were retrieved in good condition failed to provide sufficient data to form a basis for any meaningful conclusions.

In 1976, a new type of periphyton sampler was tested and used during 1977 and 1978. Its application was intended to minimize or preclude a re-occurrence of the above problems. As before, artificial substrates were employed, but the material used was roughened plexi-glass plates to provide a better surface for attachment. Two plates of known surface area were attached by wing nuts to a cube of styrofoam (Figure 2) held between two squares of 3/8" plywood. A large plastic ring was attached to the top surface of the styrofoam which, when combined with a long handled hook, simplified retrieval of the artificial substrate. The substrates were suspended 1.5 metres below the surface and anchored to the bottom with cable and a concrete building block. No surface float was directly

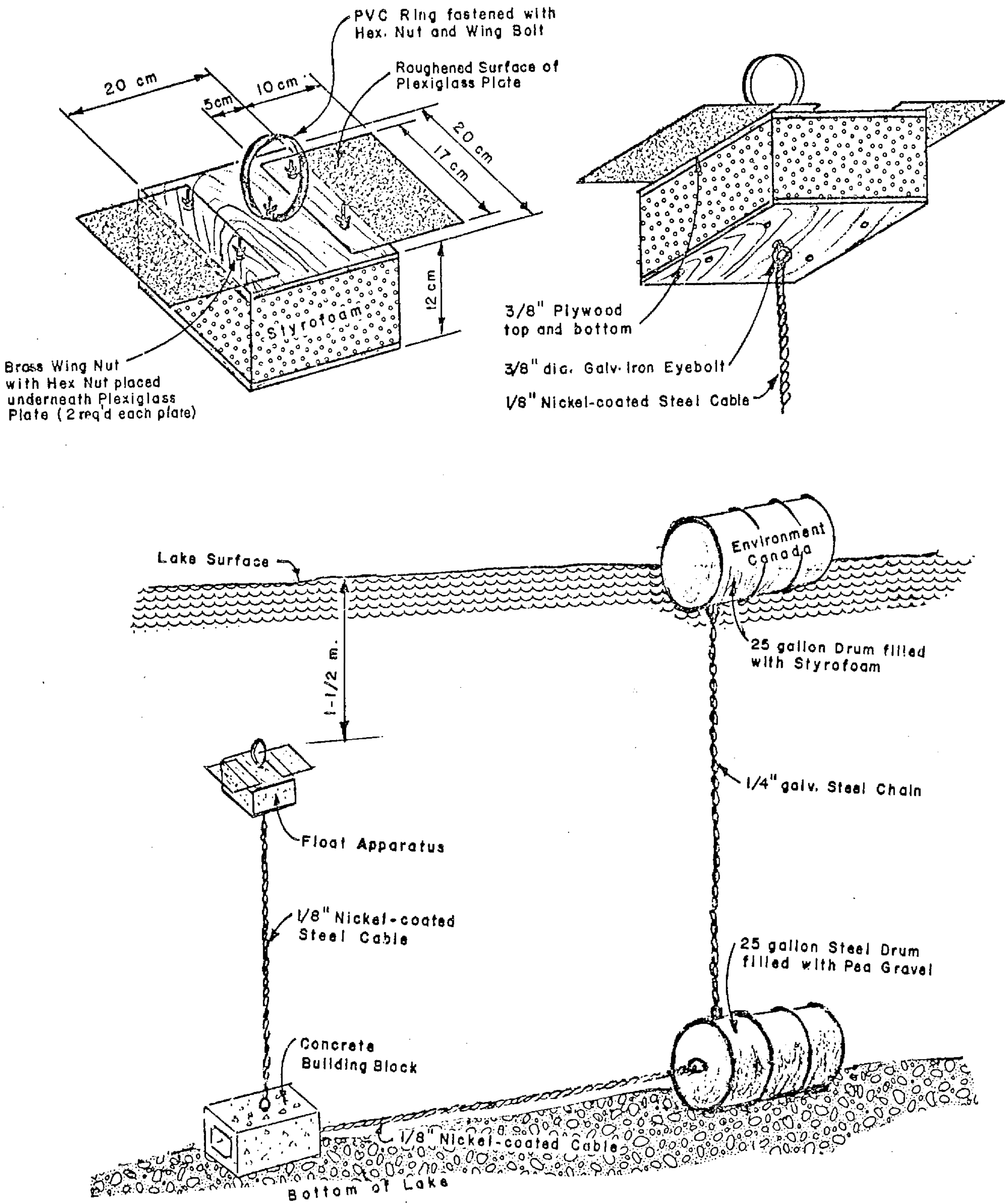

FIGURE 2 ARTIFICIAL SUBSTRATE, WEIGHTS AND FLOAT APPARATUS FOR PERIPHYTON SAMPLING - 1977

attached to the substrate. The styrofoam block was visibly located by its white colour, and was cleaned off after each sampling to maximize future identification. To aid station location, the substrate weight was attached by cable to a 25-gallon steel drum which was filled with gravel and placed on the lake bed. This heavy 25-gallon drum was attached by chain to another surface floating drum filled with styrofoam, which was labelled. Sample retrieval with this system was excellent.

The artificial substrate plates were retrieved every two weeks and new plates were installed. Instead of storing these plates in distilled water for transport to the laboratory, as was done with the glass slides in 1971 and 1976, the attached material was immediately scraped off the plexi-glass into a containers of distilled water, the scraping being done with a microscope slide. Once back at the laboratory, the sample was split into three aliquots, using a Folsom plankton splitter. One-half of the sample was sent to the laboratory for dry and ash-free dry weight analysis (Table 9); one-quarter was filtered through a Whatman GFC glass-fiber filter and shipped frozen to the laboratory for chlorophyll-a and pheopigment analysis; and one-quarter of the sample was preserved in Lugol's solution and sent to the laboratory for algal identification and enumeration.

In 1977 the same style of plexi-glass plates, as described above, was used at the Okanagan River stations but the plates were fixed directly to concrete blocks; however, considerable vandalism coupled with the scouring effect of floating fragments of Eurasian Milfoil (*Myriophyllum spicatum*) contributed to substantial sample losses, consequently the very limited results obtained were not used in this report.

In addition to periphyton samples, chemical and physical samples were taken at a depth of 1 metre using a 2-litre Van Dorn water sampler. (See Table 9 for details regarding parameters and laboratories).

During 1976 through 1978, phytoplankton identification and chlorophyll-a samples were taken at lake shallow stations using the 2-litre Van Dorn sampler. In 1976, these biological samples were taken at the surface and at 2-metre depths at each station, whereas, in 1977 and 1978 only one sample at a depth of 1 metre was taken at each station.

Parameters sampled at the 1977 river stations were the same as those sampled at the 1977 and 1978 shallow stations (Table 9), except for phytoplankton samples. In addition, stream benthic macroinvertebrate samples were taken using 0.093 m^2 circular sampler. At least three samples were taken in a transect across the river at each station.

4 RESULTS AND DISCUSSION

Prior to discussion of the study results some difficulties in comparing data from 1971 with those collected in 1976, 1977 and 1978 should be mentioned.

The first problem centered around the fact that very few data from the 1971 study (Basin Study, Technical Supplement V, 1974) were comparable to data from the 1976, 1977 and 1978 survey. The whole 1971 study consisted of a variety of different tasks accomplished by different agencies, where each agency had its own monitoring program. As a result, not all parameters were sampled at every station and the sampling periodicity varied between some stations. This was a contrast with the 1976 through 1978 program where fewer overall stations existed but all parameters were sampled at each station, and with a much higher frequency than in 1971. Therefore, the conclusions of the 1971 study were derived from much less data than were available from the 1976, 1977 and 1978 program.

The second problem concerned the considerable difficulty in identifying which 1971 data were used in the calculation of seasonal mean values for each lake. In addition, it was felt that seasonal mean values for a whole lake such as Okanagan Lake, as compiled during the 1971 study, might not be especially meaningful because of the lake's large size, varied morphometric characteristics, and different geographical influences.

It was therefore decided that in order to provide the most accurate comparison attainable between the 1971 and present studies, only the data from the 1971 study stations most closely comparable to those of 1976-1978 would be used. This necessitated reviewing the 1971 raw data and recalculating the seasonal averages. The 1971 recalculated averages as well as some data from Stein and Coulthard (1971) are found with the 1976, 1977 and 1978 averages in the various tables throughout this report.

A third problem was that at the deep stations in 1976, only one sample was taken in each of the epilimnion and hypolimnion. These samples were not as representative as those obtained from four depths during 1977 to 1978, therefore, accuracy of interpretation required more emphasis on the 1977 and 1978 deep station data in preference to that obtained in 1976. In the tables where one figure exists for either the epilimnion or hypolimnion in 1977 and 1978, it is the result of averaging the two samples taken in that stratum.

4.1 Physical Limnology

4.1.1 Temperature. Temperature profiles for all three lakes relevant to this study are given in Appendix II. There were quite variable weather trends between the four years, yet maximum water surface temperatures were always in the range of 22° to 25°C on the three lakes and averaged about 23.5°C. Maxima always occurred in August. Temperature data from 1971 were not as detailed as those for 1976, 1977 and 1978, but the latter data indicated no obvious differences in the trends between 1971 metalimnion depths and those of 1976, 1977 and 1978.

All three lakes can be classified as "dimictic" (Canada - British Columbia Okanagan Basin Study Report, Technical Supplement V), which means that two periods of isothermal circulation of all the water in the lakes occurs each year. In order to obtain information most representative of a particular lake as a whole prior to the season of most active biological production, it was necessary to sample the lake during the spring circulation.

In 1976, because the sampling began in June, it was impossible to determine when thermal stratification had begun. In 1977, deep station sampling was initiated well into April and weak stratification at that time had already begun in all three lakes. Fortunately at the start of the 1978 season, sampling was carried out during spring overturn at S-1 on Skaha Lake, at OK-3 on Okanagan Lake South, and shortly following overturn, sampling began at the other three stations. The 1977 and 1978 sampling programs indicated that spring circulation in these lakes, as a rule, occurs during late March to early April.

By May, Osoyoos Lake had formed a fairly well defined stable thermocline, but it took several weeks longer for Skaha Lake to form its stable thermocline. Presumably the reason for the slower stabilization of Skaha Lake is that the wind storms which appeared to be more frequent on Skaha Lake than Osoyoos Lake would have disrupted the stratification process. By July, fairly stable stratification had occurred on Okanagan Lake, but a poorly defined thermocline had developed at OK-2 in 1976 to 1978. Windy conditions above this southern part of Okanagan Lake could also have caused the unstable stratification.

At the Okanagan Lake stations, hypolimnetic bottom temperatures generally remained at about 4 - 5.5^{o}C all season, whereas such temperatures were warmer in lakes Skaha and Osoyoos, averaging about 7.5^{o}C and 10^{o}C respectively each year. Peak hypolimnetic temperatures in Skaha and Osoyoos lakes were reached by August and, after this month, hypolimnetic warming slowed down considerably.

4.1.2 Secchi Disc. Secchi disc measurements are a simple means of determining water transparency to light.

Secchi disc data were gathered during all four years, 1971, and 1976 through 1978. A viewing box was not used during 1971. It was noted that generally when a viewing box is not used in wavy water, Secchi readings are a value of roughly one metre less than when a viewing box is used; therefore, in the data which appears in Table 10 the 1971 values have been corrected for this difference by adding "1" to each value.

Shallow station Secchi values were not included in Table 10 because, in most cases, the light penetrated to the lake bed. The main

TABLE 10 SECCHI READINGS (m) FOR DEEP STATIONS ON LAKES OKANAGAN, SKAHA, AND OSOYOOS - 1971, 1976, 1977, and 1978

Station	Date	1971	1976	1977	1978	1976/77/78 Average
OK-1	April	-	-	6.3	6.5	
	May	10.0	-	-	-	
	June	8.0	6.0	-	-	
	July	9.5	6.8	7.5	7.0	
	August	-	10.1	-	8.5	
	September	9.0	8.5	-	-	
	October	-	-	7.3	7.5	
	Average	9.1	7.9	7.0	7.4	7.4
OK-2	April	9.5	-	8.0	5.5	
	May	-	-	-	-	
	June	9.0	-	-	-	
	July	-	6.0	8.5	8.0	
	August	-	10.7	-	8.0	
	September	-	8.5	-	-	
	October	-	7.9	7.8	7.5	
	Average		8.3	8.1	7.3	7.9
OK-3	April	-	-	8.0	8.0	
	May	-	-	-	-	
	June	7.5	4.9	-	-	
	July	12.5	7.5	8.5	6.5	
	August	-	7.3	-	9.5	
	September	-	8.0	-	-	
	October	9.0	7.6	8.5	8.5	
	Average		7.1	8.3	8.1	7.8
S-1	April	7.5	-	5.1	4.8	
	May	5.0	-	4.3	4.3	
	June	5.5	2.9	4.0	2.5	
	July	5.5	4.6	6.0	6.5	
	August	-	4.3	4.5	4.5	
	September	-	3.7	4.0	4.0	
	October	-	4.9	3.8	4.4	
	Average	5.9	4.1	4.5	4.4	4.3
O-1	April	3.5	-	3.1	4.0	
	May	-	-	5.0	2.8	
	June	4.5	3.5	3.5	2.8	
	July	3.0	4.3	4.5	4.0	
	August	4.0	4.3	2.5	3.5	
	September	-	3.5	2.8	4.0	
	October	-	4.3	3.5	5.0	
	Average	3.8	4.0	3.6	3.7	3.8

reason for Secchi readings at shallow stations was to determine whether or not light penetration was reaching the artificial substrates.

The little comparable data available from 1971 exhibited values usually 1 to 3 metres higher than in 1976, 1977 and 1978 for Okanagan Lake. The readings for 1976, 1977 and 1978 were generally quite similar to the seasonal mean values, and varied by no more than one metre. The lowest values in Okanagan Lake were found in June, the month of highest runoff. The highest Secchi values and, therefore, the highest transparencies, were found in August and September. Transparencies were slightly lower at OK-1 (averaging 7.4 m for 1976, 1977 and 1978) than at OK-2 and OK-3 which averaged 7.9 m and 7.8 m respectively for all three years.

In 1971, Secchi values for lakes Skaha and Osoyoos were generally higher by 1 to 2 m than in 1976, 1977 and 1978. The 1977 and 1978 Skaha values were slightly higher than those of 1976. The 1977 and 1978, Osoyoos values on the other hand were generally slightly less than in 1976. Maximum transparencies as indicated by the 1976, 1977 and 1978 sets of data were in July for lakes Skaha and Osoyoos. Minima for these lakes were also found during the spring runoff period - late May-June. Secchi readings averaged 4.3 m for Skaha from 1976 through 1978, and 3.8 m for Osoyoos during the same period.

The Secchi data indicated that since 1971 the transparency in Okanagan Lake has decreased. It also appears that this same trend can be noticed to a lesser extent for Skaha, but no change has been obvious for Osoyoos. In order of decreasing transparency, the lakes may be classified as follows:

(1) Okanagan (highest transparency)
(2) Skaha
(3) Osoyoos (lowest transparency)

4.1.3 Turbidity. Turbidity is a measure of the effect that suspended particulate material has on the transparency of the water column. High values of turbidity indicate a low transparency.

Complete comparison with 1971 data was limited because insufficient turbidity data were available from that year. Table 11 summarizes the limited 1971 data, as well as the 1976, 1977 and 1978 data.

Turbidities in 1976, 1977 and 1978 were generally not high at the deep water stations, averaging below 1.0 JTU (Jackson Turbidity Units) for the epilimnia of all three lakes.

At the deep stations of lakes Okanagan and Skaha, hypolimnetic turbidities were on the average slightly lower than the epilimnetic values. The opposite of this was true for Lake Osoyoos.

The shallow stations on Lake Okanagan in the Armstrong and Vernon Arms and in the Penticton area, showed higher turbidities than at the deep stations. The Okanagan Center shallow station exhibited values comparable to the deep stations.

At the Skaha Lake deep station, the 1976, 1977 and 1978 turbidity readings were generally higher than those of Okanagan Lake, but lower than those of Osoyoos. In lakes Skaha and Osoyoos, the shallow stations yielded higher turbidity values than those of the deep station epilimnia.

Maximum turbidities often correlate with periods of high runoff and Okanagan Lake appeared to be no exception. Highest Okanagan Lake epilimnetic turbidities (up to 2.5 JTU) were found in June 1976, just after peak runoff. Turbidity maxima on lakes Skaha and Osoyoos were usually found in August of 1976 through 1978, with epilimnetic values of 1.1 to 1.5 JTU. Lesser peaks were also noted in May - again a reflection of the runoff period. Of interest is the fact that the north Osoyoos shallow station showed a July 1977 peak of 1.5 JTU, which coincided with a nearby

TABLE 11 AVERAGE SEASONAL TURBIDITIES 1971/76/77/78 FOR LAKES OKANAGAN, SKAHA AND OSOYOOS

Station	Turbidity (Jackson Turbidity Units)				
	1971*	1976	1977	1978	1976/77/78 Average
OK-1 EP	.34	.40	.47	.54	.47
HYP	.72	.38	.27	.34	.33
OK-2 EP	.33	.78	.4	.48	.55
HYP	.28	.56	.38	.45	.46
OK-3 EP	.35	.78	.46	.54	.59
HYP	.4	.43	.32	.49	.41
OK-S1	-	.93	1.18	1.26	1.12
OK-S2	-	.71	1.17	1.31	3.12
OK-S3	-	.62	.46	.73	.60
OK-S5	-	1.23	.45	.67	.79
OK-S10	-	.84	1.29	.70	.96
OK-R-1E	-	-	.58	-	.58
OK-R-2E	-	-	.80	-	.80
S-1 EP	.54	.8	.75	.88	.81
HYP	.61	.68	.78	1.53	.78
S-S1	.78	.66	1.6	1.02	1.11
S-S3	-		1.5	.89	1.60
S-S2	-	.76	1.5	.98	1.12
O-1 EP	.97	.8	.89	.96	.85
HYP	.95	1.34	1.02	1.00	1.12
				-	-
O-S1	-	.9	1.33	1.10	1.11
O-S2	-	.8	1.00	1.32	1.04

* Based on only a few values.

suction dredge operation that was being conducted by Provincial Government Aquatic Weed Management program personnel.

The lowest values in Okanagan Lake were found during July, a usual period of low biological production, which correlated with high transparencies as measured by secchi disc. The same is true for Skaha and Osoyoos lakes, except for July 1978 which yielded a maximum for Osoyoos Lake. The cause of this was not clear.

Turbidities were relatively low for all three lakes, with Osoyoos Lake having the highest values and lakes Skaha and Okanagan following in decreasing order of magnitude. The shallow stations generally reflected higher values than the deep stations, a situation which corroborates the fact that littoral areas are subject to resuspension of benthic detritus as well as localized surface runoff.

4.2 Chemical Limnology

4.2.1 Phosphorus (Total and Dissolved). Total phosphorus is composed of two major components, particulate P and dissolved P, where P is defined as the P portion of the phosphate ion. At the chemistry laboratory, total P and dissolved P were determined and particulate P was later calculated by taking the difference of the two. No attempts were made to determine the separate organic and inorganic components of dissolved P, the most important of which is the inorganic orthophosphate (St. John et al, 1976). Orthophosphate, which was analyzed during the 1971 study, is the algal nutrient and it can vary from 0% to 100% of the total dissolved P. Unfortunately it is unstable, changing to other forms of P shortly after sampling (verbal communication - IWD chemistry laboratory); therefore, unless the sample is analyzed immediately, the results will be erroneous. Consequently, the most common analysis procedure is to determine dissolved P and not to attempt a determination of the orthophosphate.

A general assessment can be made regarding phosphorus concentrations in the three lakes, and that is that phosphorus levels increased (Table 12) from Okanagan Lake southward through Skaha to Osoyoos Lake. Data derived from the deep station samples during 1977 and 1978 were relied upon more heavily for this observation than those obtained in 1976 because the 1976 deep station samples were not considered as representative.

Spring turnover total P values were quite low at all the Okanagan Lake deep stations, where all values were below 10 ug/l in both 1977 and 1978 (Table 12). Since 1970 (Stein & Coulthard 1971) or 1971 (Basin Study) no appreciable change in spring total P has occurred at any of the deep stations over what naturally would occur from year to year. The 1971 spring P value at OK-3 was 29.6 ug/l compared to the 1977 and 1978 values of 7.5 and 6.0 ug/l. Such a value for 1971 seemed unusually high for Okanagan Lake and was found to be due to one surface value of 68.5 ug/l. Not including this measurement, the spring 1971 value for OK-3 was 9.8 ug/l, a value similar to those found in 1977 and 1978.

On Skaha Lake, the 1977 and 1978 spring total P values were 11.0 and 18.0 ug/l, which were less than the values of 31.0 and 20.7 ug/l found in 1970 and 1971 (Table 12). This possibly indicated a decreasing trend since the earlier studies.

The Osoyoos Lake 1977 and 1978 spring values were 21.0 and 23.5 ug/l respectively. These levels were very close to the 1971 spring value of 22.8 ug/l, but somewhat less than the 1970 spring value of 26.9 ug/l (Stein & Coulthard 1971). These differences were within the range of natural annual variability.

Spring dissolved P values on Okanagan Lake were low and did not exceed 3.0 ug/l at any of the stations. These values were similar to the 1971 orthophosphorus values of 3.3 ug/l, which at that time were at the detection limit. Since the orthophosphorus component of dissolved P varies from 1 to 100% it was impossible to draw any conclusions when the

TABLE 12 SPRING AND MEAN SEASONAL PHOSPHORUS VALUES (µg/l) AND STANDARD DEVIATIONS FROM THE MEANS (σ) FOR LAKES OKANAGAN, SKAHA AND OSOYOOS - 1971/76/77/78

Station	Total P										Dissolved P						
	1969/70		1971		1976		1977		1978		1971 Ortho	1976		1977		1978	
	µg/l	σ	µg/l	σ	µg/l	σ	µg/l	σ	µg/l	σ	µg/l	µg/l	σ	µg/l	σ	µg/l	σ
OK-1 EP	-	-	16.8	17.0	20.0	22.5	8.0	1.2	10.3	3.0		13.0	12.7	4.3	1.5	5.1	3.6
OK-1 SPRING	-	-	(8.7)	-	-	-	(9.5)	-	(8.5)	-	(3.3)	-	-	(3.0)	-	(2.5)	-
HYP	-	-	23.6	19.6	7.0	.9	12.0	2.6	8.8	1.6		7.0	2.2	8.0	1.8	5.8	2.9
OK-2 EP	10.4	3.7	12.0	9.0	7.0	.9	7.6	1.4	7.3	2.0		5.0	2.9	5.0	.8	3.5	1.0
OK-2 SPRING	(7.6)	-	(10.8)	-	-	-	(8.5)	-	(4.5)	-	(3.3)	-	-	(3.0)	-	(2.5)	-
HYP		-	11.7	9.0	10.0	7.5	15.0	5.3	7.0	1.2		6.0	1.6	6.8	1.0	3.8	.9
OK-3 EP	-	-	13.9	12.4	9.0	4.4	7.0	.9	5.8	1.3		8.0	10.8	3.0	0	3.8	.6
OK-3 SPRING	-	-	(9.8)	-	-	-	(7.5)	-	(6.0)	-	(3.3)	-	-	(3.0)	-	(3.0)	-
HYP	-	-	17.5	12.4	8.0	2.1	9.3	1.0	7.3	1.5		6.0	3.2	5.3	.8	4.1	1.1
OK-S1	-	-	-	-	21.3	7.3	16.0	10.3	16.5	6.3		7.0	6.8	6.0	2.0	7.5	3.8
OK-S2	-	-	-	-	42.0	24.7	50.0	51.1	13.6	4.6		29.0	26.0	26.0	37.2	5.2	1.6
OK-S3	-	-	-	-	7.0	1.8	9.0	4.3	8.0	1.8		4.0	.9	4.0	2.0	4.5	1.3
OK-S5	-	-	-	-	100.0	68.1	12.0	11.2	13.8	4.5		65.0	5.8	4.0	.8	6.6	3.3
OK-S10	-	-	-	-	5.0	1.4	7.0	2.8	7.8	2.8		4.0	2.1	4.0	1.1	4.1	1.2
OK-R1	-	-	-	-	-	-	8.0	2.5	-	-		-	-	3.0	.9	-	-
OK-R2	-	-	-	-	-	-	26.0	12.3	-	-		-	-	15.6	7.6	-	-
S-1 EP	18.8	8.5	29.5*	17.6	10.0	1.9	13.1*		15.3*			4.6	1.1	5.3	.8	5.1	2.3
							10.0	1.6	13.2	2.8							
S-1 SPRING	(31.0)	-	(20.7)	-	-	-	(11.0)	-	(18.0)	-	(4.3)	-	-	(5.5)	-	(2.0)	-
HYP	-	-	33.7*	11.5	12.0	4.2	42.0	20.9	40.5	31.3		9.0	3.0	31.9	20.4	31.5	31.0
S-S1	-	-	38.0*	33.0	10.7	2.1	13.0	4.0	13.1	3.6	(6.5)	5.0	1.4	6.0	2.0	5.5	1.5
S-S3	-	-	-	-	-	-	13.0	3.6	13.0	-		-	-	6.3	2.9	5.0	-
S-S2	-	-	-	-	12.0	3.5	12.0	2.3	13.5	5.0		4.0	1.7	5.0	1.5	5.0	1.0
O-1 EP	15.4	6.6	17.4*	5.0	12.0	2.1	18.0*		17.3*			4.0	.9	7.4	1.1	5.2	.8
							16.2	3.0	15.3	3.7							
O-1 SPRING	(26.9)	-	(22.8)	-	-	-	(21.0)	-	(23.5)	-	(4.3)	-	-	(8.0)	-	(4.5)	-
HYP	-	-	26.6*	1.4	54.0	32.4	51.0	15.8	32.5	19.6		41.0	30.2	37.5	17.0	24.0	19.3
O-S1	-	-	17.3*	2.3	15.9	3.6	18.0	4.2	17.5	6.0		8.0	1.7	6.0	3.0	7.5	2.4
O-S2	-	-	-	-	18.0	13.0	12.5	3.6	13.1	2.5		6.0	1.3	6.0	2.1	5.2	.9

Note: Ranges for these values are displayed in Appendix II.
( ) Values in brackets are for Spring overturn or soon after.
* Mean based on samples from April, June and October only.

dissolved value was equal to or greater than the orthophosphorus value. This situation applied in the case of Osoyoos Lake, where the 1977 and 1978 spring dissolved P values were similar or greater than orthophosphorus measurements obtained in 1971.

On Skaha Lake, however, the 1978 spring dissolved P value was 2.0 ug/l, a value two times lower than the 1971 orthophosphorus concentration of 4.3 ug/l. The 1977 dissolved P value was very close to the 1971 orthophosphorus value. From this it seems quite likely that there has been a decrease in orthophosphorus concentration in Skaha Lake since 1971.

Spring phosphorus concentrations with regard to nitrogen-phosphorus ratios are discussed in Section 4.2.3.

Epilimnetic total phosphorus levels for the main body of Okanagan Lake exhibited 1977 and 1978 deep station seasonal average values of 9.2, 7.5, and 6.4 ug/l respectively, for OK-1, OK-2 and OK-3. The two-year averages for Skaha and Osoyoos lakes were 11.6 and 15.8 ug/l respectively.

In comparison with the 1969 and 1971 studies, the 1977 and 1978 seasonal total phosphorus levels in Okanagan Lake were all close to those of 1971 (Table 12).

In the case of the 1969 and 1971 Skaha Lake total phosphorus levels, the total P values averaged 18.8 and 29.5 ug/l. The contrast between those values and the ones obtained in 1976, 1977 and 1978 for the same time period, indicated that there has been a reduction to about 15.3 ug/l in the last 5 to 6 years following implementation of tertiary waste treatment at Penticton.

Osoyoos Lake exhibited total P levels at the deep stations in 1976, 1977 and 1978 similar to those found during 1969 and 1971 (Table 12). In 1971 the seasonal mean total P value for the epilimnion of the south portion of Skaha Lake was 34.9 ug/l as compared to the recent south littoral station (S-S2) value of 12.6 ug/l during 1976, 1977 and 1978. Despite this reduction in Skaha Lake, total P levels in Osoyoos Lake still appeared to be undesirably high.

A general seasonal trend observed at the deep stations of all three lakes is that hypolimnetic P levels were higher than those of the epilimnion. This phenomena was much more pronounced in lakes Skaha and Osoyoos than in Okanagan Lake. This was an indication of phosphorus being supplied from the epilimnion to the hypolimnion in sedimenting planktonic biomass (Wetzel 1975, Schindler and Fee 1975). As a result, phosphorus supplied to the epilimnion did not tend to build up as the season progressed because it was continually being removed. On the other hand, it did tend to build up in the hypolimnion as the season progressed. Another interesting fact is that at all the deep stations, dissolved P concentrations in the hypolimnia were generally greater than particulate P concentrations.

In the case of the Okanagan Lake epilimnion, dissolved P on the average exceeded particulate P, whereas the converse was true for the epilimnia of lakes Skaha and Osoyoos. This suggested either a more extensive uptake and incorporation of dissolved P into planktonic tissue, or the presence of more detritus and suspended sediment from outside sources in the latter two lakes than in Okanagan Lake.

At the shallow stations on all three lakes, P levels throughout the seasons tended to be higher and to fluctuate more than at the deep stations. Exceptions to this trend occurred at shallow stations less proximal to sources of cultural enrichment; such as stations OK-S3 at Okanagan Center and OK-S10 at Penticton.

Three-year average total P levels at OK-S3 and OK-S10 were 8.0 and 6.7 ug/l respectively. In 1977 and 1978, OK-S1 and OK-S5 yielded two-year mean seasonal total P values of 16.5 and 13.0 ug/l respectively.

At OK-S1 and OK-S5 in 1976, much higher values were noted than in 1977 and 1978, possibly due to the unusually high 1976 runoff affecting these two areas close to the mouths of streams draining fairly large agricultural areas. Furthermore, OK-S5 was located about 300-400 yards further south in 1976 than in 1977 and 1978 and possibly was affected differently.

The total phosphorus levels at OK-S2 showed an interesting trend from one year to the next. Unlike the other shallow Okanagan stations OK-S2 yielded high total P values both in 1976 (42 ug/l) and in 1977 (50 ug/l), yet produced a significantly lower mean value of 13.6 ug/l in 1978. The same trend was exhibited by dissolved P. This large drop in both particulate and dissolved P coincided with the removal of the Vernon sewage discharge from Vernon Creek in August 1977, and probably occurred as a result of this discharge removal.

At all the shallow stations of lakes Skaha and Osoyoos and also at OK-S1, particulate P on the average exceeded dissolved P, whereas, the reverse was true for the remaining Okanagan Lake shallow stations. P levels tended to fluctuate throughout the season at all stations except OK-S3, OK-S10, S-S3, and S-S2 which were the stations least subject to perturbation.

Three-year mean total P values were in the 12.0 - 13.0 ug/l range for the Skaha Lake shallow stations, and were 17.0 ug/l for O-S1, and 14.6 ug/l for O-S2. Total P levels had dropped to 12.0 ug/l at S-S1 from the 1971 value of 21.7 ug/l. This was in keeping with the results for the deep station, indicating that the cause was reduced P loadings from the Okanagan River. P levels at the Osoyoos Lake shallow stations had not changed much since 1971.

At the Okanagan River stations in 1977, quite a contrast was noted between the results from each station. The average total P concentration at OK-R1, about a mile from Okanagan Lake, was 8 ug/l. At OK-R2, just downstream from the Penticton sewage discharge and the influx of Shingle Creek, average total P concentration was 26 ug/l. At OK-R1 about 70% of the phosphorus was in the particulate form and 30% in the dissolved form. At OK-R2 about 60% was particulate and 40% dissolved. OK-S10, the shallow station just north of the Okanagan River, yielded 1977 seasonal total phosphorus values averaging 7 ug/l. These results indicated that about 26% of the total phosphorus loading to the river above OK-R2 was from Okanagan Lake itself; whereas, the other 74% came from the sewage discharge, Shingle Creek, and other point and non-point sources between OK-R1 and OK-R2. Of interest is the fact that between OK-R2 and the Skaha Lake shallow station, S-S1, there was a drop in total phosphorus concentration from 26 ug/l to 13 ug/l. This could have been due to dilution as the sewage plume mixed with the Okanagan River south of OK-R2, and in addition, there was a likelihood of dilution of phosphorus by Ellis Creek water and other discharges.

These results form a brief assessment of nutrient flux on this stretch of the Okanagan River. A much more extensive study by the Inland Waters Directorate, which thoroughly documents nutrient loadings to the Okanagan Basin should be available at the same time as this report.

4.2.2. Nitrogen

4.2.2.1 Nitrite - Nitrate. Nitrite and nitrate along with ammonia make up the inorganic portion of dissolved nitrogen. In freshwaters, the concentrations of nitrite are usually very low in proportion to nitrate (Wetzel, 1975); therefore, this fraction will be considered as nitrate only. Nitrate along with ammonia are the principal sources of nitrogen for algal growth.

Spring concentrations of nitrate in the three lakes varied considerably. As Table 13 shows, low values were found in Okanagan Lake,

TABLE 13 SPRING AND MEAN SEASONAL NITROGEN VALUES (μg/l) AND STANDARD DEVIATIONS FROM THE MEANS (σ) FOR LAKES OKANAGAN, SKAHA AND OSOYOOS - 1971/76/77/78

Station	NO_2/NO_3 1971* μg/l	σ	1976 μg/l	σ	1977 μg/l	σ	1978 μg/l	σ	NH_3 1976 μg/l	σ	1977 μg/l	σ	1978 μg/l	σ
OK-1 EP	10.0	0	2.8	1.5	9.0	4.9	7.6	10.5	6.8	3.5	7.0	5.1	4.8	3.6
	(<10.0)	-	-	-	(14.5)	-	(23.0)	-	-	-	(11.5)	-	(2.0)	-
HYP	24.7	5.3	64.8	5.3	64.3	1.6	45.3	19.4	2.4	1.5	4.3	3.8	1.1	.3
OK-2 EP	<10.0	0	2.8	1.5	24.0	34.4	7.1	11.3	6.8	6.0	11.8	13.7	3.0	2.4
	(<10.0)	-	-	-	(63.5)	-	(24.0)	-	-	-	(27.5)	-	(2.5)	-
HYP	<10.0	0	61.0	10.0	39.5	13.5	42.1	11.5	3.2	2.2	11.1	10.0	4.1	6.3
OK-3 EP	<10.0	0	3.6	4.0	17.1	31.8	10.1	17.3	4.6	3.1	5.3	4.5	2.4	1.6
	(<10.0)	-	-	-	(51.0)	-	(36.0)	-	-	-	(10.5)	-	(1.0)	-
HYP	12.0	5.0	61.0	18.7	51.8	1.9	26.8	15.3	5.0	3.4	3.0	3.5	2.3	1.4
OK-S1	-	-	7.4	15.9	1.2	.6	10.0	1.4	23.0	23.9	13.2	14.2	4.8	3.9
OK-S2	-	-	41.5	43.6	30.9	70.0	3.4	5.5	26.3	18.4	26.0	27.1	5.2	6.6
OK-S3	-	-	2.6	1.6	1.2	.7	1.3	.8	7.4	5.6	7.1	8.1	2.7	2.7
OK-S5	-	-	49.4	51.9	2.3	3.6	3.2	6.9	38.8	41.8	8.2	8.0	7.2	9.1
OK-S10	-	-	4.4	8.8	5.3	8.9	4.4	8.3	7.6	7.9	62.	5.3	4.0	3.7
OK-R1	-	-	-	-	5.3	7.8	-	-	-	-	9.5	15.3	-	-
OK-R2	-	-	-	-	35.7	18.2	-	-	-	-	715.0	260.0	-	-
S-1 EP	10.0	4.0	2.0	1.6	5.4	8.7	1.4	.6	37.8	67.8	10.8	6.2	8.0	10.0
	(<10.0)	-	-	-	(2.0)	-	(1.0)	-	-	-	(11.5)	-	(2.0)	-
HYP	46.4	52.0	20.0	37.5	87.0	74.5	85.2	94.4	13.0	11.7	15.6	15.7	4.8	4.1
S-S1	10.0	-	5.5	4.5	7.1	5.8	8.0	7.8	26.2	30.5	39.0	31.8	28.2	22.1
S-S3	-	-	-	-	2.0	1.4	2.8	2.0	-	-	15.2	14.4	8.8	7.3
S-S2	-	-	2.0	1.9	3.3	8.0	1.0	.2	7.4	9.1	4.5	4.6	4.0	3.0
O-1 EP	17.5	10.8	2.3	1.3	24.8	31.9	7.8	9.6	5.2	4.9	13.1	7.0	11.5	6.9
	(<10.0)	-	-	-	(16.0)	-	(19.5)	-	-	-	(7.5)	-	(12.0)	-
HYP	98.8	77.0	150.0	91.1	182.4	120.1	127.8	106.4	2.8	1.9	8.4	7.7	11.3	16.6
O-S1	13.0	-	8.5	5.2	38.3	26.5	33.2	24.7	7.6	7.1	12.3	9.0	12.3	9.0
O-S2	-	-	23.7	62.0	11.2	17.8	3.2	2.6	5.4	3.7	8.8	5.7	12.8	11.7

Note: Ranges for these values are displayed in Appendix II.
( ) Values in brackets are for Spring overturn or soon after.
* Mean based on samples from April, June, August, and October 1971.

but even lower values were found in Osoyoos and Skaha lakes with levels equal to or lower than 2.0 ug/l found in Skaha Lake.

The recent Skaha and Okanagan Lake values were not comparable to the 1971 concentrations which were below the detection limit. Only the concentrations in Osoyoos Lake in 1971 were above the detection limit. These values, however, were also not comparable to the recent data because the 1971 values all came from a post-stratification period and therefore were very likely affected by algal uptake. Only in 1977 and 1978 were the spring samples from Osoyoos Lake taken close to spring circulation.

Nitrate levels in all three lakes were quite low during the 1976, 1977 and 1978 seasons, averaging from 1.4 to 24.8 ug/l in the epilimnia, and as Table 13 shows, deep station mean seasonal values tended to vary from year to year. In Skaha Lake's deep water there appears to have been a significant reduction of nitrate concentrations since 1971. This drop was not as strongly reflected by S-S1 and the reason for this was not clear.

The most definitive period, however, for sampling nutrients is the spring because concentrations at that time are less subject to biological influence than in summer or fall. Therefore not much importance can be attached to such differences in mean seasonal values as occurred in the case of Skaha Lake.

Lakes Skaha and Osoyoos displayed similar epilimnetic trends in that a marked decrease in nitrate occurred, as a rule, by late July-August, and levels tended to increase in October. The summer depletion was probably due to algal uptake. Nitrate values tended to peak in June, which coincided with the spring runoff.

Hypolimnetic concentrations showed a different trend in that they steadily continued to build up from April until October. This was due to bacterial conversion of sedimented particulate N back to the nitrate form. The fact that such a build-up occurred was indicative of epilimnetic algal assimilation of nitrate into the particulate form.

Because of the reduced frequency of sampling on Okanagan Lake, trends in values of nitrate were less obvious. Depletion of nitrate occurred in July in the epilimnia and no significant replenishment seemed to have taken place by October. In the hypolimnia, no significant build-up was noticed throughout the season. A possible explanation for this is that the volume of the hypolimnion in Okanagan Lake is very large and, as a result, concentrations would have taken longer to build up than in lakes Skaha and Osoyoos. Also, phytoplankton production was lower in Okanagan Lake than in lakes Skaha and Osoyoos as was indicated by chlorophyll-a results. This would have resulted in less loading of particulate nitrogen to the hypolimnion from the epilimnion.

The shallow Okanagan Lake stations during 1976, 1977 and 1978 all showed low mean values for nitrate (Table 13). A significant drop in the seasonal mean value was noted at OK-S2 (3.4 ug/l) in 1978, compared with the 1976 to 1977 values of 41.5 and 30.9 ug/l. This coincided with the diversion of the Vernon sewage discharge from Vernon Creek. The reason for the 1976 OK-S5 value of 49.4 ug/l being greater than the 1977 and 1978 values of 2.3 ug/l and 3.2 ug/l, could have been due to the slightly different location of the station in 1976, as described in section 4.2.1.

Nitrate values were also relatively low for Skaha and Osoyoos lake shallow stations (Table 13), and in each lake, values were less at the more southerly stations than at the northernmost stations.

Shallow station trends for nitrate were similar for all stations in that levels remained low all season except for a peak in June at OK-S1, OK-S2, OK-S5, S-S1, and O-S1. These were also the stations which exhibited the greatest amount of fluctuation throughout the seasons.

In the Okanagan River, an even greater contrast between stations was noted with the nitrate data than with the phosphorus data.

OK-R1 yielded average 1977 seasonal nitrate concentrations of about 5 ug/l, whereas OK-R2 produced an average value of about 36 ug/l. OK-S10 also produced a seasonal average of 5 ug/l. This indicated that only about 15% of the nitrate loading to the river upstream of OK-R2 came from Okanagan Lake and that the remaining 85% came from point and non-point source discharges between Okanagan Lake and OK-R2. In June, nitrate values dropped to 1 ug/l at OK-R1 and remained at that level until October. This was probably caused by nitrate depletion by phytoplankton in Okanagan Lake. In view of this, it is possible that during winter conditions when lacustrine NO_3 depletion was at a minimum, the loading from Okanagan Lake could have been higher than 15%.

4.2.2.2 Ammonia. Ammonia which is an end product of bacterial decomposition of organic matter is an algal nutrient which can be very readily assimilated. Ammonia nitrogen (NH_3) of well-oxygenated waters is usually relatively low (Wetzel, 1975). Contamination by sewage however can result in unusually high ammonia concentrations in surface waters.

Ammonia concentrations were relatively low at all the deep stations on all the lakes (Table 13). Lakes Skaha and Osoyoos showed the highest mean values, in 1977 and 1978, followed by Okanagan Lake. Spring ammonia concentrations were also low at all the stations with 1977 values generally being higher than 1978. An exception to this was Osoyoos Lake, which yielded a higher number in 1978 than 1977.

The shallow stations most subject to cultural influence yielded the highest ammonia values as well as showing considerable fluctuation through the seasons. OK-S5 in 1976 produced an extremely high mean value, but this was, at least in part, due to a single large anomalous peak value of 985 ug/l in mid-August. By disregarding the anomalous value the mean value was 38.8 ug/l, which was still higher than during 1977 and 1978.

In 1977 and 1978 the Skaha Lake shallow stations showed a gradual decrease in ammonia concentration at stations south from S-S1, past S-S3 to S-S2, which indicated that the influence of Penticton sewage decreased in proportion to the distance south from the mouth of the Okanagan River at Penticton. The ammonia values were quite high at S-S1, averaging 31.1 ug/l, due to contamination by the Penticton sewage.

The ammonia data for OK-S2 showed the same 1976, 1977 and 1978 trend as did the N and P data, in that values were much lower in 1978 following the Vernon sewage diversion.

In the hypolimnia of all the deep stations, no significant conversion of nitrate to ammonia seems to have occurred. Such a case usually occurs only in the anoxic hypolimnia of very eutrophic lakes. As the 1977 and 1978 dissolved oxygen data indicated, the hypolimnia of both Skaha and Osoyoos lakes appeared to be moving towards anoxia in the future (See section 4.2.5). Should anoxia occur, hypolimnetic ammonia concentrations would likely greatly increase in these two lakes (Wetzel, 1975). The result of this would be a toxic environment for sport fish such as rainbow trout (Salmo gairdneri), which prefer the cooler waters of the hypolimnion in summer (Scott & Crossman, 1973).

In the Okanagan River, a dramatically high ammonia seasonal average concentration of 715.0 ug/l was noted at OK-R2 as compared to 9.5 ug/l for OK-R1; therefore, the majority of ammonia loading to the river upstream of OK-R2 occurred between OK-R2 and OK-R1. This was undoubtedly a reflection of the nearby sewage discharge, as well as possibly other sources. Since ammonia has a fairly high oxygen demand, it could have been influencing dissolved oxygen levels in Skaha Lake.

4.2.2.3 Particulate Nitrogen. This fraction of the total nitrogen is largely present in protein-rich organic material in the plankton and non-living seston. This parameter was sampled at the deep stations only, during 1977 and 1978.

Hypolimnetic minima occurred in all three lakes generally in mid-summer, the period when there is a shorter supply of material from the epilimnion. The lakes all showed peaks in the spring. In the case of lakes Skaha and Osoyoos, peaks also occurred in the late summer to fall when the supply from epilimnetic biological production increased.

In Skaha Lake, the minimum epilimnetic particulate N concentration occurred in July, probably as a result of NO_3 depletion and reduced biological production. The increase of particulate N after July, which correlated well with an increase in chlorophyll-a and NO_3 was very likely due to increased primary production by phytoplankton.

Osoyoos Lake, like Skaha Lake, showed a minimum epilimnetic particulate N concentration in July. The peak concentration was in August with lesser peaks in April and September. These peak values also correlated well with chlorophyll-a concentrations, again suggesting biological processes within the lake as the source of this particulate matter.

Trends were much less obvious on Okanagan Lake because of the less intensive sampling as compared to sampling on the other two lakes.

The highest particulate N values were found in Osoyoos Lake with a 1977 and 1978 epilimnetic average of 79.5 ug/l, followed by S-1 with a mean value of 63.5 ug/l. The lowest values were found at OK-2 and OK-3 with 43.5 ug/l at both stations, and OK-1 with 26.5 ug/l. Values for OK-2, OK-3 and OK-1 were considerably lower in 1978 than in 1977, suggesting that particulate nitrogen can naturally fluctuate widely from year to year, under the influence of varying hydrology.

4.2.2.4 Total Nitrogen. Although total nitrogen was not determined at the laboratory, it was later calculated by adding together particulate nitrogen and total dissolved nitrogen (Tables 14 and 15). Since total dissolved N was not filtered, but analyzed following decanting of the sample, some suspended particulate N could have been included in the value for dissolved N. Therefore the total N data have been regarded as a general indicator with the values possible being slightly higher than if the dissolved fraction had been filtered.

Of the three lakes under study, Osoyoos yielded the highest spring total nitrogen values of 300.0 and 309.0 ug/l in 1977 and 1978.

TABLE 14 SEASONAL MEAN VALUES (μg/l) AND STANDARD DEVIATIONS FROM THE MEANS FOR PARTICULATE AND TOTAL N AND PARTICULATE CARBON AND CARBON-NITROGEN RATIOS FOR LAKES OKANAGAN, SKAHA AND OSOYOOS IN 1971, 1977 AND 1978

Station		Total N						Particulate N				Particulate C				PC:PN	
		1971*		1977		1978		1977		1978		1977		1978		1977	1978
		Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ		
OK-1	EP	129	22.9	199	17.6	210	109.4	26	4.8	27	4.0	210	25.0	281	41.6	8:1	10:1
	HYP	-	-	216	19.2	186	17.8	13	9.3	11	6.4	148	10.8	122	21.3	11:1	11:1
OK-2	EP	148	88.5	245	120.1	187	30.7	66	77.1	21	12.7	437	319.7	261	40.2	7:1	12:1
	HYP	-	-	222	40.7	211	30.8	40	41.9	19	17.9	253	171.4	147	27.9	13:1	77:1
OK-3	EP	162	97.2	216	59.4	183	23.6	70	42.6	17	7.5	299	214	197	136.3	4:1	12:1
	HYP	-	-	218	53.1	189	4.3	38	48.9	14	3.9	246	224.5	179	27.2	6:1	13:1
S-1	EP	234	153.2	265	97.4	255	32.4	68	12.9	60	13.9	545	146.3	476	86.1	8:1	8:1
	HYP	-	-	292	54.8	288	98.5	26	8.7	33	21.7	306	108.6	310	102.2	12:1	9:1
O-1	EP	169	91.0	360	94.7	288	27.4	98	58.6	61	20.2	573	175.7	486	167.2	6:1	8:1
	HYP	-	-	387	86.3	333	99.0	36	31.0	29	14.4	317	164.2	302	44.4	9:0	10:1

Note: See Appendix II for ranges of these parameters.
* Values for O-1 in 1971 are NO_3(N) plus Total Kjeldahl N whereas all other 1971 values are TKN only because the NO_3(N) values were below the detection limit.

TABLE 15 EPILIMNETIC APRIL N, P, AND N:P VALUES FOR OKANAGAN LAKES, 1971/77/78 (ug/l)

Station	TN			TP			N:P		
	1971	1977	1978	1971	1977	1978	1971	1977	1978
OK-1	160.0	190.0	201.5	8.7	9.5	8.5	18:1	20:1	24:1
OK-2	196.6	383.5	201.5	10.8	8.5	4.5	18:1	45:1	44:1
OK-3	190.0	294.5	199.0	9.8	7.5	6.0	19:1	39:1	33:1
S-1	196.6	217.0	243.0	20.7	11.0	18.0	9:1	20:1	14:1
O-1	226.6	300.0	309.0	22.8	21.0	23.5	9:1	14:1	13:1

Following O-1 was S-1 with values of 217.0 and 243.0 ug/l. In 1978, the three Okanagan Lake stations all yielded lower concentrations of about 200 ug/l. The 1977 measurements at OK-2 and OK-3 yielded values higher than Skaha Lake values and were likely a result of analytical variation. The 1977 OK-1 concentration was close to that of 1978.

The mean total N values for 1977 and 1978 from all three lakes compared with each other in a similar fashion to that of the spring values, even though the actual values were different from the spring levels (Tables 14 & 15).

Total N values were not determined in 1971; however, in the case of Osoyoos Lake they were calculated by adding together the nitrate-nitrogen values and the determined total Kjeldhal nitrogen values. Almost all the NO_3 (N) values found in the other two lakes were below the detection limit and therefore total Kjeldahl N was considered to be total Nitrogen.

When the spring concentrations from 1971 and 1978 (hydrologically similar years) were compared, there appeared to have been a general increase in the concentrations of total nitrogen at OK-1, S-1 and O-1 since 1971 (Table 16). The most marked increase occurred at O-1 where the increase was 28%. Increases of about 20% were also evident for OK-1 and S-1, whereas very little change was observed at OK-2 and OK-3. It was probable that part of the above increase in total N concentrations was due to the 1977 and 1978 method of total dissolved N analysis. It was impossible to know what percentage of the change was due to this cause or other causes such as reduced algal assimilation because of lowered phosphorus levels or increased loadings from point and non-point sources. Information provided by the I.W.D. and P.C.B. studies should allow firmer conclusions about nitrogen trends.

TABLE 16 SPRING TURNOVER TOTAL N PERCENTAGE INCREASE IN THE OKANAGAN LAKE SYSTEM BETWEEN 1971 and 1978 - TWO HYDROLOGICALLY SIMILAR YEARS

Station	Percent Increase Since 1971
OK-1	21
OK-2	3
OK-3	5
S-1	20
O-1	28

4.2.3 Nitrogen-Phosphorus Ratios. Sawyer (1965) stated that nitrogen-phosphorus ratios may be significant in predicting biological productivity because they can indicate whether N or P is limiting to algal growth. The average ratio of N to P required by algae ranges from 10:1 (Golterman, 1975) to 12:1 (Dillon and Rigler, 1974). At ratios of less than 10.1, nitrogen is the limiting nutrient, and at ratios of greater than 12:1, phosphorus is limiting.

The N:P ratios calculated on the basis of April nutrient concentrations in 1977 and 1978 except for OK-1, showed a shift to higher values since 1971 for all stations favouring phosphorus limitation (Table 15).

The reason for the shift has been an apparent increase in total nitrogen at OK-1, S-1 and O-1 and a decrease of total phosphorus at S-1.

The increase N:P ratio in Skaha Lake was supported by an *in situ* algal bioassay done in 1977 which also found P to be limiting to algal growth (Nordin, 1978).

4.2.4 Carbon. Wetzel (1975) states that a major portion of the carbon in freshwater systems is inorganic and occurs as the equilibrium products of carbonic acid. A smaller amount of carbon is organic. In assessing the trophic status of a lake, the major carbon of interest is the organic fraction. Most of the organic carbon of natural waters consists of dissolved organic carbon (DOC) and particulate organic carbon (POC). The concentration of DOC is usually 6 to 10 times that of POC.

As the majority of the carbon entering a lake from terrestrial sources has had most of its readily assimilated components removed, it is relatively resistant to biological breakdown. Furthermore, because a large amount of its nitrogen has been removed, the organic carbon is characterized by high C:N ratios of about 50:1. Organic carbon initially produced in the lake has a high nitrogen content, yielding C:N ratios of about 12:1; therefore, an investigation of C:N ratios in a lake can support other data in indicating whether the source of carbon is largely from biological production within the lake or from outside the lake.

In the case of the Okanagan Lake stations in 1977 and 1978 (Table 14), C:N ratios were calculated using particulate C and particulate N values. These ratios were all at or below 12:1, indicating that for lakes Skaha, Osoyoos, and Okanagan, the major component of particulate carbon was newly produced biomass. These results were supported by the chlorophyll-a data (Section 4.3.1.2).

The Okanagan Valley is characterized by low precipitation and, in the case of Okanagan Lake, high water retention times (Basin Study, Tech. Supp. V, 1974). This is a situation conducive to a relatively low loading of terrestrial carbon combined with the opportunity for particulate matter to sediment easily and, because of this, it could be anticipated that the majority of the particulate carbon would be produced within the lake. This does not, however, necessarily indicate high biological production, which must be determined by investigating the quantity of organic carbon, once the source is known.

Epilimnetic particulate carbon (PC) levels were relatively low for OK-1 and OK-3 in 1977 and 1978 (Table 14), with 1977 and 1978 averages of 210 and 281 ug/l for the former and 299 and 197 ug/l for the latter. This suggests that biological production was relatively low at these stations. OK-2 yielded PC concentrations of 437 and 261 ug/l, and more productive yet was S-1 with 545 and 476 ug/l. The highest values of all three lakes were found in Osoyoos Lake which had averages of 573 and 486 ug/l in 1977 and 1978.

4.2.5 Dissolved Oxygen. Oxygen is an essential requirement for all organisms possessing biochemical mechanisms for respiration and, since many of these organisms, plant and animal, live in aquatic environments, it is necessary to understand the dynamics of oxygen distribution in lake water in order to understand the ecology of the lakes. The study of dissolved oxygen alone can result in considerable knowledge about biological activity in the lake (Hutchinson, 1957).

At spring circulation in dimictic lakes, such as the three lakes under study, dissolved oxygen concentrations are usually uniform throughout the lake and are commonly above saturation levels. This is because of low biological use of oxygen in winter and the fact that most of the water in the lakes comes in contact with the air, thus dissolving more oxygen.

Once thermal stratification in a lake becomes stable, the epilimnion and hypolimnion tend to function as separate physical entities, thus inhibiting mixing. The epilimnion contains the majority of the organisms which by means of both photosynthesis and respiration maintain a daily balance of oxygen production and consumption. The hypolimnion of productive lakes, because of the self-shading effect of plankton, supports little or no photosynthesizing organisms. It largely contains organisms which respire only, and therefore use up oxygen without replenishing it.

At all stations sampled in 1977 and 1978, seasonal dissolved oxygen (DO) maxima of over 12 mg/l at over 100% saturation were noted in April. As the seasons progressed, the epilimnetic values decreased slightly with the onset of summer due to the higher water temperatures and resulting decreases in oxygen solubility. Hypolimnetic values decreased throughout the seasons more significantly because of respiration in the water and sediments (Appendix II).

The Okanagan Lake stations by October 1976, 1977 and 1978 showed a hypolimnetic (DO) concentration decrease to about 92% saturation at OK-2 and OK-3, and 87% saturation at OK-1. When these results were compared with the limited data obtained in 1971, it appeared that there has been little change in DO concentration since 1971 at the Okanagan Lake stations.

Skaha Lake showed a much greater hypolimnetic depletion in 1977 and 1978 than did Okanagan Lake as values decreased steadily throughout the season. The average hypolimnetic DO concentration reached a minimum in October 1977 of 3.6 mg/l at 33% saturation and 2.7 mg/l at 13% saturation in 1978. There were very few data for 1971 with July being the last month for DO samples at the station which was comparable in depth and location to the one sampled in 1976, 1977 and 1978. This lack of data makes it difficult to compare past depletions with recent ones. In July of 1977 and 1978 the average hypolimnetic concentrations were 8.6 mg/l at 76.5% saturation and 8.1 mg/l at 74% saturation, respectively. These compared to a July, 1971 hypolimnetic average value of 9.6 mg/l at 79.5% saturation. It was difficult to make any solid comparison between recent values and those of 1971, because onset of spring stratification has a major effect on summer values and information on 1971 time of stratification was not available.

Osoyoos Lake data showed a continual hypolimnetic decrease up to October with a minimum average concentration of 1.6 mg/l (15.1% saturation) in 1977 and 0.7 mg/l (7% saturation) in 1978. This lake produced a greater hypolimnetic DO depletion than either Okanagan Lake or Skaha Lake. In 1971, the last DO sample was taken in August, and the hypolimnetic concentration was 4.9 mg/l (45% saturation), which compares very favourably to the August, 1977 and 1978 averages of hypolimnetic concentrations of 4.9 mg/l (45% saturation) and 5.3 mg/l (50% saturation), respectively. Again one must be cautious in making such a comparison because of the lack of information concerning commencement time of spring stratification.

Calculation of the rate of areal oxygen depletion for the hypolimnia of lakes can be an extremely informative tool to investigate the general trophic status of lakes (Hutchinson, 1957; Wetzel, 1975) as changes in hypolimnetic oxygen depletion rates over several years can indicate changes in the productivity of a lake. Such calculations, however, are only meaningful for dimictic lakes from about 20 to 75 metres in depth, such as lakes Skaha and Osoyoos. If these rates were calculated for larger, deeper lakes such as Okanagan Lake, the results could be misleading due to hypolimnetic photosynthesis and oxygen production, or large respiring sediment surface areas relative to the surface area of the top of the hypolimnion (Wetzel, 1975).

Because there was a vertical DO concentration gradient in the hypolimnion in lakes Skaha and Osoyoos, it was necessary to take an average of the samples at various depths. Therefore, only the 1977 and 1978 data could be used in the calculations for depletion rates because only one sample each time was taken in the hypolimnion in 1976. Even the 1971, 1977 and 1978 calculations were subject to error, because where concentration gradients are steep as were the cases in these years, more samples are required along with a planimetric integration of the values (Wetzel, 1975).

The formula (Patalas and Salki; 1973, Basin Study, Tech. Supp. V, 1974) used for the calculations was as follows:

Hypolimnetic areal O_2 deficit ($mg/cm^2/day$)

$$= \frac{(O_2M - O_2S) . V_{20}}{A_{20} . T(days)}$$

where A_{20} = area of the 20 m izobath accepted as the upper limit of the hypolimnion ($cm^2 . 10^{10}$)

V_{20} = volume of the lake below the 20 m izobath (in litres $.10^{10}$)

T = time (days) over which depletion has occurred.

O_2S = non-weighted average hypolimnetic concentration of oxygen (mg/l) at the end of the time period T

O_2M = non-weighted average hypolimnetic concentration of oxygen (mg/l) at the beginning of time period T

for Skaha Lake A_{20} = 10.115 and V_{20} = 22.346 (from Basin Study Tech. Supp. V)

for Osoyoos Lake A_{20} = 4.855 and V_{20} = 7.1514 (from Basin Study Tech. Supp. V)

Skaha Lake (Table 17) from April to October, yielded an areal oxygen depletion rate of 0.149 $mg/cm^2/day$ in 1977 and 0.136 $mg/cm^2/day$ in 1978. From April until July, the values were 0.125 and .139 $mg/cm^2/day$ for 1977 and 1978 compared to the 1971 April to July value of 0.077 mg/l/day, and the April to October 1969 values of .076 mg/l/day.

From April until October, in the Osoyoos Lake hypolimnion, the areal oxygen depletion rate was 0.098 and .091 $mg/cm^2/day$ for 1977 and 1978 respectively compared to the 1969 value of .086 mg/cm2/. From April to August 1977 and 1978 the rates were .105 and .090 mg/cm2/day respectively compared to a 1971 value of .061/mg/cm2/day.

TABLE 17 HYPOLIMNETIC AREAL OXYGEN DEPLETION RATES FOR LAKES SKAHA AND OSOYOOS - 1969/71/77/78

Lake	Period	Year	Maximum Depth (m)	Mean Hypolimnion Thickness (m)	Number of Days per Sampling Period	Ordinary Depletion Rate (mg/l/day)	Areal Depletion Rate ($mg/cm^2/day$)
Skaha	May-July	71	50	43.7	57	.036	.077
Skaha	May-July	77	45	43.7	55	.057	.125
Skaha	May-July	78	45	43.7	98	.060	.139
Skaha	Apr-Sept	69	45	43.7	-	-	(.076)*
Skaha	Apr-Oct	77	45	43.7	182	.077	.149
Skaha	Apr-Oct	78	45	43.7	195	.057	.136
Osoyoos	Apr-Aug	71	40	10.7	123	.041	.061
Osoyoos	Apr-Aug	77	55	10.7	125	.060	.105
Osoyoos	Apr-Aug	78	55	10.7	126	.059	.090
Osoyoos	Apr-Sept	69	55	10.7	-	-	(.086)*
Osoyoos	Apr-Oct	77	55	10.7	181	.069	.098
Osoyoos	Apr-Oct	78	55	10.7	196	.061	.091

- 1971 rates were recalculated by the author using data only from 1971 stations comparable to 1976/77/78 stations - hence some values are different from those reported in Technical Supplement V.
- Maximum Depth and Mean Hypolimnion Thickness from Technical Supplement V, Canada - B.C. Okanagan Basin Agreement, 1974.

* From Patalas and Salki, 1973.

The above results indicated that there may have been an increase since 1971 in Shaka Lake hypolimnetic areal depletion and perhaps a slight increase during the same time period for Osoyoos Lake.

However programs of limited sampling intensity such as the recent one and especially the 1971 study could not provide very satisfactory information on depletion rates. A much higher vertical, horizontal, and temporal intensity of sampling is required to obtain enough data to compute really meaningful areal depletion rates.

It was not possible to determine from the 1971 data what the fall hypolimnetic dissolved oxygen concentrations were. Patalas and Salki (1973) collected DO samples in August 1971 and September 1969, but these were isolated samples, with the time of spring stratification not having been known. Those values were higher than 1977 and 1978 values in the case of Skaha Lake but similar in the case of Osoyoos Lake.

The most important point to note is that, regardless of what the situation was in 1969 to 1971, it is definite that a hypolimnetic oxygen depletion problem existed in both lakes in 1977 and 1978. By October, hypolimnetic DO concentrations reached what could be dangerously low levels in both lakes considering that the bottom samples were approaching anoxia. The rate of depletion is higher in Skaha Lake than Osoyoos Lake.

The Environmental Studies Board (1972) recommends a minimum DO concentration in freshwater of 4 mg/l to ensure survival or no sublethal effects on fish. Mean DO levels in the hypolimnia of lakes Skaha and Osoyoos were already below 4 mg/l by September-October of 1977 and 1978.

These results, did not necessarily conflict with biological data which indicated reduced algal production since 1971 (see phytoplankton and periphyton data) because oxygen depletion could have a variety of external or internal causes. Since 1971 there has been a considerable increase in biomass of Eurasian Milfoil (*Myriophyllum spicatum*) in various littoral areas of lakes Okanagan, Skaha, and Osoyoos (Water Investigations

Branch, April 1978). It seemed very likely that in the fall when these macrophytes fragment and decompose, a considerable portion of their biomass could pass into the hypolimnion. The question arose of whether this carbon would add significantly to the BOD of the water column and sediments and therefore increase the hypolimnetic depletion rate. In order to determine whether or not this was the case, some calculations were carried out using M spicatum carbon biomass figures for Skaha Lake (obtained from Water Investigations Branch). According to the calculations (see Appendix III), even if 100% of the M. spicatum carbon biomass was loaded to the hypolimnion (approximately 6.93×10^7g C) it would have required only 9.24×10^7 g of oxygen to convert it to CO_2. This amounted to about 3% of the total dissolved oxygen present in April 1977 (3.08×10^9 g of O_2). Similar values existed for 1978. As well, it was very unlikely that 100% of the M. spicatum carbon was loaded to the hypolimnion; consequently, it is very unlikely that any of this carbon would significantly reduce the oxygen concentration of the hypolimnion.

Therefore the cause of this oxygen depletion is presently unclear, but merits further investigation. If the P.C.B. and Inland Water studies find that nitrogen loadings have increased since 1971, it would also be worthwhile to investigate what role ammonia nitrogen might have played in adding to the hypolimnetic BOD in both lakes Skaha and Osoyoos.

4.2.6 Conductivity Determining the conductivity of a solution is a convenient means of measuring the concentration of dissolved ions in that solution. An estimate can be made of the quantity of dissolved ionic matter in mg/l in a water sample by multiplying the conductivity by an empirical factor ranging from 0.55 to 0.9, depending on which ionic compounds are dissolved in solution (Golterman, 1975).

Okanagan Lake epilimnetic conductivities varied from 250 - 269 umhos/cm in 1977 and 1978. Values in Skaha Lake varied between 222 and 281 umhos/cm, and those for Osoyoos Lake from 235 to 265 umhos/cm. All three lakes have exhibited a slight decrease in average conductivities since 1971 (Table 18), but this change is so slight as to be within the range of yearly variation.

TABLE 18 MEAN SEASONAL CONDUCTIVITIES 1971/76/77/78 FOR LAKES OKANAGAN, SKAHA AND OSOYOOS

Station	Conductivity (umhos/cm)				
	1971*	1976	1977	1978	1977/78 Average
OK-1 EP	276	242	262	262	262
HYP	289	247	262	265	264
OK-2 EP	271	217	261	256	259
HYP	283	225	263	263	263
OK-3 EP	273	209	261	141	201
HYP	274	225	262	259	261
OK-S1	-	252	272	271	272
OK-S2	-	261	281	277	279
OK-S3	-	233	261	254	258
OK-S5	-	263	260	256	258
OK-S10	-	243	261	256	259
OK-R-1E	-	-	260	-	-
OK-R-2E	-	-	273	-	-
S-1 EP	279	214	258	255	256
HYP	300	221	265	266	266
S-S1	-	240	259	247	253
S-S3	-	-	260	253	257
S-S2	-	228	261	256	259
O-1 EP	275	218	262	257	260
HYP	314	251	282	274	278
O-S1	-	254	262	255	259
O-S2	-	241	267	253	260

* Based on only a few values.

These values were relatively high when compared to other lakes such as Kamloops Lake, where a range of 68 - 112 umhos/cm were found (St. John et al, 1976). Such high values are a reflection of the sources of the dissolved solids draining into the Okanagan Basin as well as high residence times for the lake water. The sources of these ions consist of a variety of geological materials in the watershed which include limestones, glacial draft, clay-silt terraces, conglomerate rock and basalts (Basin Study -Technical Supplement V, 1974). Terrain composed of such materials is relatively easily erroded and results in a higher dissolved solids loading to basin lakes than areas composed of hard materials such as those which exist in the Canadian Shield.

Individual ionic concentrations and ionic balances were not determined in 1976, 1977 and 1978. It was felt that since the major source of dissolved solids is the watershed, ionic balances and relative abundances would not have changed significantly since 1971.

Using the above conversion factor and average seasonal conductivities, the average dissolved solids concentrations for lakes Okanagan, Skaha, and Osoyoos were calculated to be in the range of 110 to 180, 140 to 230, and 143 to 288 mg/l, respectively.

The shallow stations on each lake exhibited very comparable conductivities with the deep station epilimnia on the same lake.

4.2.7 Silicon Dioxide. Silicon Dioxide (SiO_2) is a component of many rocks and minerals and, as such, forms about 50% of the earth's crust. Erosion causes large quantities of silicates to occur in rivers draining the porous igneous rocks of volcanic regions. By the time water is contained in a lake, the concentration of soluble SiO_2 is usually quite low, seldom more than about 2 mg/l (Golterman, 1975). In British Columbia the silica concentrations are usually quite high . The SiO_2 concentrations are often over 2.0 mg/l and several lakes have yielded values in excess of 10.0 mg/l (personal communication - Dr. R. Nordin - B.C. Water Investigations Branch) which is a reflection of B.C. Geology.

TABLE 19 SiO_2 YEARLY AVERAGES (mg/l), 1971/76/77/78

Station	1971	1976	1977	1978
OK-1 EP	4.30 (4.97)*	4.60	-	4.6 (4.7)*
HYP	5.46	5.10	-	5.0
OK-2 EP	2.70 (4.26)*	4.53	-	4.5 (4.9)*
HYP	2.94	5.00	-	4.8
OK-3 EP	2.73 (4.5)*	4.50	-	4.4 (4.7)*
HYP	3.80	5.05	-	4.7
OK-S-1	-	5.07	-	5.3
OK-S-2	-	5.15	-	4.7
OK-S-3	-	4.51	-	4.2
OK-S-5	-	3.46	-	4.0
OK-S-10	-	4.60	-	4.5
S-1 EP	2.10 (.36)*	2.70	-	1.7 (.10)*
HYP	.99	2.13	-	1.9
S-S-1	2.13 (.30)*	3.81	-	3.0
S-S-3	-	2.57	-	1.9
S-S-2	-	-	-	1.6
O-1 EP	3.02 (2.16)*	2.68	-	2.1 (.50)*
HYP	4.02 (2.2)*	4.55	-	2.7
O-S-1	2.90	3.01	-	2.9
O-S-2	3.00	2.78	-	2.2

* Spring overturn value.

Silicate in lakewater is important biologically because it is used in relatively large quantities by diatoms for their cell walls, and this utilization can significantly effect fluctuations of SiO_2 in lakes.

SiO_2 samples were taken in 1976 and 1978 only. At the deep stations on Okanagan and Osoyoos lakes, levels were all higher than the 2 mg/l quoted above (Table 19). Skaha values were lower, largely due to a depletion in April 1978.

All three Okanagan Lake deep stations exhibited seasonal average 1978 epilimnetic values of about 4.5 mg/l, whereas, lakes Skaha and Osoyoos exhibited values of 1.7 and 2.1 mg/l, respectively. On Okanagan Lake there was little fluctuation about the mean. On Skaha and Osoyoos lakes reduced values of 0.1 and 0.5 mg/l, respectively, were found in April. Therefore it seemed likely that fairly active diatom growth had already taken place by that time. During the rest of the year values were above 1 mg/l on both lakes, probably as a result of replenishment by the spring freshet and loadings from Okanagan Lake. In 1971, a significant depletion took place in April on Skaha Lake with levels of about 0.3 mg/l being found, whereas no depletion was noted on Okanagan or Osoyoos lakes. The 1976 mean values for lakes Skaha and Osoyoos were higher than 1978 mean because the low values from April/May were not measured, and therefore were not factors in lowering the overall seasonal means in the former year.

Okanagan Lake hypolimnetic values averaged slightly higher than those of the epilimnion; however, such a situation is not uncommon, even for oligotrophic lakes (Wetzel, 1975).

Osoyoos Lake exhibited gradually increasing hypolimnetic values throughout the 1978 season, reaching a maximum of 5.7 mg/l in October. The mean seasonal value of 2.7 mg/l was very close to the epilimnetic value. Such an accumulation was indicative of biological uptake in the epilimnion, sedimentation of algal cells and then re-dissolution of silica in the hypolimnion causing a build-up as the season progressed.

Skaha Lake hypolimnetic waters exhibited a seasonal trend very similar to that of Osoyoos Lake - increasing values all season and finally reaching a maximum of 3.5 mg/l in October, and similarly producing a seasonal mean of 1.9 mg/l.

Okanagan Lake values in 1978 were comparable to 1971 values only in the case of OK-1. The other two stations, OK-2 and OK-3, both had generally higher levels in 1978 than in 1971. The 1978 Skaha mean was also very comparable to the 1971 mean, whereas the 1978 Osoyoos Lake mean was lower than in 1971.

The shallow stations exhibited very similar seasonal averages to those of the deep station epilimnia. Although levels tended to fluctuate at the stations proximal to streams, levels were quite high all season in 1976 and 1977. No great depletion occurred at any of these stations. The lowest value, 1.2 mg/l, was found at S-S2 in May 1978. Those shallow stations in 1971 that produced silicon data had similar values to those of 1976 and 1978, except for S-S1 which produced a higher mean value in 1976 and 1978 than in 1971. This could have been due to the 1976 and 1978 shallow station monitors missing the low April values.

It appeared that in all three lakes in the study, silica values were fairly high all season, except during April on lakes Skaha and Osoyoos; therefore, during April silicon might have been limiting diatom growth.

4.3 Biological Limnology

4.3.1 Phytoplankton. Phytoplankton, the algae of the open water of lakes, consists of a highly diverse assemblage of the various taxonomic groups. A number of species can make up the total population of phytoplankton at a given time or place. This coexistence of species, their abundance, and their seasonal periodicity depends on the interaction of certain environmental factors including: temperature, light, inorganic and organic nutrients, herbivorous predation, and parasitism (Wetzel, 1975).

In unperturbed systems, the seasonal periodicity of phytoplankton biomass and productivity is ordinarily quite constant from year to year. Therefore, changes in this periodicity and standing crop can give indications of change in the underlying environmental factors, as well as changes in levels of biological primary production.

4.3.1.1 Phytoplankton Chlorophyll-a. Measurement of chlorophyll-a, the photosynthetic pigment most commonly found in algae, is an excellent means of indirectly measuring fluctuations in phytoplankton biomass.

This measurement, though reliable, contains an inherent problem which takes the form of degradation products of chlorophyll (pheopigments) that can accumulate and constitute a significant fraction of the total green pigments (Lorenzen, 1967). This problem is usually overcome by determining the concentration of pheopigments in the chlorophyll-a sample, and subtracting this value from that of the chlorophyll-a, thereby arriving at a true figure for chlorophyll-a. This procedure was followed during the analysis of the 1976, 1977 and 1978 samples. The quantity of pheopigment present in a sample is possibly inversely related to the photosynthetic capacity of the algae in the sample (Golterman, 1975).

Another problem arose in attempting to compare the 1976, 1977 and 1978 chlorophyll-a data with that of 1971. There was some difference in chlorophyll-a data between 1976, 1977 and 1978 and 1971 for areas where no implementation of reduced nutrient loadings had taken place (Okanagan Lake in Table 20). It was found that the technique for determining chlorophyll-a in 1971 was that of Yentsch and Menzel (1963). Lorenzen (1967) states that generally the fluorometric method of Yentsch and Menzel (1963) is excellent. Though this method was used in 1971, it does not appear that the pheopigment fractions were determined; therefore it was suspected that the difference between some of the 1976, 1977 and 1978 data and the 1971 data may have been due to the fact that the 1971 reported chlorophyll-a values were higher because they included the pheopigment fraction.

TABLE 20 SEASONAL MEANS OF PHYTOPLANKTON CHLOROPHYLL-A (μg/l) AND PHEOPIGMENT (μg/l) FROM 1971, 1976, 1977, and 1978 (WEIGHTED MEAN VALUES - SURFACE TO PHOTIC ZONE)

Station	Chlorophyll-a *	Chlorophyll-a			Chlorophyll-a + Pheopigments		
	1971	1976	1977	1978	1976	1977	1978
OK-1	5.63	1.45	1.72	2.09	2.15	2.13	3.05
OK-2	3.78	.97	1.22	2.39	1.67	1.62	3.25
OK-3	4.01	1.05	.67	1.33	2.38	1.25	2.22
OK-S1	-	5.56	2.25	2.99	-	-	-
OK-S2	-	4.97	4.16	2.50	-	-	-
OK-S3	-	1.38	1.03	2.30	-	-	
OK-S5	-	3.27	1.43	2.08	-	-	
OK-S10	-	.89	.77	2.05	-	-	-
S-1	13.19 (33.40)	2.96	3.22	4.16	3.46	3.76	5.80
S-S1	17.25	2.35	2.20	3.32	-	3.56	4.27
S-S3	-	-	2.08	3.27	-	-	-
S-S2	-	2.57	2.22	2.95	-	-	-
O-1	19.59	4.08	4.98	5.64	4.64	6.3	6.95
O-S1	-	3.73	5.40	3.55	-	-	-
O-S2	9.81	4.29	4.64	3.67	-	6.0	4.80

* It would appear from a comparison study (Appendix IV) that these 1971 values include both chlorophyll-a and pheopigment.
These figures were recalculated from 1971 raw data for specific stations and therefore are different from means in Technical Supplement V (1974).

(Value in brackets includes peak September, 1971, value of 114.28 μg/l).

- 1971 means based on period of late May to early October (monthly samples).
- 1976 means based on period of early June to late October (monthly samples).
- 1977 and 1978 means based on period of early April to late October (monthly samples).
- See Table 21 for comparison of summer chlorophyll-a values.

An attempt was made to find out if this difference was analytical by setting up a small comparison study with the cooperation of Dr. J. Stockner, who had been integrally involved in the original 1971 study. The methods and results of this comparison are reported in Appendix IV. The conclusion from this comparison was that the results from the two methods were not exactly the same, but are different by about only 10% if the E.P.S. chlorophyll-a and pheopigment values are added together and considered as chlorophyll-a. This was done for purposes of generally comparing 1976, 1977 and 1978 data with that of 1971 (Table 20).

4.3.1.2 Deep Station Phytoplankton Chlorophyll-a. Mean weighted chlorophyll-a and pheopigment values were calculated for the vertical column of water from the surface to the bottom of the photic zone at deep stations.

Okanagan Lake. The Okanagan Lake deep station chlorophyll-a and pheopigment values were generally very low in the oligotrophic range in 1976, 1977 and 1978. All three stations showed seasonal averages of less than 3.5 ug/l in all three years (Table 20). This is less than the mean values obtained in 1971 even with pheopigments added, but the differences were not great. Such small differences between 1971 and recent values could easily be attributed to fewer samples taken in 1971, or to yearly fluctuations.

Skaha Lake. Skaha Lake chlorophyll-a and pheopigment data showed strikingly low values in the mesotrophic range averaging less than 6 ug/l for 1976, 1977 and 1978. These values may be compared with the 13.19 ug/l obtained in 1971. Such a difference cannot be attributed solely to sampling or analytical differences and, therefore, indicates a substantial drop in phytoplankton standing crop biomass since 1971.

Osoyoos Lake. Osoyoos Lake data also showed that chlorophyll-a and pheopigment values for 1976, 1977 and 1978 were all significantly less than in 1971. The 1976, 1977 and 1978 mean seasonal values all were below 7.0 ug/l representing meso-euthrophic values compared to the eutrophic 19.75 ug/l in 1971. This has occurred despite the fact that seasonal and spring total P levels have not obviously changed compared to the values found in 1971. However, in comparing 1976, 1977 and 1978 spring and seasonal total P values with 1969 and 1970 values, there does appear to have been a reduction (Table 12) which would probably lead to the reduced phytoplankton biomass shown by these chlorophyll-a results.

Okanagan Lake, then, is the least productive of the three lakes in terms of chlorophyll-a, whereas, Osoyoos Lake is the most productive.

4.3.1.3 Chlorophyll-a - Nutrient Relationships at Deep Stations. Once spring overturn values of total P are known, it is possible to predict summer chlorophyll-a concentrations (Dillon and Rigler, 1974). The accuracy of this prediction will of course depend on how much of the spring total P was in a biologically available form. Samples were obtained during spring circulation at OK-3 and S-1 in 1978, and shortly after circulation at O-1, OK-1, and OK-2 in 1978, and at all five stations in 1977.

Circulation of these lakes usually occurs in late March to early April, and as temperature data indicated the 1971 sampling was initiated at least a few weeks after spring circulation. In 1970 (Stein & Coulthard, 1971) sampling occurred in March just before circulation.

Using the total P values obtained during these samplings summer (June-August) chlorophyll-a values were predicted by the present author using the linear regression equation of Dillon and Rigler (1974):

(1) $LOG_{10} [CHLa] = 1.449\ LOG_{10} [P] - 1.136$
with a correlation coefficient of $r = .96$
For all values of P except Skaha and Osoyoos Lakes in 1970 and 1971.

(2) LOG_{10} [CHLa] = 1.583 LOG_{10} [P] - 1.134
with $r = 0.975$
For Skaha and Osoyoos Lakes in 1970 and 1971 because the N:P ratios were below 10:1

As Table 21 shows, the actual summer chlorophyll-a values in 1971, 1977 and 1978 generally agreed quite well with the predicted values. All actual values were within the 95% confidence intervals established by Dillon and Rigler (1974) except the 1971 Skaha and Osoyoos lakes concentrations, and the 1978 OK-2 station value.

Stein and Coulthard (1971) found spring total PO_4 (P) values for Skaha and Osoyoos lakes in 1970 which were somewhat higher than those found in 1971 by the Okanagan Basin Study (Table 21). The chlorophyll-a values predicated from the 1970 spring total P concentrations compared with actual or predicted 1977 and 1978 chlorophyll-a values, again suggests a drop in Skaha Lake algal production since 1970. Declines in chlorophyll-a concentrations since 1970 were also evident for Osoyoos Lake. The 1970 chlcrophyll-a values for this lake were also slightly higher than the 1977 and 1978 predicted values, but were markedly higher (twice) than the actual values.

On the basis of these comparisons of 1970 and 1971 data with present data, it seems fairly conclusive that since 1970 and 1971 there has been an obvious decrease in production of algal biomass in Skaha Lake. A smaller but definite decrease of algal biomass has also ocurred in Osoyoos Lake during the same period. No significant change during this period has occurred at the Okanagan Lake stations.

TABLE 21 A COMPARISON OF ACTUAL MEAN SUMMER CHLOROPHYLL-A VALUES (μg/l)* WITH VALUES PREDICTED** ON THE BASIS OF SPRING TOTAL P (μg/l)

Station	1970		1971			1977			1978		
	Total P	Predicted Chl-a	Total P	Predicted Chl-a	Actual Chl-a	Total P	Predicted Chl-a	Actual Chl-a	Total P	Predicted Chl-a	Actual Chl-a
	Mar. 25		Apr.22-May 3		July 27	Apr. 19-20		July 25	Apr. 3-10		July & Aug.
OK-1	-	-	8.7	(1.68)	<u>5.44</u>	9.5	(1.91)	<u>0.72</u>	8.5	(1.62)	<u>1.44</u>
OK-2	7.6	(1.38)	10.8	(2.30)	<u>1.84</u>	8.5	(1.62)	<u>0.40</u>	4.5	(0.65)	<u>2.20</u>
OK-3	-	-	9.8	(1.99)	<u>2.75</u>	7.5	(1.36)	<u>0.40</u>	6.0	(0.98)	<u>1.16</u>
					June-Aug.			June-Aug.			June-Aug.
S-1	31.0	(16.86)	20.7	(13.61)	<u>15.65</u>	11.0	(2.36)	<u>3.33</u>	18.0	(4.82)	<u>5.05</u>
					June-Aug.			June-Aug.			June-Aug.
O-1	26.9	(13.46)	22.8	(10.36)	<u>22.93</u>	21.0	(6.02)	<u>4.79</u>	23.5	(7.09)	<u>4.55</u>

* Actual measured values underlined.
** Predicted values in brackets.

If any change has occurred in Okanagan Lake, it is not conclusive. The 1971 chlorophyll-a data for Okanagan Lake, in many cases, were based on only one surface sample per station, and therefore are not very comparable to the 1976, 1977 and 1978 data. A very general comparison seemed to indicate that not much obvious change has taken place on this lake since 1970/71, except perhaps a slight drop in production at OK-2 and OK-3, which could possibly be attributed to a small drop in total P concentrations.

Chlorophyll-a levels throughout the seasons showed similar trends on both lakes Skaha and Osoyoos, with the highest levels being found during the August-September period. It is interesting to note that for both lakes the 1978 August bloom produced more biomass than the 1977 August bloom (see figures in Appendix V). The peak values for Skaha Lake were 4.1 and 8.2 ug/l in 1977 and 1978, respectively. The Osoyoos Lake peak values were 7.2 and 9.8 ug/l in 1977 and 1978, respectively. These values are within the range of mesotrophy to meso-eutrophy for Skaha Lake, and eutrophy for Osoyoos Lake.

In the cases of lakes Skaha and Osoyoos in 1977 and 1978 an attempt was made to find a correlation between chlorophyll-a values and various nutrient concentrations throughout the seasons. A positive correlation was found to exist where total nitrogen and particulate carbon were concerned (Table 22 and Figures A-D in Appendix V); on the other hand little or no correlation was found in the case of total phosphorus, dissolved phosphorus, or nitrite-nitrate nitrogen. This was not surprising considering the tendency of these latter three nutrients to fluctuate under a variety of influences, such as biological uptake, outside loadings, and bacterial remineralization.

TABLE 22 CORRELATIONS (r) BETWEEN 1977/78 SEASONAL CHLOROPHYLL-A AND VARIOUS PARAMETERS BASED ON LINEAR REGRESSION ANALYSIS

Parameters	1977		1978	
	S-1	O-1	S-1	O-1
Chlorophyll-a vs Total N	.40	.63	.66	.90
Chlorophyll-a vs Particulate Carbon	.78	.78	.50	.75

N.B. Each r value based on 7 samplings.

4.3.1.4 Shallow Station Phytoplankton Chlorophyll-a. All the shallow stations in 1976, 1977 and 1978 which have been subject to cultural enrichment, exhibited remarkably low phytoplankton chlorophyll-a values, considering the high nutrient levels (Table 20). Wetzel (1975) reported that a number of studies have clearly indicated a distinct inhibition of phytoplankton development in littoral zones containing heavy stands of macrophytes. Stuch stands are close to virtually all the shallow station locations except for OK-S3 at Okanagan Centre, and likely contributed significantly to the cause of the unusually low values. For this reason it is felt that shallow station phytoplankton chlorophyll-a results are not a reliable indicator of biological production in those areas, compared to deep stations, but can be used generally to compare one shallow station with another.

According to these data the most productive shallow stations in the valley were the ones on Osoyoos Lake, followed by those on Lake Skaha. The Okanagan Lake stations yielded generally the lowest chlorophyll-a production, except for OK-S2 in 1976, and 1977 which had relatively high values. There was however a drop in phytoplankton biomass at OK-S2 in the Vernon Arm of Okanagan Lake between 1977 and 1978, which was probably a response to the sewage diversion from that area.

4.3.1.5 Deep Station Phytoplankton Identification, Enumeration and Biovolumes. The most recent phytoplankton study done in the Okanagan Basin prior to 1976 was undertaken by Stein and Coulthard (1971) in 1969 to 1970, at which time algal identifications and enumerations were carried out. For comparison purposes, the same analysis was done with the 1976, 1977 and 1978 samples. Numbers of organisms however are biased indicators because of the great differences in cell size among algae (Wetzel, 1975). Therefore, biovolumes were also determined for the phytoplankton species sampled in the 1976, 1977 and 1978 program. In order to be as accurate as possible in the comparison of 1969 and 1970 data with those obtained in 1976, 1977 and 1978, average cell concentrations for the water column were calculated for all years including 1969 and 1970. The raw seasonal periodicity and biovolume data are available from the Okanagan Basin Implementation Board*.

Okanagan Lake. OK-2 was the only 1976, 1977 and 1978 station on Okanagan Lake that was located in the same place as a 1969 and 1970 station. At OK-2 the mean cell concentrations for the summer-fall period in 1976, 1977 and 1978 varied from 121 to 367 cells/ml. This range encompassed the value of 342 cells/ml formed in 1969 (Table 23). A small April bloom of diatoms and phytoflagellates (cryptomonads) was found in 1970 at this station. A similar situation existed during April 1977 and 1978 and at the same time Blue green algae represented up to 32% of the assemblage. The dominant species were Selenastrum sp.; Chroomonas acuta and Asterionella formosa in 1977 and 1978, compared to Crytomonas ovata in 1970.

No obvious bloom of Blue green algae was noted at OK-2 during the summer of any of the years sampled. In 1969 however, the summer period was dominated by Blue green algae, the most notable being Aphanotheca nidulans, whereas, in 1976, 1977 and 1978, Blue green algae were a minority with dominancy being shared by diatoms and phytoflagellates (Asterionella formosa and Chroomonas acuta) and, to a lesser degree, by the green alga (Oocystis sp).

From this comparison it appeared that no great change had taken place at this station since 1969 and 1970, except perhaps for a slight shift to a more oligotrophic algal assemblage.

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*Okanagan Implementation Office, Box 458, Penticton, B.C., Canada.

TABLE 23 TOTAL PHYTOPLANKTON AT DEEP STATIONS 1969/76/77/78
SUMMER-FALL MEAN NUMBER (cells/ml), AND IN BRACKETS MEAN SPRING-FALL AND MAXIMUM BIOVOLUMES IN cm^3/m^3

Station	1969	1976			1977			1978		
	June-Oct.	June-Oct.	June-Oct.		June-Oct.	April-Oct.		June-Oct.	April-Oct.	
OK-1	-	428	(1.53)	(3.24)* Oct.	130	(0.42)	(0.70)* April	432	(1.04)	(1.27)* Aug.& Oct.
OK-2	342	248	(1.25)	(2.65)* Sept.	121	(0.45)	(0.77)* April	367	(0.78)	(1.05)* July
OK-3	-	678	(1.32)	(2.54)* Oct.	238	(0.28)	(0.39)* April	517	(0.58)	(0.94)* July
S-1	774	1615	(4.44)	(7.83)* July	415	(0.84)	(1.30)* Oct.	1846	(2.55)	(4.35)* Sept.
O-1	953	4558 June-Aug.	(7.01) June-Aug.	(7.82)* July	1072	(2.52)	(6.54)* Sept.	1532	(4.50)	(15.54)* Sept.

* Maximum biovolume and month of occurrence.

Cell volumes (μ^3) of 1969, 1976, 1977 and 1978 dominants based on measurements of organisms found in 1976, 1977 and 1978:

Aphanizomenon flos-aquae - 45 700
Aphanothece microscopica - 5
Anabaena sp. - 50 000 - 56 000
Oscillatoria sp. - 9 620
Oscillatoria microcystis sp. - 8 000
Lyngbya limnetica - 8 000
Dinobryon sertularia - 1 410
Asterionella formosa - 240
Fragilaria crostonensis - 710
Synedra acus - 1400
Cryptomonas ovata (*borealis*?) - 1890
Chroomonas acuta - 90
Cyclotella sp. - 820

At all three Okanagan Lake stations in 1976, 1977 and 1978, seasonal mean biovolumes as well as peak biovolumes produced were well within the oligotrophic range (Table 23).

The seasonal periodicity of algae based on biovolumes at these stations was quite different from seasonal periodicity based on cell concentrations. Periodicity based on biovolume will be considered more valid because of its greater representativeness.

Biovolumes remained low on Okanagan Lake usually averaging well below 1.6 cm^3/m^3, at all stations throughout each season. Small blooms were noted in October of 1976 and 1978 (3.24 and 1.27 cm^3/m^3) at OK-1, September 1976 and July 1978 (2.65 and 1.05 cm^3/m^3) at OK-2, and in October 1976 and July 1978 (2.54 and .94 cm^3/m^3) at OK-3. The year 1977 exhibited markedly lower algal production than either 1976 or 1978 at all three stations. The fact that 1977 was a much drier year than 1976 or 1978 could have resulted in less nutrient loading from surface runoff. The data derived from chemical sampling agreed with this hypothesis.

There was some variability between years as to which species were the major dominants at various times of the year. There was, however, relative consistency from year to year in terms of the same species being found in the assemblage. April months were characterized by a dominancy of phytoflagellates: Gymnodinium sp in all three years and at all stations; Cryptomonas Corealis in 1977/78 at OK-1 and OK-2; and the Blue green alga Oscillatoria sp at OK-3, 1978. July months were characterized by dominancy of the Blue green algae Anabaena spp at all stations, Oscillatoria sp at OK-1 and OK-3, and Lyngbya sp at OK-3. The phytoflagellate Ceratium sp was also dominant in 1978 at OK-2. The late summer through fall months were characterized largely by the dominancy of Blue green algae including: Anabaena spiroedes mainly at OK-1 and OK-2, with Aphanizomenon sp being found at all three stations in 1978. In addition, Ulothrix sp was found at OK-1 and OK-3 and Stephanodiscus niagare was found at OK-3. These organisms, though dominant, were present in very low biovolumes. On the basis of biovolume, all three stations can be classed as oligotrophic.

Skaha Lake. In Skaha Lake from 1976 through 1978, mean June to October cell concentrations varied from a low of 415 cells/ml in 1977 to a high of 1846 cells/ml in 1978. This range compares to a mean June to October 1969 value of 774 cells/ml (Table 23). In view of this range of annual cell concentration variability, no reliable conclusions could be made regarding phytoplankton enumerations based on concentrations alone.

On the other hand, there has been a significant shift in seasonal periodicity based on cell numbers since 1969. Stein and Coulthard (1971) found that at the end of their monitoring program in April 1970, that there was a bloom of phytoflagellates (Cryptophyceae) and diatoms which was not significantly different from the bloom in April 1977 and 1978. Those years were also characterized by April diatom blooms as well as a lesser bloom of green algae in 1977. A great change which has occurred since 1969 is evidenced by the composition of the assemblage during the summer months of 1976, 1977 and 1978. From June through to September 1969 there was a steady increase in numbers of Blue green algae, which made up 10% of the population in June and then peaked at 86% and 91% in August and September, respectively. The dominant species at first was Aphanizomenon flos - aquae later giving way to large numbers of Oscillatoria spp. This increase in Blue green algae was mirrored by a corresponding steady decrease in diatom numbers from 76% of the population in June to lows of 7% in August and 6% in September.

The 1976, 1977 and 1978 data did not show a similar trend. Blue green algae numbers remained at relatively low levels all season, reaching maximum composition of 15 to 17% in July through August. Numbers of the organisms were in most cases 50% lower in 1976, 1977 and 1978 in July through September than in 1969 during the same period. This suggested a decrease in total biomass since 1969 because the majority of the summer biomass of that year was probably composed of Blue green tissue. This was inferred from the fact that these organisms' volumes were found to be much greater than the diatoms which dominated in 1976 through 1978 (Table 23 Footnotes). The 1976, 1977 and 1978 diatoms showed a trend which is the reverse of that in 1969. Diatom numbers in the recent years remained consistently high all through the three seasons and made up from 42 to 82% of the population. Common dominants were *Asterionella formosa, Fragillaria crotonensis, Cyclotella* spp., *Dinobryon sertularia* and *Chroomononas acuta*. This shift was strongly indicative of a shift in trophic status of the lake from eutrophy towards mesotrophy.

On the basis of biovolume of total phytoplankton, Skaha Lake would presently fit into a mesotrophic category (Table 23). The year 1977 exhibited a much lower mean biovolume production than did 1976 and 1978, by having a value of 0.84 cm^3/m^3 compared to the 1976 and 1978 values of 4.44 and 2.55 cm^3/m^3, respectively. Computation of the 1976 mean value was based on only the June to October period. However, there were blooms in July of 1976 (7.83 cm^3/m^3) and September of 1978 (4.35 cm^3/m^3), which were still significantly larger than the small 1977 October bloom (1.30 cm^3/m^3).

The seasonal periodicity of organisms based on measured biovolumes, as in the case of Okanagan Lake, was different from that based on cell numbers. Diatoms were a consistently dominant group throughout most of each season, usually comprising 45-70% of the algal volume. Blue green algae became more prominant in July to August 1976 and 1977, and replaced the diatoms as the most dominant group in September to October by representing about 60-77% of the volume. This increase in Blue green algae corresponded to a steady decrease in diatoms. The dominant species during 1976 and 1977 were *Gymnodinium* sp, *Ulothrix* sp, and *Anabaena* spp.

In 1978 this same trend was not observed. Diatoms consistently dominated throughout the sampling season with peaks of 85% of the volume in April and 33 to 55% by volume in August through October. Blue green algae, however, were still strongly represented in the fall of 1978. The 1978 sequence of dominants were Cyclotella sp, Stephanodiscus niagarae, Mallamonas sp, Ceratium sp, Surirella ovata, until September, then Anabaena sp assumed dominancy, followed by Aphanizomenon sp.

Osoyoos Lake. In Osoyoos Lake, cell concentrations varied from a low mean 1977 value of 1072 cells/ml (Table 23) to a high 1978 mean of 1532 cells/ml. The 1976 mean was higher than in 1977 or 1978 but was based only on the June to August period. The 1969 mean value was 953 cells/ml, a value close to that of 1977. Of more importance than numbers of total phytoplankton, was the comparison of seasonal periodicity of organisms.

The 1969 sampling ended in August, therefore an assessment of the whole spring to fall period was not possible. The 1969 monitoring program indicated that Blue green algae were low in number in the early spring but increased rapidly from 24% of the total in May to 96% in June, and remained above 70% until August. Diatoms, although comprising 36.0% of the total in April 1970), were below 7% during May 1969 through August. Phytoflagellates (Crypotophyceae) were dominant in April 1970 and May 1969 and represented 46 and 70% respectively of the total, but were a minority during the remainder of the monitoring period.

Dominant species in 1969 and 1970 were Asterionella formosa, Lyngbya limnetica, Aphanizomenon flos - aguae, and Aphanothece nidulans.

The 1976, 1977 and 1978 monitoring study evidenced a trend similar to, but not so marked as, that of Skaha Lake for the same period. Though Blue green algae did increase in number during the July to August period, the numbers were much less during all three years than in 1969, and reached a maximum of 36% of the total in August of 1978. Correspondingly, diatom numbers in 1976, 1977 and 1978 were consistently higher than during the summer months of 1969, and continued to make up 21 to 54% of the total phytoplankton. Phytoflagellates, in addition to being present in relatively high percentages (28-65%) in the spring months of 1976, 1977 and 1978, continued throughout the summer of 1978 at about 20% of the total, but were poorly represented during the 1976 and 1977 summer months. These data therefore indicated a decrease in algal biomass between 1969 and 1976 through 1978.

The highest deep station phytoplankton biovolume in the valley were found in Osoyoos Lake. Mean seasonal values for total phytoplankton varied from 2.52 cm^3/m^3 in 1977 to 4.50 cm^3/m^3 in 1978. The 1976 June to October mean was 7.01 cm^3/m^3.

A large bloom which had a total biovolume of 15.54 cm^3/m^3 occurred in September of 1978. A large portion (9.43 cm^3/m^3) of this biovolume was composed of Aphanizomenon sp. Smaller but still considerable blooms occurred in September 1977 (6.54 cm^3/m^3) and in July of 1976 (7.82 cm^3/m^3). Ulothrix sp. was the major dominant in the 1976 and 1977 blooms with its own biovolumes of 3.01 and 4.38 cm^3/m^3.

Diatoms comprised most of the biovolume during the April to May periods (37 to 80% of the total). In 1978, yellow brown algae (Chrysophyta) were well represented in May and June with about 35-38% of the total volume. The Blue green algae increased greatly in the July-October period, and comprised from 14 to 87% of the total volume. Dominant species found were Tabellaria fenestrata, Stephanodiscus niagarae, Coscinodiscus lacustris, and Dinobryon sertularia in the spring. Summer dominants were Fragilaria crotonensis, Oedogonium sp. and Anabaena sp. Fall dominants included Ulothrix sp and Oscillatoria sp.

On the basis of the above phytoplankton data, the three lakes under study can be classified in terms of the main body of each lake:

Okanagan Lake	Oligotrophic
Skaha Lake	Mesotrophic
Osoyoos Lake	Eutrophic

Although Osoyoos Lake currently appears to be eutrophic, it is less eutrophic than it was during 1969 and 1971.

4.3.1.6 Shallow Station Phytoplankton Identification and Biovolumes. Phytoplankton identification and biovolume data were collected at all shallow stations in 1977 and 1978. Even though macrophytic inhibition could have affected phytoplankton biomass at some of these stations (Wetzel, 1975), the data can still be used to support other littoral productivity data. These values are likely to have been less representative of the epilimnion than the deep water samples because the former are based on only one sample at one metre depth.

As Table 24 indicates, data are missing for some months, particularly in 1977. This is because budgetary constraints prohibited sample analysis. Therefore, in addition to presenting 1978 mean seasonal values, the values for only the same periods sampled in both 1977 and 1978 are compared in Table 24.

These data support the other biological data in indicating a trend of higher biological production in 1978 compared to 1977 at all stations. This is probably a result of climatic variation between 1977 and 1978. The only exception to the trend occurred at OK-S2 near Vernon, where a markedly lower 1978 biovolume (2.97 cm^3/m^3) was found compared to 1977 (9.55 cm^3/m^3). This is in agreement with the periphyton data in strongly indicating a reduced biological production in the Vernon Arm as a result of the sewage diversion from Vernon Creek.

In 1978, the most productive shallow station was OK-S1 which had a eutrophic value of 9.98 cm^3/m^3. Large blooms occurred at this station during June to July (10-28 cm^3/m^3) and in late August (15.6 cm^3/m^3). The dominant organisms were *Gymnodinium* sp and *Aphanizomenon* sp.

Although the productivity at OK-S2 has decreased since 1971, the seasonal mean value of 5.23 cm^3/m^3 places it as the second most productive

TABLE 24 TOTAL PHYTOPLANKTON BIOVOLUME (cm^3/m^3) AND DOMINANT GENERA AT PEAK PRODUCTION AT SHALLOW STATIONS - 1977/78

Station	Mean 1977 Values	1978 Mean Values Comparable to 1977	1978 Seasonal Mean (Missing 2 Sept. values & 1 value from May & Oct.)
OK-S1	1.32 (Aug. 2/Oct. 2)	4.74	9.98 (15.69)* July 3 <u>Gymnodinium sp.</u>
OK-S2	9.55 (July 2/Aug. 2/Oct. 2)	2.97	5.23 (15.52)* July 3 <u>Gymnodinium sp.</u>
OK-S3	-	-	1.91 (3.03)* June 13 <u>Aphanizomenon sp.</u>
OK-S5	-	-	1.23 (2.96)* June 19 <u>Aphanizomenon sp.</u>
OK-S10	0.78 (May 2/May 3/June 2)	1.40	0.84 (2.05)* May 30 <u>Aphanizomenon sp.</u>
S-S1	1.17 (July 2/Aug. 2/Sept. 1/Oct. 1)	2.18	3.40 (12.86)* June 13 <u>Oedogonium sp.</u>
S-S3	0.70 (July 2/Aug. 2/Sept. 1/Oct. 1)	2.63	2.48 (4.19)* May 16 <u>Cymbella sp.</u>
S-S2	0.82 (July 2/Aug. 2/Sept. 1/Oct. 1)	3.86	3.68 (13.15)* July 11 <u>Ulothrix sp.</u>
O-S1	2.35 (July 2/Aug. 2/Sept. 1/Oct. 1)	6.29	2.40 (15.55)* Sept. 5 <u>Aphanizomenon sp.</u>
O-S2	2.90 (July 2/Aug. 2/Sept. 1/Oct. 1)	8.51	3.44 (23.49)* Sept. 5 <u>Aphanizomenon sp.</u>

* Peak value for season.

station that exhibited a eutrophic condition. A fairly large bloom occurred at OK-S2 in early July 1978 (15.5 cm^3/m^3) which was largely composed of Gymnodinium sp.

The other three Okanagan Lake stations yielded quite low oligotrophic values. Presumably the low values for OK-S5 are affected by the dense Myriophyllum spicatum (milfoil weed) beds in the area. If the milfoil had been absent much higher values would have been expected, considering the nutrient concentrations in that area.

All three Skaha Lake stations showed lower values than OK-S1 and OK-S2, averaging 2.48 to 3.68 cm^3/m^3, respectively. Blooms occurred at S-S1 in June (12.86 cm^3/m^3) and at S-S2 in mid-July (13.5 cm^3/m^3). These values are considerably higher than the deep station values. Based on the seasonal values, all three stations would be classified as in the mesotrophic state, but the blooms suggest a state of eutrophy.

The values for Osoyoos Lake remained surprisingly low throughout the May to October period of 1978, averaging 2.4 and 3.44 cm^3/m^3 for O-S1 and O-S2. Only in early September did bloom conditions occur with high values of 15.55 cm^3/m^3 for O-S1 and 23.49 cm^3/m^3 for O-S2. The dominant organism at both stations was Aphanizomenon sp. It is interesting that both these peaks occurred in September, whereas, peaks at all the other stations occurred in late spring to early summer. Possibly the Osoyoos Lake blooms are related to the fall decline and disintegration of Myriophyllum spicatum and the concommitant remineralization of nutrients. The seasonal values would place the Osoyoos Lake shallow stations in a mesotrophic state, but the peak values suggest a eutrophic tendency.

4.3.2. Periphyton. Periphyton are algae which live attached to various substrates such as rocks, macrophytes, animals, sediment, and sand in the littoral zone. Because their habitat lies in littoral areas, they are good indicators of water quality in those areas, and for this reason, periphyton samples were taken to determine primary biological production in areas most proximal to sources of nutrients being loaded to the lakes.

The only adequate information in literature concerning periphyton involves taxonomy (Wetzel, 1975). Very little information exists about the ecology of periphyton or the appropriate techniques for sampling them.

Stockner et al (1972) used glass slide artificial substrate samplers in their periphyton studies on the Okanagan Basin lakes in 1971. During the 1976 sampling program, this style of sampler was again used but was discontinued in 1977 and 1978 for reasons which are outlined in Section 3.2. In 1977 and 1978 a roughened plexiglass sampler was used, which produced a high yield of data compared to that obtained in 1976.

In order to establish a basis for comparison between the periphyton results of the 1976, 1977 and 1978 study and those obtained in 1971, an experiment was conducted to compare the glass slide and plexiglas samplers. The methods and results of this experiment are reported in Appendix VI.

Chlorophyll-a and the dry weights are parameters which are of great use in gauging the biological production of periphyton at a given time (standing crop biomass). However, they cannot be considered as absolute values because in measuring these parameters, factors such as grazing cannot be estimated.

4.3.2.1 Periphyton Chlorophyll-a. The comparison study (Appendix VI) indicates that the pigment content of glass and plexiglass sampled periphyton are comparable. However, a difficulty still exists in being able to closely compare the 1971 and 1977 and 1978 data because of probable experimental variability between methods of chlorophyll-a sample preparation. In order to provide as close as possible a comparison between the 1971 and 1977 and 1978 data, the 1977 and 1978 pheopigment and chlorophyll-a data were added together (Appendix IV) before the comparison was made (Table 25). In addition to the tabulated form, the 1977 and 1978 chlorophyll-a data are also presented in graphical form (Figures 3 and 4) to depict seasonal trends.

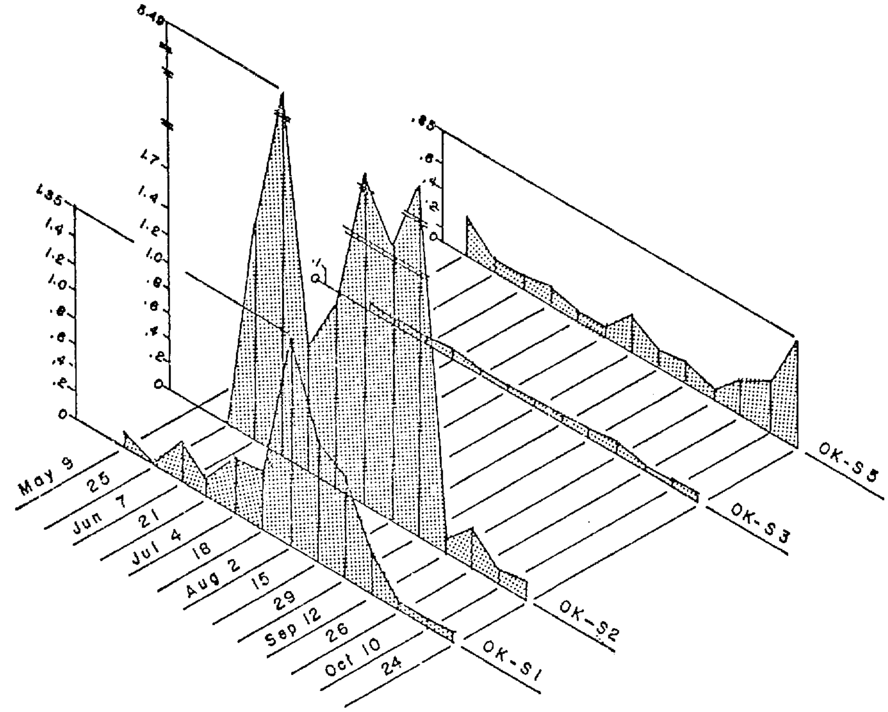
Okanagan Lake. The stations at Okanagan Center (OK-S3) and at Penticton (OK-S10) produced the lowest chlorophyll-a and pheopigment levels measured in the valley in 1977 and 1978 (Table 25). Seasonal averages at these stations were less than 0.3 ug/cm^2. The stations in the North Arm (OK-S1) and at Kelowna (OK-S5), because of the nutrient loadings in those areas, showed somewhat higher values (0.48 and 0.35 ug/cm^2 in 1977 and 0.47 and 0.29 ug/cm^2 in 1978). OK-S1, 5 and 10 in 1971 were all somewhat higher than in 1977 and 1978 but it was felt that this difference could be within experimental variability and was not due to a change in standing crop of periphyton produced. There was a significant difference between the 1977 Vernon Arm station seasonal value of 2.28 ug/cm^2 and that of the 1971 value of 8.5 ug/cm^2. Although experimental variation may account for part of this difference, a decrease in production since 1971 has probably also contributed to this change. Such a decrease in production very likely arose from the reduction of the sewage discharge to this Arm from Vernon during the spring and summer months since 1971. Since 1977, the Vernon sewage has been completely diverted from the lake system and this has apparently contributed to a further decrease in productivity to 0.70 ug/cm^2 of chlorophyll-a.

Skaha Lake. Chlorophyll-a and pheopigment content at the 1977 and 1978 Skaha stations were highest at S-S1, the station off the mouth of the Okanagan River. The seasonal average 1977 and 1978 values there were 0.73 and 1.35 ug/cm^2, compared to 0.16 in both years for S-S3 and 0.11 ug/cm^2 in both years for S-S2. These southwardly decreasing values indicate as did ammonia concentrations, that the influence from the Penticton sewage decreases as the distance south from the discharge increases.

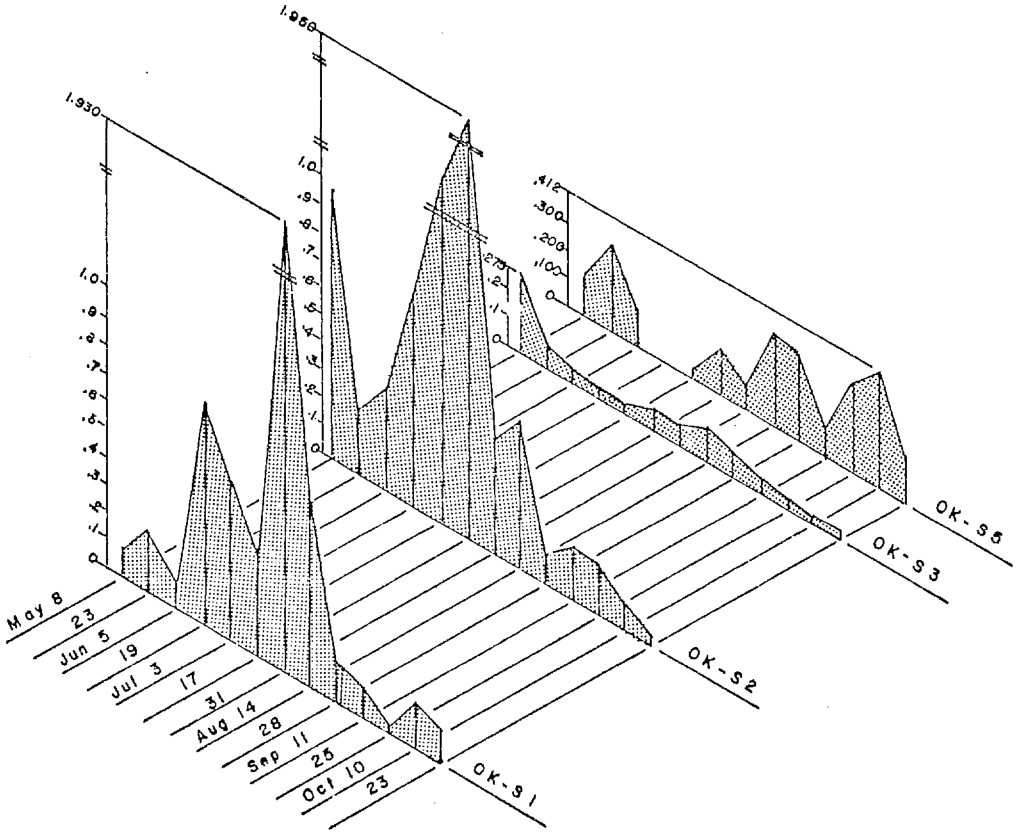
TABLE 25 A COMPARISON OF MEAN SEASONAL CHLOROPHYLL-A AND PHEOPIGMENT VALUES (ug/cm2) FOR PERIPHYTON FROM 1971, 1977, and 1978 (14 DAY SAMPLING PERIODS)

Station	1971	1977			1978		
	Chlorophyll-a	Chlorophyll-a	Pheopigments	Chlorophyll-a & Pheopigments	Chlorophyll-a	Pheopigments	Chlorophyll-a & Pheopigments
OK-S1	0.8	0.42	0.06	0.48	0.40	0.07	0.47
OK-S2	8.5	1.87	0.41	2.28	0.58	0.12	0.70
OK-S3	-	0.05	0.01	0.06	0.07	0.02	0.09
OK-S5	0.6*	0.24 0.17*	0.11 0.12*	0.35 0.29*	0.21	0.08	0.29
OK-S10	0.5	0.04	0.1	0.05	0.03	0.01	0.04
S-S1	15.8	0.59	0.14	0.73	1.08	0.27	1.35
S-S3	-	0.12	0.04	0.16	0.12	0.04	0.16
S-S2	1.1	0.06	0.05	0.11	0.09	0.03	0.12
O-S1	6.3	0.32	0.14	0.46	1.18	0.41	1.59
O-S2	1.9	0.15	0.03	0.18	0.09	0.04	0.13

* Value is the mean for the May through June period.



1977



1978

FIGURE 3 SEASONAL CHANGES OF PERIPHYTON CHLOROPHYLL a ($\mu g/cm^2$) FOR LAKE OKANAGAN (NORTH TO CENTRAL) 1977 AND 1978

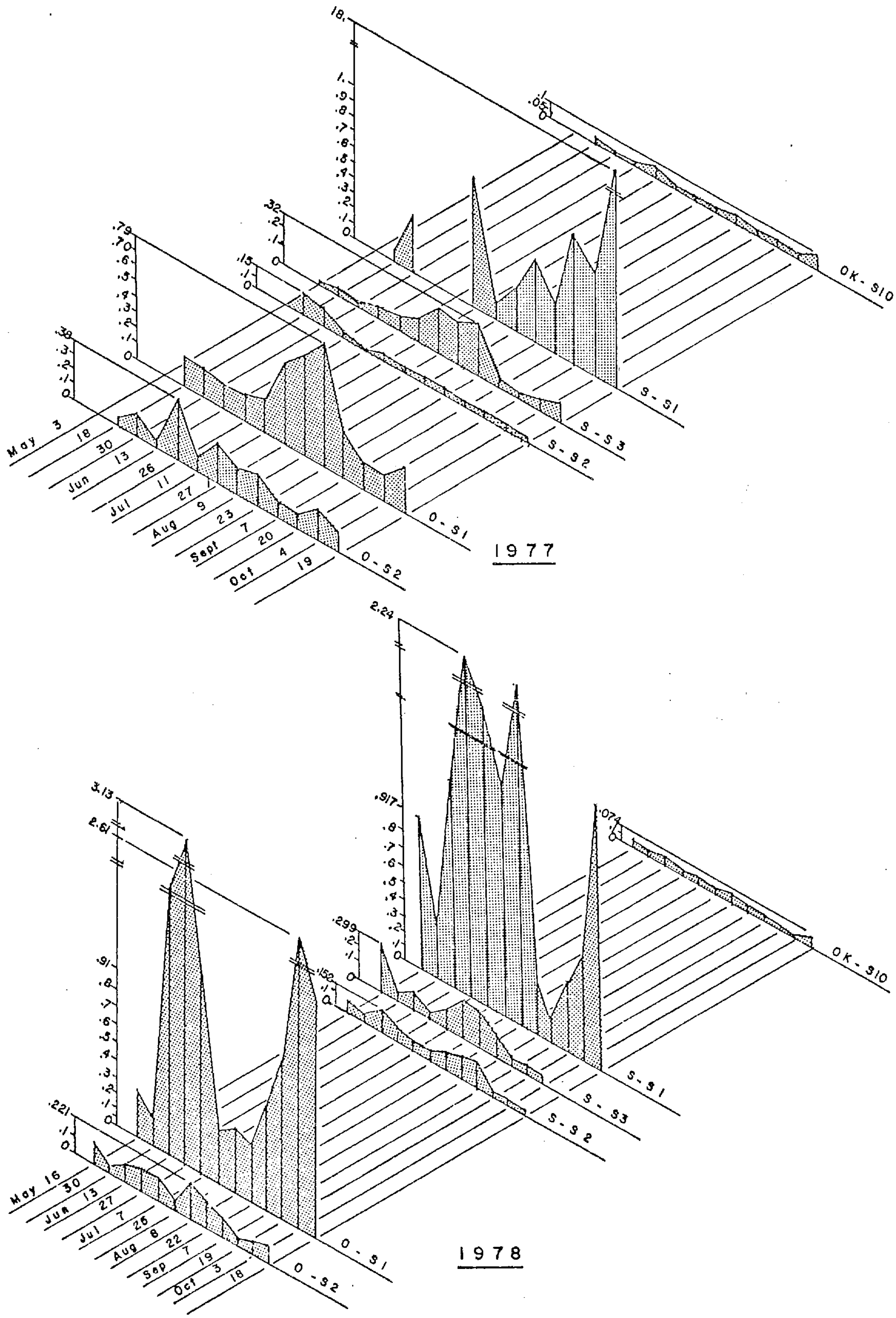


FIGURE 4 SEASONAL CHANGES OF PERIPHYTON CHLOROPHYLL *a* ($\mu g/cm^2$) FOR LAKES OKANAGAN (SOUTH END), SKAHA AND OSOYOOS - 1977 AND 1978

In 1971, no samples were taken at the S-S3 station. Both of the 1971 stations' seasonal values were higher than in 1977 and 1978. The greatest difference was noted at S-S1 where, in 1971, the seasonal mean chlorophyll-a and pheopigment content was 15.8 ug/cm^2. The magnitude of this difference suggests that it is largely caused by a marked decrease in biological production due to reduced phosphorus loadings to Skaha Lake. The 1971 seasonal average for S-S3 was 1.1 ug/cm^2 - again higher than the 1977 and 1978 values. This difference was probably also due to a decrease in biological production, but since the impact of sewage was less marked at this station in all years studied, the degree of response to reduced nutrient loadings would also have been less marked.

Osoyoos Lake. At the Osoyoos Lake shallow stations, the highest chlorophyll-a values were produced at O-S1, the station just south from the mouth of the Okanagan River. This is not surprising because this station was under the most direct influence of nutrients being loaded to Osoyoos Lake from point and non-point sources south of Skaha Lake.

Since 1971 quite a change has been noted at both Osoyoos Lake stations in terms of chlorophyll-a production, with the greatest change having occurred at O-S1. At this station in 1971 the average seasonal chlorophyll-a and pheopigment production was 6.3 ug/cm^2 compared to 1977 and 1978 values of 0.46 and 1.59 ug/cm^2. At OS-2, which was located in the north east section of the central basin, the 1971 seasonal mean value was 1.9 ug/cm^2, whereas, in 1977 and 1978 it was 0.18 and 0.13 ug/cm^2, respectively. Both these changes were large enough especially in the case of O-S1, to indicate a decrease in periphyton production since 1971.

This response to reduced nutrient loadings in Osoyoos Lake is not as marked as in the case of Skaha Lake, and was very likely due to the effect of additional nutrient input downstream of Skaha Lake.

4.3.2.2 Periphyton Dry Weight. Dry weight is simply a measure of the weight of all material removed from the substrate and then dried. This material can be inorganic or organic and the two are not differentiated in this measurement. The source of this material can be biological production on the substrate or material that has sedimented onto the substrate, again this measure does not differentiate between the two. In the past, dry weights have been used as an estimation of biomass.

Ash-free dry weight (or volatile weight) is a measure of the weight of volatile material given off during the process of ashing the dried material. The ash free dry weight value is obtained by subtracting the weight of the ash from the dry weight. From these measurements, an estimation can be made of what fraction of the dry weight is organic (volatile) and what fraction is inorganic (non-volatile) ash.

These measurements when used in conjunction with the chlorophyll-a data can often provide a reliable estimate of standing crop biomass of algae, even though the dry weight may include material from animal or bacterial sources.

Stockner et al (1972) based their estimates of 1971 ash free dry weight on 50% of the dry weight values. This was not found to be the case in 1977. The 1977 laboratory determinations of ash free dry weight produced results which were substantially less than 50% of the dry weights (Table 26). Generally, ash free dry weight seasonal averages were between 15% and 27% of the dry weight values, which is agreement with values of Sladecek and Sladeckova (1964). Therefore it is felt that the above 50% estimation in 1971 might not be very meaningful or very comparable to the 1977 data; furthermore, the study comparing glass and plexiglass substrates (Appendix VI) concluded that only the dry weights from the two samplers were comparable.

Ash free dry weight rather than dry weight is a closer estimation of biological production at one station relative to another because it measures the weight of organic matter. For this reason, more emphasis was placed on ash-free dry weight fraction in the interpretation of the 1977

TABLE 26 PERCENT OF PERIPHYTON DRY WEIGHT COMPOSED BY ASH FREE DRY WEIGHT (1977)

Station	May 9	May 24	June 8	June 22	July 4	July 18	Aug. 1	Aug. 15	Aug. 29	Sept. 12	Sept. 26	Oct. 10	Oct. 24	Average
OK-S1	14	-	14	20	16	15	17	20	17	28	28	23	24	20
OK-S2	-	23	6	30	21	22	30	40	20	24	30	22	18	24
OK-S3	39	4	16	8	20	29	25	34	24	26	33	36	48	26
OK-S5	20	16	26	8	18	16	28	36	20	21	31	39	27	24
OK-S10	17	12	21	13	14	12	16	15	-	15	-	-	-	15
S-S1	20	(24) 14	-	39	16	28	13	(22) 14	-	(40) 15	(32) 15	(27) 17	-	(29) 20
S-S3	17	20	13	29	36	21	20	(30) 18	-	(33) 48	(42) 16	(27) 15	-	(33) 23
S-S2	20	18	17	20	13	11	11	(19) 13	-	(24) 25	(30) 12	(15) 31	-	(22) 17
O-S1	15	13	18	18	14	17	19	17	-	23	24	19	-	18
O-S2	25	21	20	23	18	43	49	23	-	24	29	25	-	27

( ) Glass Slide Sampler

and 1978 data. In this measurement the inorganic portion of algae such as diatom frustules is not included.

Okanagan Lake. On this lake in 1977 and 1978 the highest net daily periphyton ash free dry weight production rates (NPR) were noted at OK-S2 in the Vernon Arm, at OK-S1 in the North Arm, and at OK-S5 at Kelowna (Table 27). In order of decreasing magnitude OK-S3, and OK-S10 were of much lower values.

Seasonal fluctuations of ash free dry weight values throughout the season were much more extensive at OK-S1, OK-S2, and OK-S5 than at the two remaining stations (Figure 5). Less biological fluctuation at OK-S3 and OK-S10 is characteristic of a more stable nutrient flux in those areas which is usual in relatively unproductive waters. It can be seen that there was variation in values between 1977 and 1978, suggesting that these values are influenced by yearly runoff as well as by the biological productivity of the water.

Dry weight values appear to be subject to yearly variation much more so than either ash free dry weight or chlorophyll-a. This is to be expected considering that dry weight is more apt to be influenced by surface runoff conditions than the latter two parameters. This can be seen in the large increases in dry weight in 1978 compared to 1977 at OK-S2 and OK-S10 (Table 27). Such increases were not paralleled by ash free dry weight or chlorophyll-a values; therefore, they were more likely due to yearly hydrological fluctuations than to changes in production.

Sladeckova (1960) found that seston and mud settled on horizontally placed slides. This suggests that dry weight and ash free dry weight values from vertically placed plates would have been more closely correlated to biological production than were the values found in 1977 and 1978 or in 1971, because there would have been less influence exerted by seston settling on the plates.

TABLE 27 AVERAGE PERIPHYTON DAILY NET PRODUCTION RATES (NPR) - 1971/77/78

Station	Dry Weight ($mg/m^2/day$)	Dry Weight ($mg/m^2/day$)		Ash Free/ Dry Weight ($mg/m^2/day$)		Ash Free/ Dry Weight Rank	
	1971	1977	1978	1977	1978	1977	1978
OK-S1	321	645	736	107.8	153.5	3	2
OK-S2	1214	1085	1621	245.0	220.7	1	1
OK-S3	-	195	136	101.4	40.7	4	5
OK-S5	536	592	343	190.0	73.5	2	4
OK-S10	314	220	1243	51.0	77.1	5	3
S-S1	1000	1164	5057	217.1	480.0	1	1
S-S3	-	535	557	122.8	82.1	2	2
S-S2	207	475	329	84.2	45.7	3	3
O-S1	1000	1100	4936	271.4	508.5	1	1
O-S2	343	231	393	92.8	62.8	2	2

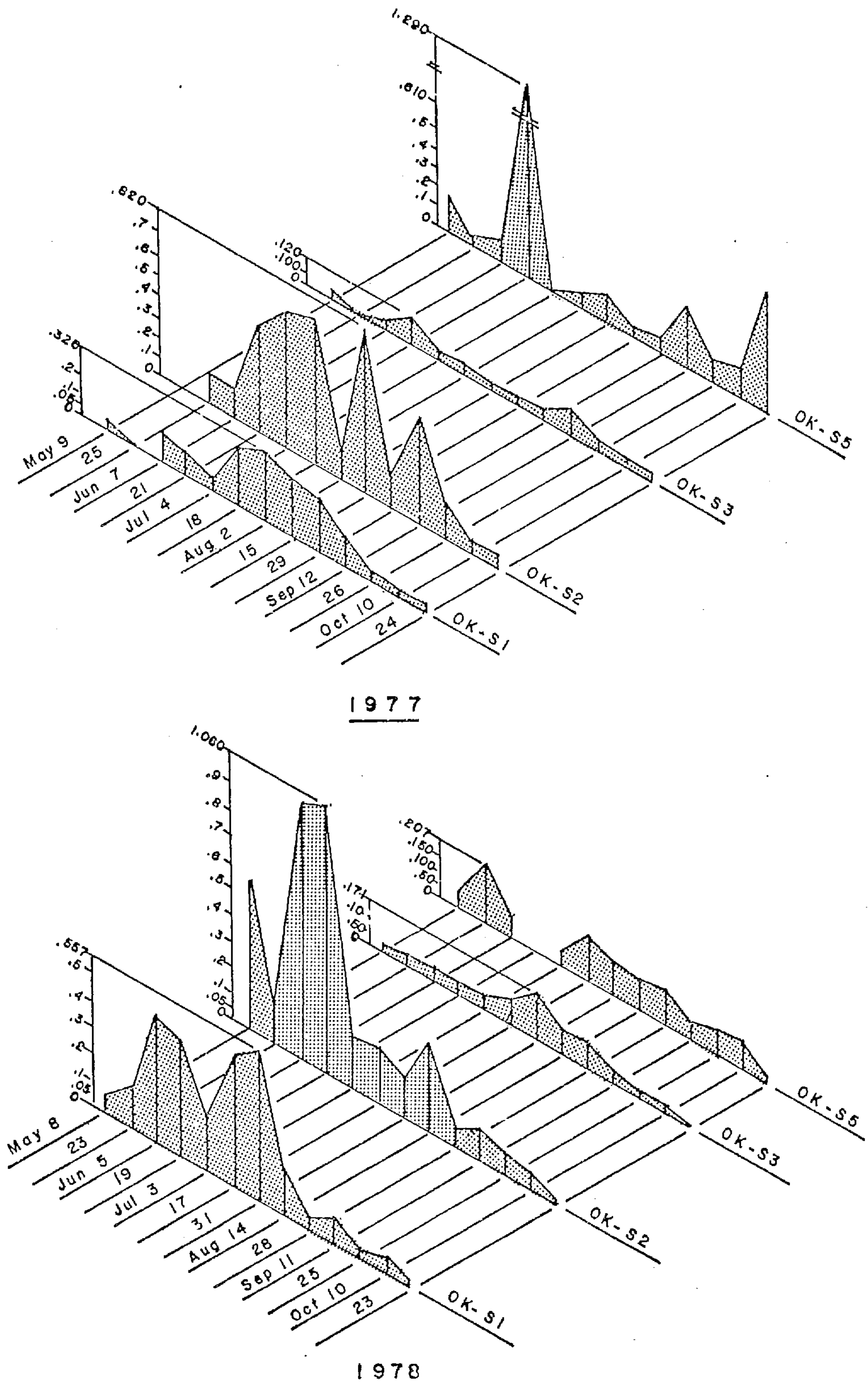


FIGURE 5 SEASONAL CHANGES OF PERIPHYTON ASH FREE DRY WEIGHT (mg/cm2) FOR LAKE OKANAGAN (NORTH TO CENTRAL), 1977 AND 1978

Skaha Lake. The highest ash free dry weight daily NPR's were found at S-S1 adjacent to the mouth of the Okanagan River (Table 27). As in the case of chlorophyll-a content of periphyton in Skaha Lake, the NPR values for S-S3 and S-S2 decrease as the distance from Penticton increases, with the lowest value being noted at the Okanagan Falls station S-S2 in both 1977 and 1978.

All stations in Skaha Lake exhibited a fair degree of fluctuation in ash free dry weight results throughout the seasons (Figure 6). As in the case of Okanagan Lake, the dry weight results, especially for S-S1 which was close to the Okanagan River, appeared to be quite subject to yearly fluctuations and therefore are not really comparable to the 1971 values.

Osoyoos Lake. Ash free dry weight daily NPR values were markedly higher at O-S1 than at O-S2. This is undoubtedly due to its proximity to the Okanagan River as a source of nutrients and settleable organic seston.

A greater fluctuation of values was noted at O-S1 during the 1977 and 1978 seasons than at O-S2 (Figure 6). In the case of O-S1, the results appeared to be strongly influenced by runoff. Dry weight values at O-S1 fluctuated widely between 1977 and 1978, again suggesting a poor basis for comparison with the 1971 data.

In terms of ash free dry weight, O-S1 is the most productive station of all the shallow stations with 1977 and 1978 NPR values of 271 and 508 mg/m^2/day. The next most productive station is S-S1 at Penticton with 1977 and 1978 values of 217 and 480 mg/m^2/day. Following in sequence were OK-S2 at Vernon with 1977 and 1978 values of 245 and 220 mg/m^2/day and OK-S1 with values of 108 and 154 mg/m^2/day.

4.3.2.3 Periphyton Identification and Biovolumes. Considerable difficulty existed in drawing a comparison between the 1971 periphyton

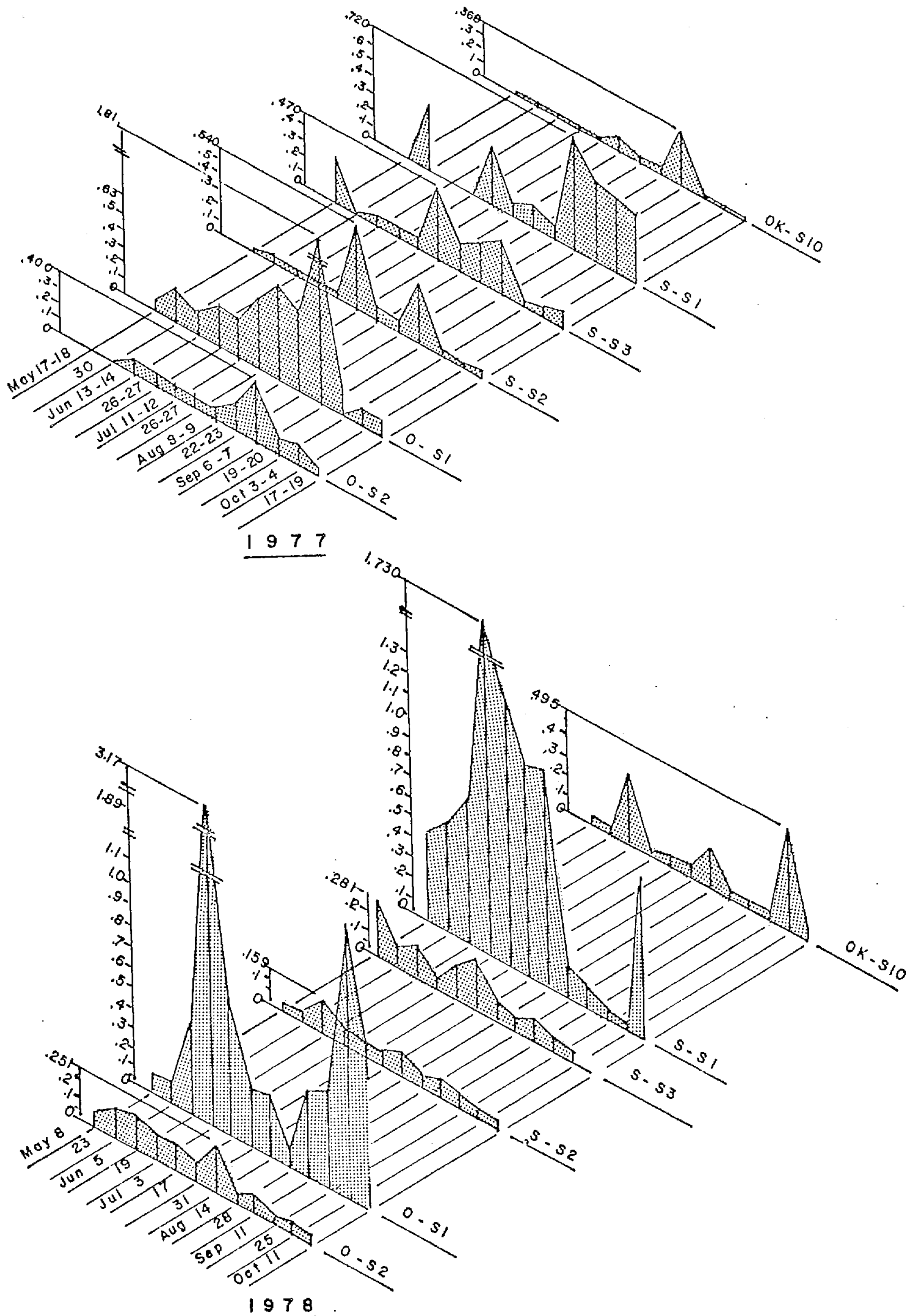


FIGURE 6 SEASONAL CHANGES OF PERIPHYTON ASH FREE DRY WEIGHT (mg/cm2) FOR LAKES OKANAGAN (SOUTH END), SKAHA AND OSOYOOS - 1977 AND 1978

identification data and that of 1977 and 1978 for two reasons. Firstly, as the comparison study in Appendix VI outlines, there is some variation in species which colonize glass slides compared to roughened plexiglass plates. Secondly, during the 1971 study dominant species numbers were estimated but not reported along with seasonal periodicity information. This was considerably different from the 1977 and 1978 data where dominant diatom biovolumes were accurately determined and non-diatom dominant taxa were estimated on a percent by volume basis. It was therefore concluded that a comparison of dominant algal species between the studies in 1971 and those of 1977 and 1978 would be of little value.

The 1977 and 1978 periphyton algal identification samples were dealt with in two ways (see Appendix VII for details of analysis). The diatom taxa were identified, counted, and biovolumes were calculated. The non-diatom taxa were also identified; however, absolute counts were not carried out. Instead percentages by volume relative to the total algal assemblage were estimated. From the non-diatom percentages and the actual diatom biovolumes, approximate biovolumes for non-diatoms were back calculated.

A detailed description of seasonal periodicity of dominant species will not be given because of the large number of stations. However, the data can be obtained from the Okanagan Basin Implementation Board. Table 28 shows the seasonal mean biovolumes and relative percentages by volume of the major phyla.

<u>Okanagan Lake</u>. During both 1977 and 1978, diatoms formed the majority of the algal assemblage by volume, varying from means of 73% to 100% of the total (Table 28). In 1977 green algae made up much higher mean percentages of the total (26, 12 and 18% at OK-S2, OK-S3 and OK-S5, respectively) than in 1978 (4, 0 and 6% at the same respective stations). Blue green algae were very poorly represented in 1977 and 1978, and except for OK-S2 (4% in 1978), S-S3 (about 8% both years), and S-S2 (9% in 1977), the algal species usually made up no more than 2% of the total.

TABLE 28 MEAN SEASONAL BIOVOLUMES (mm^3/cm^2) AND MEAN PERCENT COMPOSITION BY VOLUME OF MAJOR PERIPHYTON PHYLA - 1977/78

Station	Rank in Production	Major Taxa	Mean Seasonal Biovolume with dates of minima and maxima (mm^3/cm^2) 1977		1978		Mean Seasonal Percent by Volume 1977	1978
				(May 9 - Aug. 15)		(Sept. 25 - July 17)		
OK-S1	1	Total	1.56	(0.05 - 6.91)	0.40	(0.01 - 1.36)		
		Diatoms	1.51		0.38		96	95
		Greens	0.04		-		2	-
		Blue Greens	0.04		0.01		2	3
				(Oct. 10 - July 18)		(Aug. 28 - July 31)		
OK-S2	2	Total	1.72	(0.18 - 7.07)	0.26	(0.05 - 1.04)		
		Diatoms	1.25		0.24		73	92
		Greens	0.46		0.01		26	4
		Blue Greens	0.01		0.01		<1	4
				(Oct. 24 - July 4)		(Oct. 23 - July 31)		
OK-S3	4	Total	0.16	(0.01 - 0.57)	0.05	(0.01 - 0.16)		
		Diatoms	0.14		0.05		88	100
		Greens	0.02		<0.01		12	-
		Blue Greens	-		<0.01		-	-
				(June 21 - Aug. 29)		(July 3 - May 23)		
OK-S5	3	Total	0.56	(0.13 - 1.15)	0.16	(0.03 - 0.46)		
		Diatoms	0.46		0.15		82	94
		Greens	0.11		0.01		18	6
		Blue Greens	0.01		<0.01		<1	<1
				(Oct. 19 - May 18)		(Sept. 7 - May 16)		
OK-S10	5	Total	0.09	(0.01 - 0.28)	0.03	(0.01 - 0.11)		
		Diatoms	0.09		0.03		99+	100
		Greens	<0.01		<0.01		<1	-
		Blue Greens	<0.01		<0.01		<1	-
				(Aug. 22 - July 11)		(Sept. 7 - July 11)		
S-S1	1	Total	0.97	(0.12 - 5.71)	0.35	(0.06 - 1.05)		
		Diatoms	0.93		0.34		96	97
		Greens	0.03		0.01		3	3
		Blue Greens	0.01		<0.01		1	<1
				(Sept. 20 - July 27)		(June 27 - Sept. 7)		
S-S3	3	Total	0.26	(0.02 - 0.97)	0.13	(0.003 - 0.49)		
		Diatoms	0.22		0.12		85	92
		Greens	0.02		<0.01		7	-
		Blue Greens	0.02		0.01		7	8
				(Oct. 19 - May 30)		(Oct. 3 - July 25)		
S-S2	2	Total	0.33	(0.01 - 1.55)	0.10	(0.02 - 0.23)		
		Diatoms	0.29		0.10		88	100
		Greens	0.01		<0.01		3	-
		Blue Greens	0.03		<0.01		9	-
				(June 14 - Aug. 22)		(May 29 - Oct. 2)		
O-S1	1	Total	0.47	(0.10 - 1.50)	0.60	(0.01 - 2.63		
		Diatoms	0.40		0.58		85	96
		Greens	0.06		0.01		13	2
		Blue Greens	<0.01		0.01		<2	2
				(Oct. 3 - June 14)		(Sept. 18 - Oct. 16)		
O-S2	2	Total	0.14	(0.06 - 0.30)	0.19	(0.002 - 0.97)		
		Diatoms	0.12		0.19		86	100
		Greens	0.02		-		14	-
		Blue Greens	<0.01		-		<1	-

As expected, algal biovolumes were highest at the stations closest to areas of nutrient loading such as OK-S1, OK-S2 and OK-S5 (in order of decreasing magnitude). There were drops in total mean bivolumes between 1977 and 1978 which were generally in the order of 67% to 75% of total volumes except for OK-S2 which declined by 85%. The only factor likely to contribute to a reduction at every station was weather. This was considered surprising because a general increase was noted in the case of deep and shallow station phytoplankton since 1977. It seemed probable that the cause of the largest decline in periphyton production which occurred at OK-S2, was in part due to the diversion of Vernon sewage from the lake system.

Seasonal mean total biovolumes varied on Okanagan Lake from a low of 0.03 mm^3/cm^2 in 1978 at OK-S10 to a high of 1.72 mm^3/cm^2 in 1977 at OK-S2. The 1977 and 1978 diatom biovolumes are comparable to those found by Ennis (1972) on Kootenay Lake. He found mean seasonal values of over 0.2 mm^3/cm^2 to be characteristic of eutrophic areas of the lake and under 0.2 mm^3/cm^2 characteristic of oligotrophic to mesotrophic areas. Based on the 1977 and 1978 data and Ennis' classification, Okanagan Lake biovolumes indicated states of eutrophy for OK-S1, OK-S2 and OK-S5, and oligotrophy for OK-S3 and OK-S10.

Maximum production at most of these stations occurred during the July to August period, except for OK-S10 which exhibited a small peak in mid-May.

<u>Skaha Lake</u>. As in the case of Okanagan Lake, diatoms constituted the major portion of the periphytic assemblage in Skaha Lake at all the stations, averaging over 85% of the total volume (Table 28).

Green algae formed 3% of the volume at S-S1 in both 1977 and 1978, whereas, the composition at S-S3 and S-S2 changed from 7 and 3% in 1977 to 0% in 1978.

Blue green algae constituted 1% or less at S-S1 in both years but were present in relatively greater proportions at the other two stations. At S-S3, Blue green algae averaged 7-8% of the total in both years, whereas, they averaged 9% at S-S2 in 1977 and 0% in 1978.

S-S1 was the most productive station in terms of total biovolume on Skaha Lake, followed by S-S2 and S-S3 which had similar productivity. This was expected considering the proximity of S-S1 to nutrient loading from the Okanagan River. This influence of the river on S-S1 is shown by the low production at the control station OK-S10, north of the Okanagan River. Seasonal mean biovolumes ranged from a low of 0.10 mm^3/cm^2 at S-S2 in 1978 to a high value of 0.97 mm^3/cm^2 at S-S1 in 1977. Skaha Lake's mean biovolumes are indicative of eutrophy for S-S1 and mesotrophy for S-S3 and S-S2.

Skaha Lake periphyton production had the same trend as Okanagan Lake in that overall production was lower for all stations in 1978 than in 1977.

Osoyoos Lake. At both stations, diatoms made up an average of 85% of the total volume in 1977, and 96% to 100% at all stations in 1978.

Green algae in 1977 comprised an average of 13% and 14% of the O-S1 and O-S2 volumes, but in 1978 these stations had averages of only 2% and 0%.

Blue green algae were present in very low volumes in both years, being no more than 2% of the volume at both stations.

The O-S1 station was the most productive of the two stations with mean 1977 and 1978 biovolumes of 0.47 and 0.60 mm^3/cm^2. Station O-S2 had values of 0.14 and 0.19 mm^3/cm^2 in 1977 and 1978. The values of these biovolumes indicated states of eutrophy for O-S1 and mesotrophy for O-S2.

Of the ten shallow stations sampled in the whole study area, the two Osoyoos stations (OS-1 and OS-2) were the only ones where periphyton production increased in 1978 as compared to 1977.

4.3.3 Zooplankton. Zooplankton (secondary producers) are the animal component of the fresh water plankton. The net zooplankton sampled in this study were evaluated both qualitatively and quantitatively. In all three years 1976, 1977 and 1978, settled volumes were determined in order to ascertain the existing standing crop biomass. In addition, the organisms were identified and counted in 1977 and 1978 to determine species composition.

Patalas and Salki (1973) collected zooplankton data on all three lakes in the study area in early September 1969 and again in late August 1971. Although their sampling program was of high intensity, it monitored the same approximate short period of time each year. Consequently, knowledge concerning seasonal periodicity and abundance were not derived, and the data base was very limited in terms of its comparability to the 1976, 1977 and 1978 data.

4.3.3.1 Zooplankton Identification and Enumeration:

Okanagan Lake. Of the three stations sampled in 1977 and 1978, OK-1 yielded the highest standing crop of zooplankton with seasonal mean values of 116 and 219 individuals/cm^2. The values were higher than the 97 and 179 individuals/cm^2 for OK-2, and 96 and 148 individuals/cm^2 for OK-3. The 1978 means included the August values, but whether the August values were included or not, the 1978 secondary production was higher than in 1977. This was in agreement with the trend in deep water primary production.

At all of these stations, Copepoda comprised 85-90% of the total zooplankton standing crop throughout the 1977 and 1978 seasons (Figure 7). Cladocera were virtually absent at the April sampling, probably due to their preference for warm temperatures (Wetzel 1975), but like the Copepoda they were present in maximum numbers during the July-August period. These maxima were 7-9% of the total at OK-1, 13% of the total at OK-2, and 3-7% of the total at OK-3. Rotifera were even more poorly represented than Cladocera, except for April 1977 at OK-1 where they comprised 12% of the population.

The dominant Copepoda were Diaptomus ashlandi (a small form) and Cyclops bicuspidatus (a large form). There were also high numbers of the nauplius stage of unidentified genera of Copepoda.

The dominant Cladocera at OK-1 and OK-2 in 1977 and 1978 were Bosmina corregoni, a small form, and the large Daphnia longiremus. In 1977, the large Daphnia thorata was dominant as well - but was not found at all in 1978. In 1977 and 1978, Bosmina corregoni and the large Sida crystallina were dominants at OK-3.

Wetzel (1975) and Brooks (1969) suggest that relative abundance of large zooplankton, such as Cladocera, compared to smaller forms such as Copepoda is often significantly affected by fish predation. Therefore, it is quite possible that these low numbers of Cladocera in Okanagan Lake are due to fish predation, because planktivorous fish such as Kokanee (Onchorhynchus nerka) which are found in these lakes (Northcote et al, 1971) prefer large bodied zooplankters over small ones. Perhaps this is a factor which has affected the disappearance of Daphnia thorata since 1977. Invertebrate predators such as Leptodora kindtii and Epischura nevadensis were also present but in very low numbers, and therefore were probably a smaller controlling factor than fish.

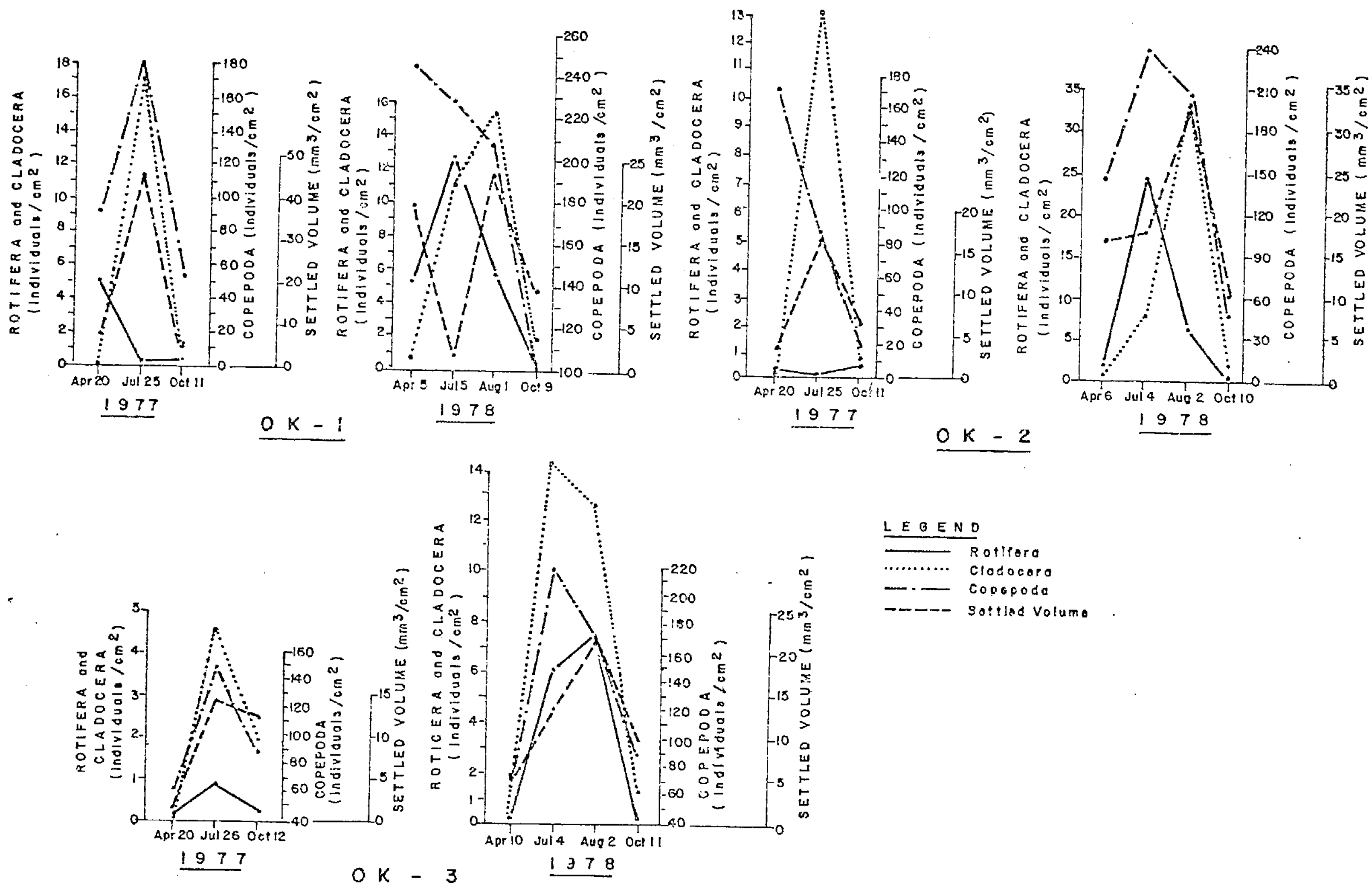


FIGURE 7 SEASONAL ZOOPLANKTON ABUNDANCE AND SETTLED VOLUME TRENDS FOR OKANAGAN LAKE (OK-1; OK-2; OK-3) IN 1977 AND 1978

Since 1971 when the respective totals for Crustacea were 117, 129 and 122 individuals/cm^2, there has been an apparent increase in numbers of zooplankton at all stations (Table 29). The increase has been in both Copepods and Cladocera and was especially marked for the Cladocera which in 1971 were less than 7.0 individuals/cm^2 at all stations. The same Copepods were dominant in 1971 as in 1977 and 1978, even though there was some change in dominancy of Cladocera species.

Skaha Lake. Total standing crop of zooplankton in Skaha Lake averaged 147 and 219 individuals/cm^2 for the 1977 and 1978 sampling seasons. Peak production of total zooplankton was found in May 1977 with 231 individuals/cm^2 and in May 1978 with 479 individuals/cm^2. As in the case of Okanagan Lake, production was higher in 1978 than in 1977. In order to compare Skaha Lake to Okanagan Lake, mean values for only April, July and October 1977 and 1978 were calculated to be 134 and 209 individuals/cm^2. These were greater net productions than at any of the Okanagan Lake stations.

Copepoda, as in the case of Okanagan Lake, comprised the majority of the zooplankton, ranging from 60 to 95% of the total number. The Copepoda reached maximum numbers in June through October, and in April/May were displaced slightly by Rotifera which were 23-40% of the total (Figure 8). Rotifera, though present throughout the season, dropped in numbers to 4-9% of the total during June to October. Cladocera were not found in April or May and generally made up 1 to 6% of the total during the rest of the season except for July, when maximum numbers were reached (10 and 19% in 1977 and 1978). These Cladocera were probably cropped by predators in subsequent months. As in the case of Okanagan Lake Cladocera dropped in number between the summers of 1977 (19% of total) and 1978 (10% of total).

Highest total zooplankton numbers were recorded in April and May of 1977 and May and July of 1978. Rotifers were greatly dominated by *Felina longiseta*, with *Keratella cochlearis* and *Kellicotia longispina* being

TABLE 29 A COMPARISON OF CRUSTACEAN ZOOPLANKTON ABUNDANCE (INDIVIDUALS/ cm^2) BETWEEN 1969/71 AND 1977/78

Station	Order	September			August		
		1969*	1977	1978	1971*	1977	1978
OK-1	Total Cladocera	-	-	-	2.7	-	15.3
	Total Copepoda	-	-	-	113.9	-	206.4
	Total Crustacea	-	-	-	116.6	-	221.7
OK-2	Total Cladocera	-	-	-	6.9	-	33.7
	Total Copepoda	-	-	-	121.9	-	209.9
	Total Crustacea	-	-	-	128.8	-	243.6
OK-3	Total Cladocera	-	-	-	3.9	-	12.5
	Total Copepoda	-	-	-	118.2	-	173.0
	Total Crustacea	-	-	-	122.1	-	185.5
S-1	Total Cladocera	7.3	7.5	5.4	12.1	3.5	11.0
	Total Copepoda	245.4	117.6	162.7	232.6	114.4	189.0
	Total Crustacea	252.7	125.1	168.1	244.7	117.9	200.0
O-1	Total Cladocera	10.8	10.8	10.8	9.8	21.8	21.8
	Total Copepoda	172.6	94.9	94.9	84.0	78.3	78.3
	Total Crustacea	183.4	105.7	105.7	93.8	100.1	100.1

* From Patalas and Salki (1973).

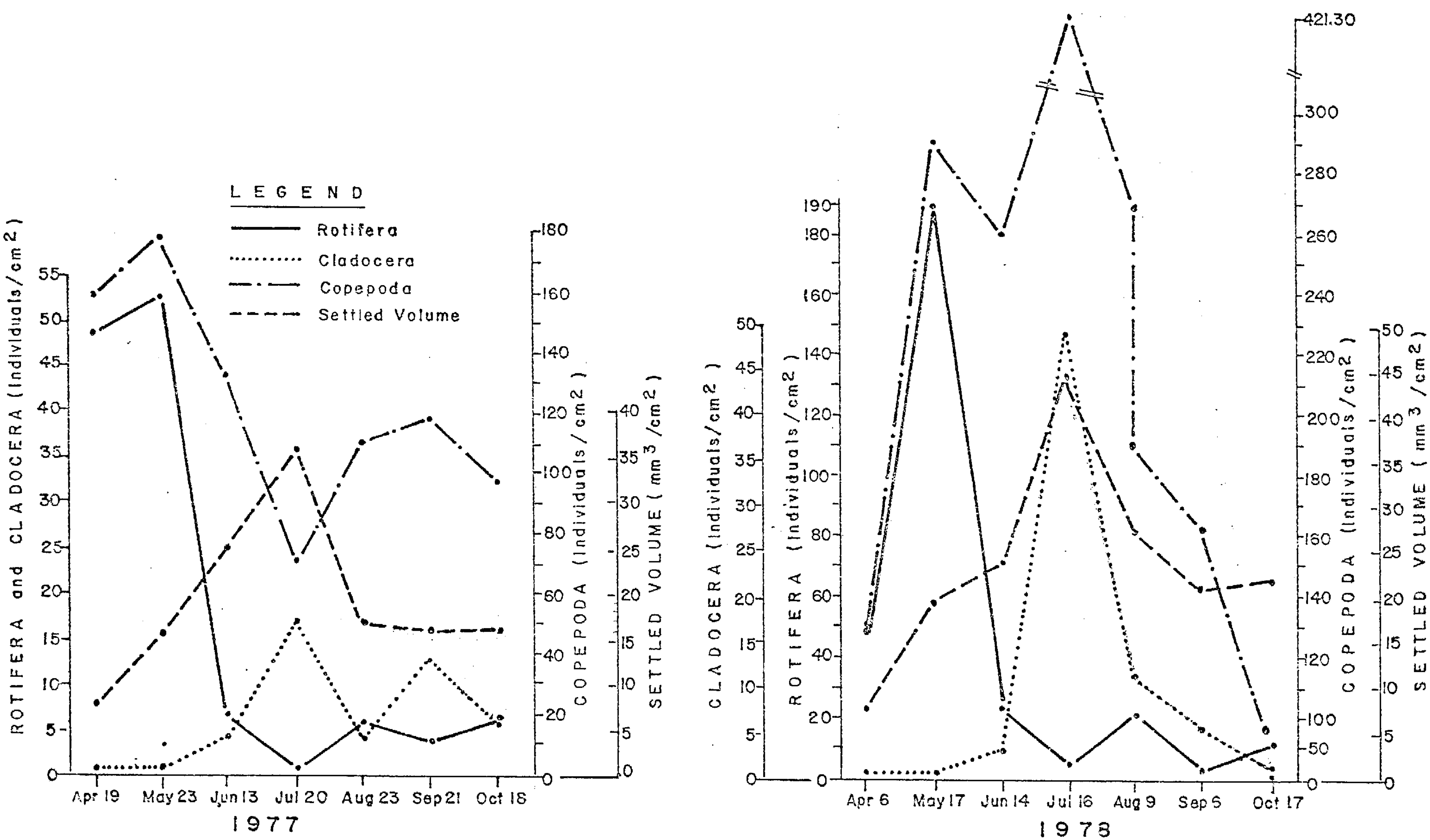


FIGURE 8 SEASONAL ZOOPLANKTON ABUNDANCE AND SETTLED VOLUME TRENDS FOR SKAHA LAKE (S-1), 1977 AND 1978

present. Dominant Cladocera were Daphnia thorata in 1977 and Daphnia longiremus in 1978. The dominant Copepoda again were Diaptomus ashlandi and Cyclops bicuspidatus, as well as two species of nauplius larvae. Epischura nevadensis increased in numbers after July to levels of about 1.4 individuals/cm^2 in 1977 and 0.5 individuals/cm^2 in 1978, probably as a result of predation on Cladocera. Lower numbers of E. nevadensis in 1978 possibly could have been correlated with the conspicuous absence of Daphnia thorata, which presumably would have been an item in their diet.

Of particular interest is the fact that the Malacostracan Mysis relicta was found in significant numbers in Skaha Lake from June to October in 1978, and to a lesser degree in 1977. This organism reached Skaha Lake following its introduction into Okanagan Lake in approximately 1965 by the B.C. Fish and Wildlife Branch. It has obviously become established in Skaha Lake, but was not found in Okanagan Lake during the 1977 and 1978 sampling seasons. The B.C. Fish and Wildlife Branch did, however, net large numbers of these organisms at night in 1974 (personnel communication, Chris Bull). Therefore, it is likely that these Mysids were not found in Okanagan Lake in 1977 and 1978 because of their preference for the deeper and darker strata beyond the range of predetermined sampling depth of 50 metres.

Since 1971, there appears to have been a decrease in total crustacean zooplankters, due largely to a decrease in Copepoda. Cladocera have maintained approximately the same abundance (Table 29). The list of dominants for 1977 and 1978 was basically the same as that for 1969 and 1971 except that Daphnia thorata was not found in 1969 or 1971, as it was found in 1977. As well, Diaphanosoma leuchtenbergianum was a major Cladocera in 1969 and 1971, but was not found in 1977 and 1978.

Osoyoos Lake. Total standing crop of zooplankton in Osoyoos Lake averaged 138 and 237 individuals/cm^2 for 1977 and 1978. Peak total production occurred in October 1977 with 189 individuals/cm^2 and in June 1978 with 472 individuals/cm^2. Like the two previous lakes, production was higher in 1978 than in 1977. In 1977 and 1978 overall secondary production in Osoyoos Lake was slightly less than in Skaha Lake. The lakes then, could be ranked in the following order in terms of secondary productivity:

1. Okanagan Lake	least productive
South	
Central	
North	
2. Osoyoos Lake	
3. Skaha Lake	most productive

Copepoda in this lake were the most abundant order ranging from 50 to 96% of the total. Both Cladocera and Rotifera were more prominent than in the other lakes, significantly decreasing the dominancy of copepods at certain times (Figure 9).

Peak months for Rotifera were May and August to September when relative abundance climbed to as much as 27% of the total (23 Rotifera/cm^2 in September 1978). Cladocera were found in maximum abundance in June through to August reaching up to 24% of the total (38 Cladocera/cm^2 in June 1977).

Dominant Rotifera were _Felina longiseta_ for all of the 1977 season except for August when _Trichocerca_ sp. became dominant. The latter species was dominant during May and June of 1978 as well. _Kellicotia longispina_ was the main dominant in May 1978 and persisted as such all season. The dominant Cladocera were _Daphnia longiremus_ throughout both seasons as well as _Bosmina corregoni_ in June 1977, _Sida crystallina_ in August 1977 as well as July and September of 1978. The dominant Copepods were again _Diaptomus ashlandi_ and _Cyclops bicuspidatus_ with high numbers of unidentified nauplius larvae.

In comparison with 1969 and 1971 data, the 1977 and 1978 data showed a decreased production in September (Table 29) but a very similar production in August. The September decrease is due to a drop in Copepoda

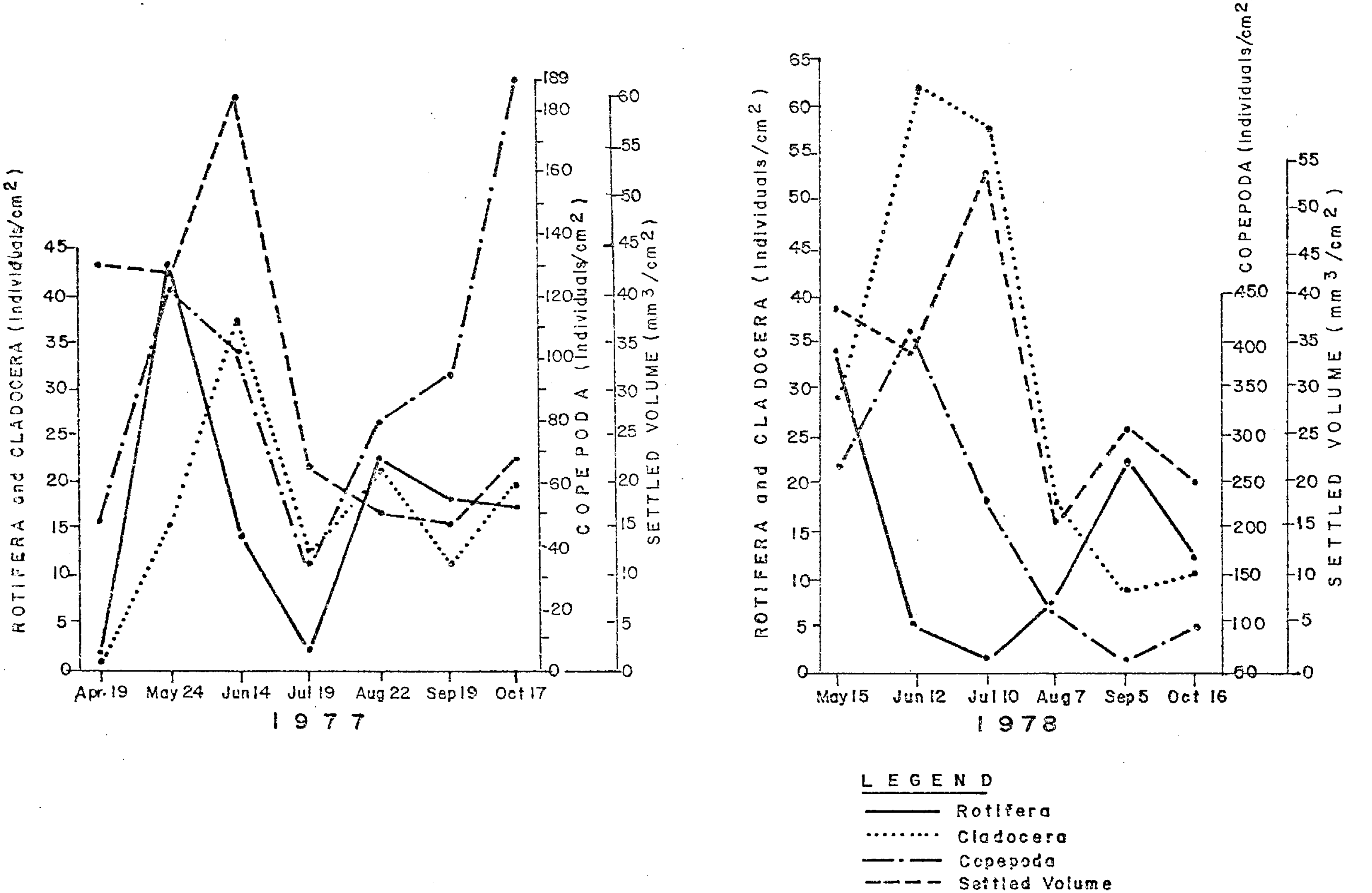


FIGURE 9 SEASONAL ZOOPLANKTON ABUNDANCE AND SETTLED VOLUME TRENDS FOR OSOYOOS LAKE (O-I), 1977 AND 1978

numbers. The August data showed a 1977 and 1978 increase in Cladocera since 1971, but a decrease in Copepoda. From these differences in data it is not possible to conclude that there has been an overall change in secondary production since 1969 and 1971.

4.3.3.2 Zooplankton Settled Volumes. Settled volume determination is a simple technique which measures the sedimented volume of zooplankton and is a good estimate of the standing crop of zooplankton. Like identification and enumeration it is only a measure of net secondary production, and does not take into acount factors such as predation or maintenance losses through respiration or excretion.

In September of 1969 and August of 1971, Patalas and Salki (1973) collected zooplankton settled volume data as well as identification and enumeration data. Again, these data were from approximately the same season in both years, and therefore were very limited in their ability to indicate true values because of the seasonal variation of zooplankton populations. The 1969 and 1971 data and the 1976 and 1977 data are given in Table 30.

Okanagan Lake. Zooplankton volume varied considerably throughout the 1976, 1977 and 1978 sampling seasons (Figure 7). Of course as the 1977 and 1978 data were collected only three and four times respectively in those years it imposed a limitation on the indication of seasonal trends. In 1976 the maxima of 19.9 and 21.1 mm^3/cm^2 for OK-1 and OK-2 occurred in mid August and 18.3 mm^3/cm^2 for OK-3 in late October. The values at all three stations were within the range of 10.4 mm^3/cm^2 all season. In 1977, maxima of 45.58, 16.78, and 14.87 mm^3/cm^2 for OK-1, OK-2 and OK-3 respectively all occurred during the late July sampling (Figure 7). In 1978, maxima of 23.83, 33.2, and 21.28 mm^3/cm^2 were all recorded in August for OK-1, OK-2 and OK-3 (Figure 7). As Table 30 shows, the seasonal averages vary between the three years as do the seasonal maxima. This could have been due either to different sampling periodicity or natural population fluctuations from one year to another. The 1976 seasonal averages for all three stations were

TABLE 30 ZOOPLANKTON SETTLED VOLUMES (mm^3/cm^2) FOR AUGUST & SEPTEMBER 1969/71/76/77/78 AND SEASONAL MEAN VALUES 1976/77/78

Station	August				September				Average June to October			Average April to October	Average April to October
	1971*	1976	1977	1978	1969*	1976	1977	1978	1976	1977	1978	1977	1978
OK-1	(11.5)	19.9	-	23.83	21.0	18.3	-	-	14.5	-	-	19.3**	15.3 (12.4)**
OK-2	(11.5)	21.1	-	33.20	8.9	20.5	-	-	14.1	-	-	10.6**	19.6 (15.0)**
OK-3	-	13.4	-	21.28	17.0	13.9	-	-	14.8	-	-	10.6**	12.1 (9.0)**
S-1	24.1	13.7	16.9	16.7	23.2	9.7	16.1	25.46	33.7	22.1	30.09	19.0	23.6
0-1	10.9	18.6	16.8	27.01	25.9	6.1	15.5	20.98	23.8	27.4	27.66	31.9	31.5

* From Patalas and Salki (1973).
** Average does not include August sample.
( ) Mean value for transect.

very close, all between 14.1 and 14.8 mm^3/cm^2. The 1977 values were lower for OK-2 and OK-3 (10.6 mm^3/cm^2) but higher for OK-1 (19.3 mm^3/cm^2), possibly because fewer data were collected that year. The 1978 seasonal means were relatively close to those of 1977 if the August sampling was left out of the calculation. From these results it appeared that OK-3 is slightly lower in production than the other two stations. It is not possible to determine on the basis of these data whether OK-1 or OK-2 was more productive.

In comparing the August 1976 and 1978 values with 1971 values, and September 1976 values with those of 1969, the following observations were made. An increase in production has apparently occurred at OK-2 since 1969 and 1971. There may also have been an increase in zooplankton biomass produced at OK-1 and OK-3, but the data supporting this are much less conclusive. These suggested increases agree with increases indicated by the identification and enumeration data. An increase in biovolume since 1969 and 1971 at all three stations is not surprising since there has been some increase in Cladocera numbers.

Since zooplankton populations are reduced by fish predation as well as other factors, it is necessary to be cautious in making conclusions concerning trophic status from these data. In the case of Okanagan Lake, there has been a considerable decrease in the number of shore spawning Kokanee over the years, with a low total of 50,000 having been found for 1978 compared to a 1971 total of 987,858 (unpublished data, B.C. Fish and Wildlife Branch 1979). Such a considerable drop in Kokanee spawning and, presumably the population, would result in a considerable reduction in planktivory (especially of Cladocera) in Okanagan Lake and therefore could have been, in part, the cause of increased zooplankton biomass.

Skaha Lake. As for Okanagan Lake, zooplankton volume varied considerably throughout each season (Figure 8). Maximum values were 77.1 mm^3/cm^2 in June 1976, 36.4 mm^3/cm^2 in July 1977, and 44.8 mm^3/cm^2 in July of 1978. As Table 30 shows the April to October mean values for 1977 and 1978 (19.0 and 23.6 mm^3/cm^2) are quite close. There appears to be a general trend of higher settled volumes in Skaha Lake than Okanagan Lake.

This is not surprising in view of the higher biomass of primary producers found in Skaha Lake. Except for the September 1978 value which was close to the September 1969 value, all other 1976, 1977 and 1978 values were markedly lower than in 1969 and 1971. On the basis of this it appears that there has been a reduction in zooplankton volume in Skaha Lake since 1969 and 1971.

Osoyoos Lake. Settled volume trends for 1977 and 1978 are found in Figure 9. Maximum values were 47.1 mm^3/cm^2 in June 1976, 61.1 mm^3/cm^2 in June 1977 and 53.7 mm^3/cm^2 in early July 1978. Osoyoos Lake settled volumes were on the average considerably higher than in both lakes Okanagan and Skaha (Table 30). The 1977 and 1978 mean seasonal values were almost identical and a comparison of 1977 and 1978 June to October values with that of 1976, again showed little variation. The settled volume data, therefore, agree well with the identification and enumeration data in the indication of relative secondary production of the three lakes. In comparing 1976, 1977, and 1978 data with 1969 and 1971 data, no trend can be identified, as the September data indicated a decrease since 1969 and 1971 and August data indicated an increase.

It can generally be said, in comparing the three lakes using the 1976, 1977, and 1978 data, that the lowest net secondary production was found on Okanagan Lake. Skaha Lake was more productive than Okanagan Lake and Osoyoos more productive than Skaha Lake. Since 1969 and 1971 there has been an apparent increase in zooplankton production in Okanagan Lake, a decrease in production in Skaha Lake, and no change has been obvious for Osoyoos Lake.

4.3.4 Okanagan River Benthic Macroinvertebrates. Benthic macroinvertebrates tend to fluctuate seasonally, with numbers declining in late spring due to emergence, but increasing again in the late summer (Hynes 1970). In addition, abundance and distribution of these organisms is affected by a number of factors including temperature, current velocity, substrate, amount of detritus, salinity, acidity, and hardness.

At the Okanagan River stations there was a seasonal variation in abundance as well as a variation in abundance between stations. The substrate was the same at both stations, consisting of gravel and small boulders.

As Table 31 shows, the seasonal trend at these stations tended to comply with that described above by Hynes (1970). However, spatially, the numbers are sometimes greater at one station and, at other times, greater at the other station. Generally, OK-R-1 showed markedly higher numbers than OK-R-2 which was located downstream of the Penticton sewage discharge and the Shingle Creek discharge.

Indices of diversity and evenness for the genera were calculated using the Shannon formula (Hamilton, 1975) and are presented in Table 31. From this it can be seen that generally both stations yielded a fairly good diversity of organisms. OK-R-1 yielded an assemblage of organisms less evenly distributed than OK-R-2. This is largely due to two low values for June and September 1977 at OK-R-1.

The assemblage of organisms and percentage composition are presented in Table 31. The organisms forming 10% or more of the total assemblage are considered dominants. At OK-R-1, the dominants in May were *Hydra* sp., *Nais variabilis* and *Diaptomus ashlandi*. In June the only dominant was the Oligochaete worm *Nais variabilis* which made up 85% of the sample and was undoubtedly the cause of the high density, low diversity and evenness values at that time. In July the oligochaetes dropped in number leaving only *Hydra* sp. and *Episcura nevadensis*, a predaceous Copepod, as the dominants. In September *E. nevadensis* was the only dominant, comprising 85% of the assemblage, again contributing to a low evenness score. In September the dominants again were *Hydra* sp. which comprised 76% of the assemblage, and *E. nevadensis*, along with a new member - the mite (Acarina) *Hermannia* sp.

TABLE 31 NUMBERS, DIVERSITY, AND EVENNESS OF BENTHIC MACROINVERTEBRATES IN THE OKANAGAN RIVER - 1977 [NUMBER OF ORGANISMS/FT^2 (0.093 m^2)]

Date	OK-R-1 (North Station)			OK-R-2 (South Station)		
	Number	Diversity	Evenness	Number	Diversity	Evenness
May 26	33.0	3.195	0.799	106.0	3.242	0.717
June 22	800.0	0.885	0.208	274.0	2.761	0.552
July 29	539.0	2.427	0.500	64.0	3.801	0.791
September 2	96.0	6.350	0.191	199.0	2.003	0.437
September 27	253.0	2.130	0.485	147.0	2.893	0.669
Average	344.2	2.997	0.433	158.0	2.940	0.633

The periodicity of dominants was generally different at OK-R-2 than that described above, even though some of the dominants were the same genera. In May the four dominants were *Cataclysta* sp., Chironomidae, *Orthocladius* sp., and *Eukiefferiella* sp. In June *Orthocladius* sp. continued as a strong dominant with *Nais variabilis* and *Episcura nevadensis*. Again in July, *Orthocladius* sp. was dominant along with *Nais variabilis*. A shift occurred in September when *Episcura nevadensis* and *Cataclysta sp*. again resumed dominancy. In September the largest number of dominants were found, and were *Hydra* sp., *Episcura nevadensis*, *Cataclysta sp*., *Cheumatopsyche* sp. and *Hermannia* sp. A full list of all organisms found at these stations is presented in Appendix VIII.

In summary, a fairly diverse assemblage of organisms existed at both stations which, in the case of OK-R-1 is not very evenly distributed, especially during June and September. Both stations support intolerant and facultative organisms (Table 32) especially OK-R-2 and exhibited a healthy degree of secondary production. Intolerant and facultative organisms were more strongly represented among the dominants at OK-R-2 than at OK-R-1. All these results indicate that the Okanagan River has not been affected adversely by the Penticton Sewage discharge or by the Shingle Creek discharge.

TABLE 32 SEASONAL PERIODICITY OF DOMINANT MACROINVERTEBRATES IN THE OKANAGAN RIVER (1977) IN NUMBER/FT2 (.093 m^2) AS WELL AS PERCENT COMPOSITION OF TOTAL ASSEMBLAGE

		May 26		June 22		July 29		September 2		September 27	
		#	%	#	%	#	%	#	%	#	%
	OK-R-1 Dominant Taxa										
U	Hydra sp	9.27	28.1	-	-	86.24	16.0	-	-	191.27	75.6
T	Nais variabilis	4.00	10.9	680.00	85.0	-	-	-	-	-	-
U	Diaptomus ashlandi	4.98	15.1	-	-	-	-	-	-	-	-
U	Episcura nevadensis	-	-	-	-	243.63	45.2	81.6	85.1	45.03	17.8
U	Hermannia sp	-	-	-	-	-	-	-	-	47.56	18.8
	OK-R-2 Dominant Taxa										
	Hydra sp	-	-	-	-	-	-	-	-	27.64	18.8
T	Nais variabilis	-	-	32.88	12.0	11.52	18.0	-	-	-	-
U	Episcura nevadensis	-	-	62.47	22.8	-	-	122.78	61.7	22.19	15.1
U	Cataclysta sp	12.51	11.8	-	-	-	-	24.28	12.2	29.11	19.8
I	Cheumatopsyche sp	-	-	-	-	-	-	-	-	27.34	18.6
F	Chironomidae	11.55	10.9	-	-	-	-	-	-	-	-
F/I	Orthocladius sp	30.21	28.5	103.84	37.9	13.95	21.8	-	-	-	-
T	Eukiefferiella sp	11.98	11.3	-	-	-	-	-	-	-	-
	Hermannia sp	-	-	-	-	-	-	-	-	22.05	15.0

U Unclassified
T Tolerant to Organic Pollution
F Facultative to Organic Pollution
I Intolerant to Organic Pollution [after Servizi and Burkhalter (1970) and Resh and Unzicker (1975)].

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APPENDIX I

PRECIPITATION RECORDS FOR THE OKANAGAN VALLEY

1971, 1976, 1977

APPENDIX I PRECIPITATION RECORDS (inches) FOR THE OKANAGAN VALLEY
1971, 1976, 1977
(provided by the Atmospheric Environment Service, Victoria, B.C.)

	Year	Average	April	May	June	July	Aug.	Sept.	Oct.
Vernon (Coldstream Ranch)									
	1971	1.40	0.57	2.47	2.41	1.12	1.02	0.38	1.88
	1976	2.04	0.99	2.20	3.00	1.77	4.79	0.44	1.10
	1977	1.08	0.22	1.57	0.75	1.34	1.62	1.28	0.78
Vernon (Upper Air Station)									
	1971	------------(Station opened in October)----------							1.12
	1976	1.77	1.07	2.10	2.07	1.28	4.40	0.27	1.21
	1977	0.78	0.26	1.15	0.69	1.63	0.59	0.83	0.37
Oyama									
	1971	1.40	0.54	1.71	2.52	1.30	1.71	0.87	1.20
	1976	1.8	0.79	2.20	1.60	1.20	5.36	0.42	1.03
	1977	0.97	0.54	1.76	0.38	0.96	1.30	1.17	0.68
Okanagan Centre									
	1971	1.27	0.49	1.54	2.51	1.10	0.92	1.31	1.03
	1976	1.34	0.75	0.96	0.98	1.27	4.36	0.30	0.79
	1977	0.80	0.45*	1.01*	0.56	1.11	1.22	0.93	0.34
Winfield									
	1971	1.21	0.51	1.69	2.19	1.05	0.94	1.13	0.98
	1976	1.49	0.77	1.28	1.27	1.11	4.93	0.22	0.87
	1977	0.90	0.36	1.61	0.44	0.95	1.27	1.22	0.50
Kelowna Airport									
	1971	1.14	0.53	1.67	1.83	1.28	0.99	0.86	0.86
	1976	1.48	0.59	1.42	1.24	1.15	4.86	0.30	0.80
	1977	0.77	0.49	1.79	0.51	0.89	0.69	0.78	0.24
Kelowna City (Sewage Treatment Plant)									
	1971	0.86	0.34	1.20	1.59	0.52	0.62	0.58	1.18
	1976	1.14	0.42	0.77	1.36	0.74	3.63	0.17	0.86
	1977	0.62	0.40	1.11	0.58	0.65	0.57	0.59	0.47

(continued)

	Year	Average	April	May	June	July	Aug.	Sept.	Oct.
Peachland									
	1971	0.87	0.31	1.39	1.59	0.55	1.16	0.71	0.39
	1976	1.26	0.50	1.09	1.45	0.84	3.94	0.05	0.95
	1977	0.67	0.35	1.28	0.69	0.62	0.37	1.21	0.21
Peachland (Brenda Mines)									
	1971	1.33	0.47	1.92	2.63	0.63	0.46	0.74	2.47
	1976	1.76	1.13	1.73	1.48	1.61	4.62	0.35	1.42
	1977	1.22	0.67	2.63	1.14	0.67	0.95	1.48	1.00
Summerland Research Station									
	1971	1.04	0.54	1.77	2.06	0.47	1.19	0.76	0.54
	1976	1.37	0.61	1.00	1.59	1.92	3.15	0.71	0.61
	1977	0.76	0.55	1.82	0.40	0.79	0.53	0.92	0.32
Penticton Airport									
	1971	1.12	0.65	1.16	2.39	0.97	1.32	0.87	0.49
	1976	1.04	0.65	1.16	0.62	0.89	3.39	0.12	0.46
	1977	0.97	0.60	2.40	0.37	0.78	1.20	1.34	0.11
Okanagan Falls									
	1971	1.08	1.10	0.89	2.47	0.63	0.88	0.84	0.79
	1976	0.95	1.06	1.31	0.74	0.19	2.85	0.05	0.48
	1977	2.85	0.46	2.91	0.22	0.48	0.88	0.56	0.20
Osoyoos									
	1971	1.35	1.51	1.77	2.24	0.79	0.70	1.51	0.98
	1976	0.90	0.22	1.35	1.10	0.20	2.94	0.13	0.38
	1977	0.67	0.35	1.28	0.69	0.62	0.37	1.21	0.21
Area Seasonal Mean									
	1971	1.17							
	1976	1.41							
	1977	1.00							
	1978	Data not available							

APPENDIX II

VARIOUS NUTRIENT RANGES; DISSOLVED OXYGEN, PERCENT SATURATION VALUE TABLES; AND MONTHLY DEPTH PROFILES OF TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY

A. Ranges for Phosphorus Values (µg/l) for Lakes Okanagan, Skaha and Osoyoos - 1971, 1976, 1977 and 1978

B. Ranges for Nitrogen Values (µg/l) for Lakes Okanagan, Skaha and Osoyoos - 1971, 1976, 1977 and 1978

C. Ranges for Total and Particulate Nitrogen, and Particulate Carbon Values (µg/l) for Lakes Okanagan, Skaha and Osoyoos - 1977 and 1978

D. Dissolved Oxygen Concentrations and Percent Saturation Values (in brackets) for Okanagan Lake - 1971, 1976, 1977, and 1978
   a) OK-1
   b) OK-2
   c) OK-3

E. Dissolved Oxygen Concentrations and Percent Saturation Values (in brackets) for Skaha Lake - 1971, 1976, 1977, and 1978

F. Dissolved Oxygen Concentrations and Percent Saturation Values (in brackets) for Osoyoos Lake - 1971, 1976, 1977, and 1978

G. Profiles of Temperature (°C), Dissolved Oxygen (mg/L), and Turbidity (JTU) for Okanagan Lake (North, OK-1; Central, OK-2; and South, OK-3) 1977 and 1978

H. Profiles of Temperature (°C), Dissolved Oxygen (mg/L), and Turbidity (JTU) for Skaha Lake - 1977 and 1978

I. Profiles of Temperature (°C), Dissolved Oxygen (mg/L), and Turbidity (JTU) for Osoyoos Lake - 1977 and 1978

A. Ranges for Phosphorus Values (μg/l) for Lakes Okanagan, Skaha and Osoyoos - 1971, 1976, 1977 AND 1978

Station	Total P				Dissolved P		
	1971	1976	1977	1978	1976	1977	1978
OK-1 EP	6.5 - 42.4	7.0 - 60.0	7.5 - 9.5	7.0 - 13.5	2.0 - 28.0	3.0 - 6.0	2.5 - 10.5
HYP	6.5 - 48.9	6.0 - 8.0	9.0 - 14.0	8.0 - 11.0	3.0 - 8.0	5.5 - 9.0	2.5 - 9.5
OK-2 EP	5.4 - 25.0	6.0 - 8.0	6.0 - 8.5	4.5 - 9.5	2.0 - 10.0	3.0 - 4.5	2.5 - 5.0
HYP	5.0 - 25.0	5.0 - 23.0	9.5 - 20.0	5.5 - 8.0	3.0 - 7.0	6.5 - 13.5	2.5 - 4.5
OK-3 EP	3.3 - 29.3	5.0 - 16.0	6.0 - 7.5	4.5 - 7.5	2.0 - 27.0	3.0 - 3.0	3.0 - 4.5
HYP	6.5 - 29.4	7.0 - 10.0	4.5 - 6.0	6.0 - 9.0	4.0 - 12.0	4.5 - 6.0	3.0 - 5.5
OK-S1	-	14.0 - 30.0	10.0 - 48.0	10.0 - 32.0	3.0 - 25.0	4.0 - 11.0	4.0 - 18.0
OK-S2	-	15.0 - 90.0	10.0 - 158.0	8.0 - 22.0	8.0 - 9.0	3.0 - 129.0	3.0 - 8.0
OK-S3	-	5.0 - 10.0	5.0 - 22.0	5.0 - 11.0	3.0 - 6.0	2.0 - 10.0	3.0 - 7.0
OK-S5	-	8.0 - 190.0	6.0 - 48.0	11.0 - 24.0	3.0 - 140.0	3.0 - 5.0	4.0 - 16.0
OK-S10	-	3.0 - 8.0	4.0 - 15.0	5.0 - 15.0	1.0 - 8.0	2.0 - 6.0	3.0 - 7.0
OK-R1	-	-	5.0 - 14.0	-	-	2.0 - 5.0	-
OK-R2	-	-	14.0 - 53.0	-	-	7.0 - 28.0	-
S-1 EP	17.9 - 49.7	8.0 - 12.0	9.0 - 12.5	9.5 - 18.0	3.0 - 6.0	4.0 - 6.5	2.0 - 9.5
HYP	22.8 - 45.7	8.0 - 18.0	19.0 - 79.0	13.5 - 86.0	6.0 - 13.0	5.0 - 64.0	2.0 - 75.5
S-S1	13.0 - 84.8	6.0 - 13.0	9.0 - 21.0	8.0 - 22.0	3.0 - 7.0	4.0 - 9.0	4.0 - 8.0
S-S3	-	-	10.0 - 22.0	-	-	4.0 - 12.0	-
S-S2	-	9.0 - 19.0	9.0 - 16.0	10.0 - 28.0	3.0 - 8.0	4.0 - 9.0	4.0 - 7.0
O-1 EP	13.0 - 22.8	9.0 - 12.0	12.0 - 21.0	12.5 - 23.0	4.0 - 6.0	6.0 - 9.0	4.5 - 6.0
HYP	25.0 - 27.7	18.0 - 100.0	29.0 - 72.0	16.0 - 74.5	9.0 - 84.0	11.0 - 62.0	5.0 - 63.5
O-S1	16.3 - 19.6	10.0 - 21.0	13.0 - 28.0	13.0 - 35.0	6.0 - 11.0	4.0 - 13.0	4.0 - 12.0
O-S2	-	8.0 - 41.0	6.0 - 21.0	9.0 - 18.0	4.0 - 8.0	4.0 - 10.0	4.0 - 8.0

B. Ranges for Nitrogen Values (μg/l) for Lakes Okanagan, Skaha and Osoyoos - 1971, 1976, 1977 and 1978

Station	NO_2- NO_3 1971 Range	NO_2- NO_3 1976 Range	NO_2- NO_3 1977 Range	NO_2- NO_3 1978 Range	NH_3 Nitrogen 1976 Range	NH_3 Nitrogen 1977 Range	NH_3 Nitrogen 1978 Range
OK-1 EP	10	1.0 - 4.0	7.5 - 14.5	1.0 - 23.0	3.0 - 11.0	1.5 - 11.5	2.0 - 9.5
HYP	18.8 - 31.3	58.0 - 71.0	62.5 - 65.0	21.0 - 68.5	1.0 - 5.0	1.0 - 8.5	1.0 - 1.5
OK-2 EP	10	1.0 - 5.0	1.0 - 63.5	1.0 - 24.0	7.0 - 15.0	5.5 - 27.5	1.0 - 6.5
HYP	10	44.0 - 70.0	26.5 - 53.5	25.5 - 50.0	2.0 - 7.0	1.0 - 21.0	1.0 - 13.5
OK-3 EP	10	1.0 - 11.0	.5 - 56.0	1.0 - 36.0	2.0 - 8.0	2.0 - 10.0	1.0 - 4.0
HYP	10.0 - 17.5	29.0 - 75.0	51.0 - 54.0	2.5 - 37.0	1.0 - 9.0	1.0 - 7.0	1.0 - 3.5
OK-S1	-	1.0 - 50.0	1.0 - 3.0	1.0 - 6.0	3.0 - 81.0	1.0 - 48.0	1.0 - 10.0
OK-S2	-	7.0 - 139.0	1.0 - 240.0	1.0 - 21.0	10.0 - 61.0	2.0 - 82.0	1.0 - 25.0
OK-S3	-	1.0 - 4.0	1.0 - 3.0	1.0 - 3.0	3.0 - 21.0	2.0 - 30.0	1.0 - 9.0
OK-S5	-	1.0 - 137.0	1.0 - 14.0	1.0 - 26.0	2.0 - 118.0	2.0 - 32.0	1.0 - 35.0
OK-S10	-	1.0 - 28.0	1.0 - 28.0	1.0 - 30.0	1.0 - 22.0	1.0 - 17.0	1.0 - 13.0
OK-R1	-	-	1.0 - 19.0	-	-	1.0 - 57.0	-
OK-R2	-	-	13.0 - 67.0	-	-	454.0 - 1400.0	-
S-1 EP	10.0 - 13.3	0 - 4.0	2.0 - 25.0	1.0 - 2.5	2.0 - 158.0	2.5 - 2.5	1.0 - 29.5
HYP	6.6 - 116.6	1.0 - 87.0	16.0 - 195.0	1.0 - 230.0	2.0 - 24.0	1.5 - 33.5	1.0 - 12.5
S-S1	-	0 - 14.0	4.0 - 18.0	1.0 - 18.0	1.0 - 98.0	10.0 - 121.0	8.0 - 72.0
S-S3	-	-	1.0 - 5.0	1.0 - 8.0	-	2.0 - 45.0	1.0 - 25.0
S-S2	-	1.0 - 7.0	1.0 - 30.0	1.0 - 2.0	1.0 - 31.0	1.0 - 18.0	1.0 - 10.0
O-1 EP	8.3 - 31.6	1.0 - 4.0	1.0 - 91.0	1.0 - 24.0	1.0 - 11.0	8.0 - 22.0	3.0 - 23.5
HYP	25.0 - 204.6	45.0 - 280.0	9.0 - 335.0	25.5 - 335.0	1.0 - 6.0	2.0 - 19.0	1.0 - 45.5
O-S1	-	1.0 - 15.0	1.0 - 79.0	10.0 - 79.0	2.0 - 21.0	2.0 - 32.0	10.0 - 33.0
O-S2	-	0 - 189.0	1.0 - 53.0	1.0 - 8.0	2.0 - 12.0	3.0 - 20.0	10.0 - 32.0

C. Ranges for Total and Particulate Nitrogen, and Particulate Carbon Values (μg/l) for Lakes Okanagan, Skaha and Osoyoos - 1977 and 1978

Station		Total N*			Particulate N		Particulate Carbon	
		1971	1977	1978	1977	1978	1977	1978
OK-1	EP	105.0 - 150.0	187.0 - 219.0	101.0 - 362.0	22.0 - 31.0	23.0 - 32.0	185.0 - 235.0	225.0 - 324.0
	HYP	-	195.0 - 233.0	169.0 - 204.0	5.0 - 23.5	4.0 - 19.0	139.0 - 160.0	100.0 - 140.0
OK-2	EP	27.0 - 233.3	161.0 - 383.5	143.0 - 212.0	13.5 - 155.0	3.0 - 33.0	275.0 - 805.0	218.0 - 295.0
	HYP	-	191.5 - 268.5	188.0 - 256.0	6.9 - 87.5	3.0 - 44.0	88.0 - 430.0	129.0 - 188.0
OK-3	EP	40.0 - 276.6	166.0 - 295.0	156.0 - 206.0	21.0 - 100.0	10.0 - 26.0	107.0 - 530.0	6.0 - 300.0
	HYP	-	185.0 - 279.0	185.0 - 195.0	5.0 - 94.0	10.0 - 19.0	108.0 - 505.0	151.0 - 209.0
S-1	EP	43.0 - 395.0	76.0 - 385.0	221.0 - 302.0	50.0 - 89.0	36.0 - 77.0	360.0 - 745.0	360.0 - 610.0
	HYP	-	217.0 - 372.0	191.0 - 436.0	15.0 - 38.0	16.0 - 79.0	225.0 - 545.0	240.0 - 539.0
O-1	EP	33.0 - 223.0	275.0 - 530.0	253.0 - 321.0	45.0 - 210.0	33.0 - 89.0	315.0 - 775.0	275.0 - 598.0
	HYP	-	279 - 500.0	229.0 - 515.0	5.0 - 100.0	3.0 - 47.0	190.0 - 675.0	219.0 - 350.0

* Values are Total Kjeldahl (N) plus NO_3(N) for O-1 in 1971. All other 1971 values are only Total Kjeldahl N because NO_3(N) values were almost all below detection limit at that time.

D. a) Dissolved Oxygen Concentrations and Percent Saturation Values (in brackets) for Okanagan Lake - 1971, 1976, 1977, and 1978..........OK-1

Depth (m)	Apr. 1977	Apr. 1978	May 1971	June 1976	July 1971	July 1976	July 1977	July 1978	Aug. 1976	Aug. 1978	Sept. 1971	Sept. 1976	Oct. 1976	Oct. 1977	Oct. 1978
1	12.3 (106)	12.9 (112)	12.9 (109)	10.2 (110)	9.3 (114)	9.8 (116)	9.7 (114)	9.4 (111)	9.2 (105)	9.6 (119)	9.4 (110)	9.3 (105)	9.3 (101)	9.2 (99)	9.5 (102)
5	- -	- -	13.0 (108)	- -	9.3 (95)	- -	9.8 (114)	9.5 (111)	- -	10.0 (121)	9.4 (110)	- -	- -	- -	- -
10	12.6 (108)	12.8 (110)	13.1 (107)	- -	10.4 (101)	- -	- -	- -	- -	- -	9.4 (110)	- -	- -	- -	- -
15	- -	12.7 (109)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
20	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	10.1 (108)
25	- -	- -	12.2 (97)	- -	10.8 (91)	- -	- -	- -	- -	- -	11.0 (93)	- -	- -	9.1 (96)	- -
30	- -	- -	- -	- -	- -	- -	- -	10.4 (92)	- -	10.8 (96)	- -	- -	- -	- -	9.4 (84)
35	- -	- -	- -	- -	- -	- -	11.1 (96)	- -	- -	- -	- -	- -	- -	10.1 (90)	- -
40	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
45	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
50	- -	- -	12.3 (97)	- -	11.2 (90)	- -	- -	- -	- -	- -	11.5 (91)	- -	- -	- -	- -
75	12.3 (104)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	10.5 (91)	- -
100	- -	- -	12.4 (97)	- -	11.4 (90)	- -	- -	- -	- -	- -	11.6 (91)	- -	- -	- -	- -
125	- -	- -	- -	11.2 (94)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
150	11.6 (96)	11.8 (100)	- -	- -	- -	11.7 (94)	9.4 (79)	10.4 (87)	11.2 (93)	10.7 (89)	- -	10.8 (90)	10.8 (90)	- -	- -
175	- -	- -	- -	- -	10.8 (85)	- -	- -	- -	- -	- -	- -	- -	- -	- -	9.5 (80)
200	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	11.2 (88)	- -	- -	- -	- -
220	- -	- -	12.3 -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

D. b) Dissolved Oxygen Concentrations and Percent Saturation Values (in brackets) for Okanagan Lake - 1971, 1976, 1977, and 1978 .... OK-2

Depth (m)	Apr. 1971	Apr. 1977	Apr. 1978	June 1971	June 1976	July 1976	July 1977	July 1978	Aug. 1976	Aug. 1978	Sept. 1976	Oct. 1976	Oct. 1977	Oct. 1978
1	15.6 (128)	12.4 (110)	12.3 (106)	10.4 (104)	10.7 (116)	9.8 (115)	9.4 (113)	9.4 (111)	9.1 (105)	8.7 (107)	9.6 (109)	9.3 (101)	9.6 101)	10.2 (110)
5	15.6 (125)	- -	- -	11.5 (104)	- -	- -	- -	9.4 (107	- -	9.3 (111)	- -	- -	- -	- -
10	15.2 (124)	12.9 (113)	- -	11.2 (106)	- -	- -	10.3 (113)	- -	- -	- -	- -	- -	- -	- -
15	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	9.6 (100)	9.8 (100)
20	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
25	14.9 (118)	- -	- -	12.6 (104)	- -	- -	- -	- -	- -	9.8 (8.9)	- -	- -	10.3 (93)	10.2 (94)
30	- -	- -	- -	- -	- -	- -	- -	10.7 (95)	- -	- -	- -	- -	- -	- -
35	- -	- -	- -	- -	- -	- -	10.8 (94)	- -	- -	- -	- -	- -	- -	- -
40	- -	11.8 (101)	12.2 (103)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
45	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	10.5 (90)	- -
50	14.8 (117)	- -	11.7 (98)	12.2 (99)	- -	- -	10.6 (91)	10.5 (90)	- -	10.5 (91)	- -	- -	- -	10.8 (94)
75	- -	11.5 (98)	11.7 (99)	12.2 (98)	- -	- -	- -	- -	- -	- -	- -	11.2 (96)	- -	- -
100	- -	- -	- -	- -	- -	11.3 (91)	- -	- -	11.5 (98)	- -	11.0 (93)	- -	- -	- -
125	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
150	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
175	- -	- -	- -	- -	11.6 (98)	- -	- -	- -	- -	- -	- -	- -	- -	- -
200	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
220	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

D. c) Dissolved Oxygen Concentrations and Percent Saturation Values (in brackets) for Okanagan Lake - 1971, 1976, 1977, and 1978..OK-3

Depth (m)	Apr. 1977	Apr. 1978	June 1971	June 1976	July 1971	July 1976	July 1977	July 1978	Aug. 1976	Aug. 1978	Sept. 1976	Oct. 1971	Oct. 1976	Oct. 1977	Oct. 1978
1	11.2 (105)	12.0 (101)	10.9 (110)	10.5 (114)	9.8 (107)	10.0 (116)	9.6 (112)	10.0 (110)	9.2 (106)	8.9 (108)	9.1 (102)	10.6 (107)	9.1 (99)	9.6 (100)	10.0 (109)
5	-	-	10.8 (102)	-	9.8 (103)	-	9.4 (109)	9.6 (105)	-	-	-	10.5 (104)	-	-	-
10	12.7 (110)	-	11.4 (103)	-	10.4 (102)	-	-	-	-	8.8 (101)	-	10.5 (103)	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0 (109)
20	-	-	-	-	-	-	-	-	-	-	-	-	-	9.5 (98)	-
25	-	-	12.2 (102	-	11.3 (97)	-	-	-	-	8.8 (78)	-	11.4 (96)	-	-	-
30	-	-	-	-	-	-	10.9 (95)	10.3 (92)	-	-	-	-	-	-	10.0 (90)
35	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0 (89)	-
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	12.2 (102)	12.0 (101)	12.3 (100)	-	11.1 (90)	-	-	-	-	-	-	11.7 (96)	-	-	-
75	-	-	-	11.6 (99)	-	-	-	-	-	-	-	-	-	10.7 (93)	-
100	11.9 (93)	-	-	-	11.2 (90)	11.5 (94)	11.2 (95)	10.9 (94)	11.4 (96)	10.8 (93)	11.0 (93)	-	-	-	10.7 (93)
125	-	-	-	-	11.3 (92)	-	-	-	-	-	-	11.9 (97)	10.6 (90)	-	-
150	-	-	-	-	-	-	-	-	-	-	-	12.0 (98)	-	-	-
175	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
220	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

E. Dissolved Oxygen Concentrations and Percent Saturation Values (in brackets) for Skaha Lake - 1971, 1976, 1977, and 1978

Depth	Apr. 1977	Apr. 1978	May 1971	May 1977	May 1978	June 1971	June 1976	June 1977	June 1978	July 1971	July 1976	July 1977	July 1978	Aug. 1976	Aug. 1977	Aug. 1978	Sept. 1976	Sept. 1977	Sept. 1978	Oct. 1976	Oct. 1977	Oct. 1978
1	13.3 (120)	14.0 (115)	11.3 (113)	11.9 (122)	11.8 (115)	10.4 (107)	9.9 (107)	7.3 (81)	10.1 (110)	10.4 (124)	9.3 (104)	9.3 (107)	8.9 (104)	9.2 (107)	8.5 (105)	9.1 (115)	9.0 (101)	9.0 (100)	8.7 (100)	9.0 (96)	9.7 (98)	9.3 (99)
5	- -	- -	11.2 (109)	- -	- -	10.1 (104)	- -	8.0 (81)	9.9 (106)	11.5 (130)	- -	- -	8.9 (102)	- -	- -	9.2 (115)	- -	- -	- -	- -	- -	- -
10	13.6 (113)	- -	11.2 (104)	11.9 (113)	11.8 (110)	9.9 (104)	- -	- -	- -	9.2 (95)	- -	9.2 (93)	- -	- -	8.6 (105)	- -	- -	8.9 (98)	8.5 (93)	- -	- -	- -
15	- -	- -	- -	- -	- -	10.4 (91)	- -	- -	- -	- -	- -	- -	- -	- -	- -	6.5 (63)	- -	- -	- -	- -	9.6 (97)	9.1 (95)
20	- -	- -	- -	12.5 (109)	- -	11.0 (95)	- -	- -	10.1 (92)	- -	9.2 (78)	- -	8.2 (76)	- -	7.7 (71)	- -	- -	5.4 (50)	6.6 (63)	- -	5.0 (47)	4.6 (43)
25	14.2 (122)	- -	12.4 (102)	- -	12.5 (111)	- -	- -	- -	- -	10.2 (86)	- -	9.1 (82)	- -	- -	- -	- -	8.9 (81)	- -	- -	- -	- -	- -
30	- -	- -	- -	- -	- -	11.2 (93)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
35	- -	- -	- -	- -	- -	- -	- -	7.1 (62)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
40	- -	14.0 (115)	- -	- -	- -	10.8 (87)	10.3 (89)	- -	- -	- -	- -	- -	- -	9.5 (82)	- -	- -	- -	- -	- -	- -	- -	- -
45	13.5 (115)	- -	- -	11.8 (101)	- -	- -	- -	8.1 (71)	- -	8.9 (73)	- -	8.2 (71)	- -	- -	5.3 (47)	5.2 (47)	- -	4.1 (36)	- -	- -	2.1 (18.3)	- -
50	- -	- -	10.9 (88)	- -	12.3 (106)	- -	- -	- -	9.5 (83)	- -	- -	- -	8.0 (72)	- -	- -	- -	- -	- -	0.7 (6.3)	- -	- -	0.8 (7.3)
55	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

F. Dissolved Oxygen Concentrations and Percent Saturation Values (in brackets) for Osoyoos Lake - 1971, 1976, 1977, and 1978

Depth (m)	Apr. 1971	Apr. 1977	Apr. 1978	May 1977	May 1978	June 1971	June 1976	June 1977	June 1978	July 1971	July 1976	July 1977	July 1978	Aug. 1971	Aug. 1976	Aug. 1977	Aug. 1978	Sept. 1976	Sept. 1977	Sept. 1978	Oct. 1976	Oct. 1977	Oct. 1978
1	9.4 (78)	12.4 (112)	13.1 (115)	9.8 (102)	11.2 (115)	10.0 (106)	9.3 (102)	7.4 (83)	9.6 (107)	9.7 (119)	9.6 (109)	9.3 (108)	8.7 (104)	8.8 (104)	9.0 (106)	8.5 (105)	8.8 (113)	9.2 (103	8.7 (98)	9.0 (104)	9.3 (100)	9.6 (99)	9.2 (97)
5	10.2 (86)	-	-	-	-	-	-	-	9.3 (100)	9.4 (106)	-	-	8.4 (100)	8.6 (101)	-	-	-	-	-	-	-	-	-
10	9.8 (82)	12.6 (113)	13.1 (114)	9.8 (93)	11.1 (112)	9.6 (98)	-	6.8 (63)	-	8.1 (88)	-	8.9 (102)	-	-	-	8.3 (100)	8.8 (99)	-	8.8 (98)	9.0 (102)	-	-	-
15	-	-	12.7 (109)	-	-	9.0 (88)	-	-	-	-	-	-	-	5.2 (52)	-	-	-	-	-	-	-	9.2 (94)	8.8 (92)
20	-	-	-	-	-	8.8 (76)	-	6.3 (57)	8.8 (83)	-	6.2 (60)	6.7 (62)	5.3 (50)	4.8 (43)	-	5.0 (47)	-	-	-	8.3 (80)	-	-	-
25	9.4 (78)	-	-	10.3 (92)	10.9 (99)	-	-	-	-	7.3 (64)	-	-	-	-	5.0 (45)	-	6.4 (61)	3.4 (78)	3.3 (31)	-	1.4 (13)	1.8 (17)	0.7 (7)
30	-	12.7 (112)	-	-	-	8.8 (75)	-	-	-	-	-	-	-	4.8 (43)	-	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	9.3 (77)	-	-	-	-	8.6 (75)	-	-	-	6.7 (59)	-	-	-	4.9 (43)	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	-	11.9 (104)	12.9 (110)	10.0 (90)	10.8 (97)	-	7.6 (70)	-	7.9 (73)	-	-	-	5.2 (49)	-	-	-	-	-	2.8 (26)	2.8 (27)	-	1.4 (13)	0.7 (7)
55	-	-	-	-	-	-	-	6.1 (55)	-	-	-	6.1 (56)	-	-	-	4.6 (42)	4.1 (39)	-	-	-	-	-	-

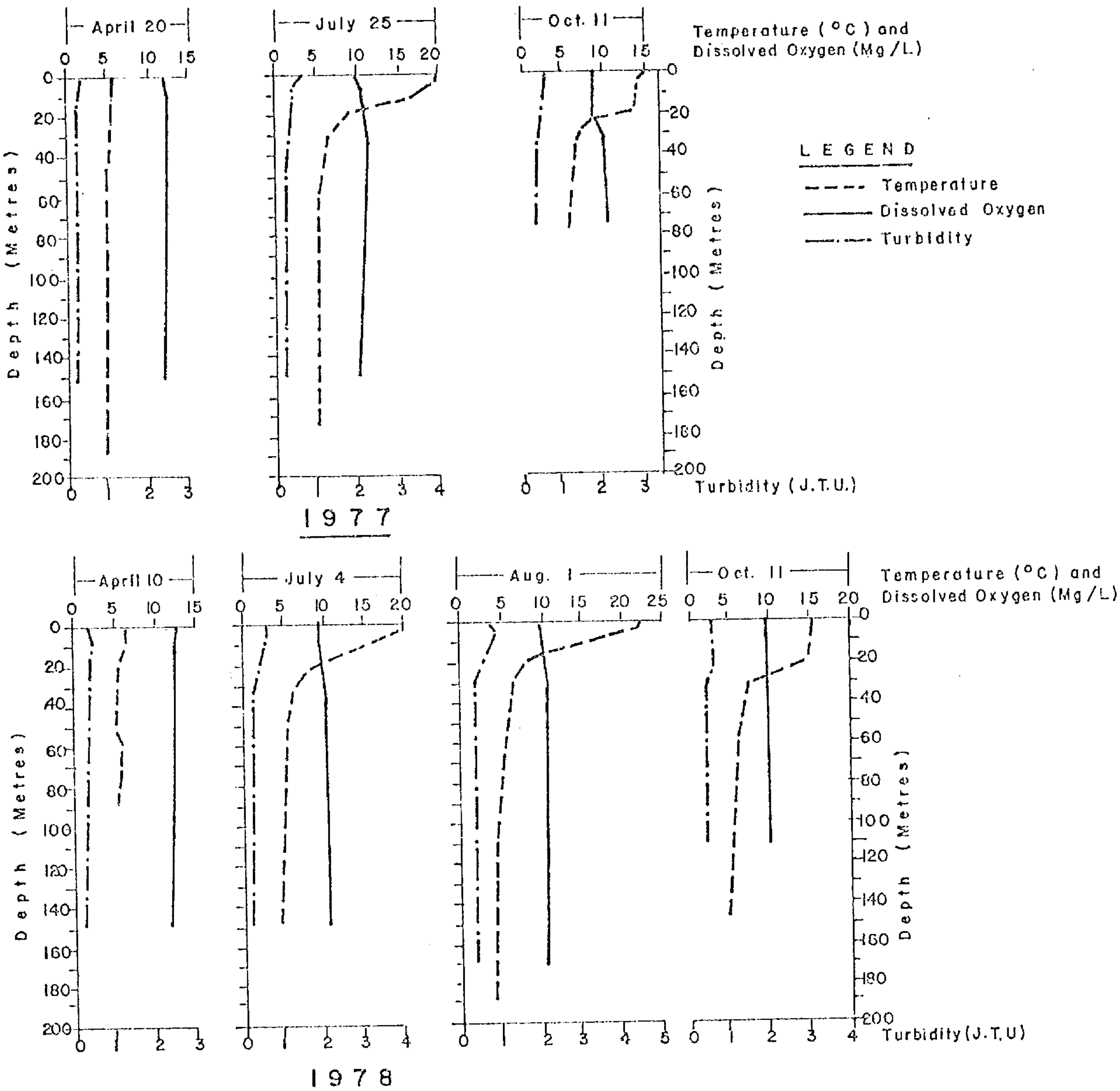

FIGURE 6(a) PROFILES OF TEMPERATURE, DISSOLVED OXYGEN AND TURBIDITY FOR OKANAGAN LAKE NORTH (OK-1), 1977 AND 1978

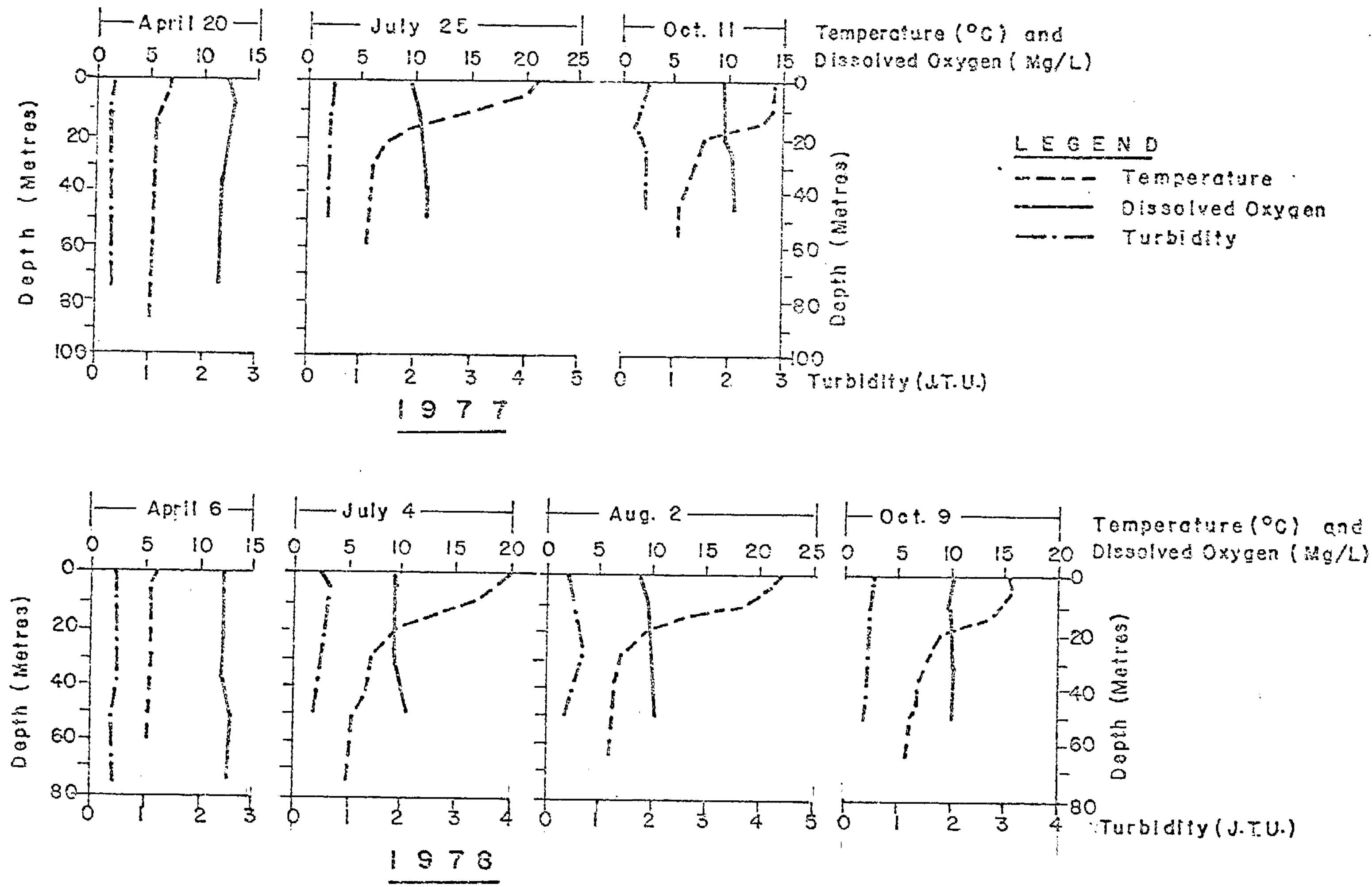

FIGURE G(b) PROFILES OF TEMPERATURE, DISSOLVED OXYGEN AND TURBIDITY FOR CENTRAL OKANAGAN LAKE (OK-2), 1977 AND 1978

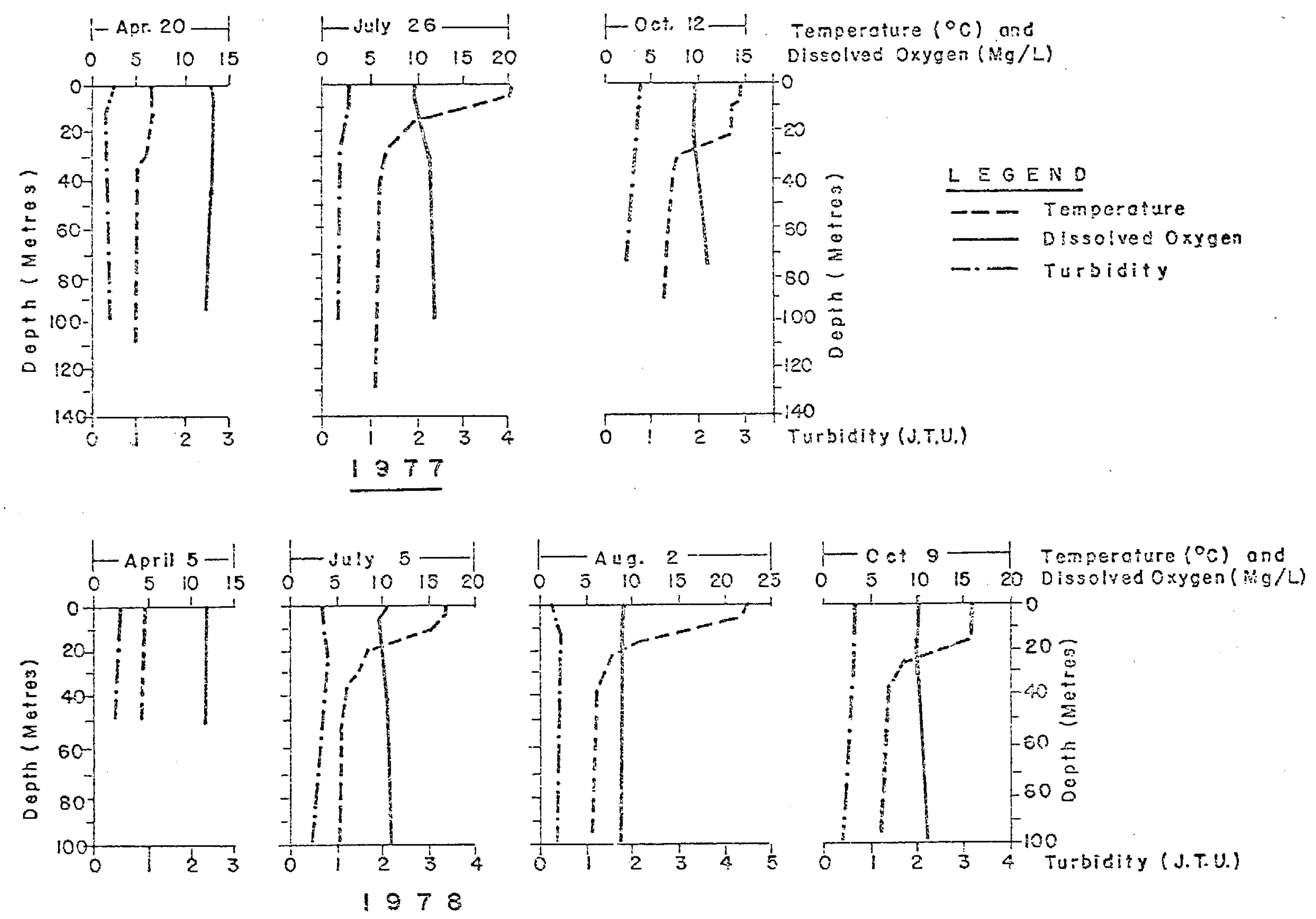

FIGURE G(c) PROFILES OF TEMPERATURE, DISSOLVED OXYGEN AND TURBIDITY FOR OKANAGAN LAKE SOUTH (OK-3), 1977 AND 1978

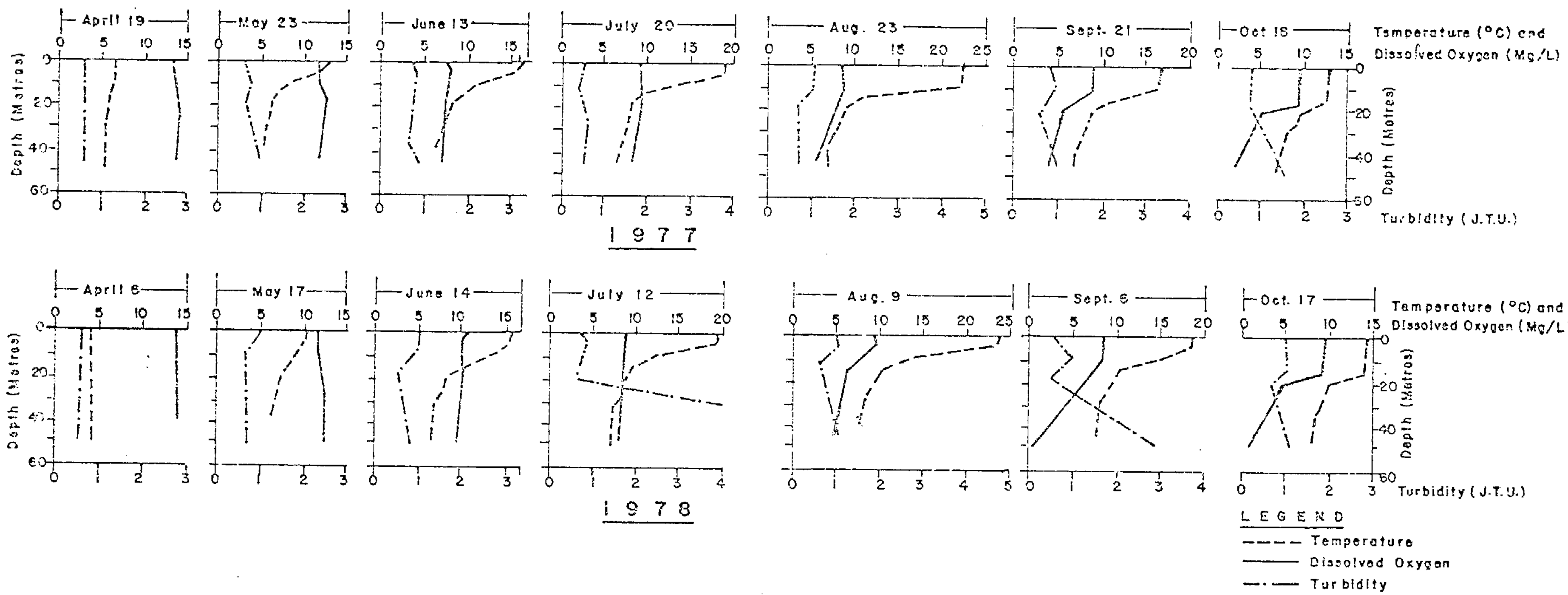

FIGURE H PROFILES OF TEMPERATURE, DISSOLVED OXYGEN AND TURBIDITY FOR SKAHA LAKE (S-1), 1977 AND 1978

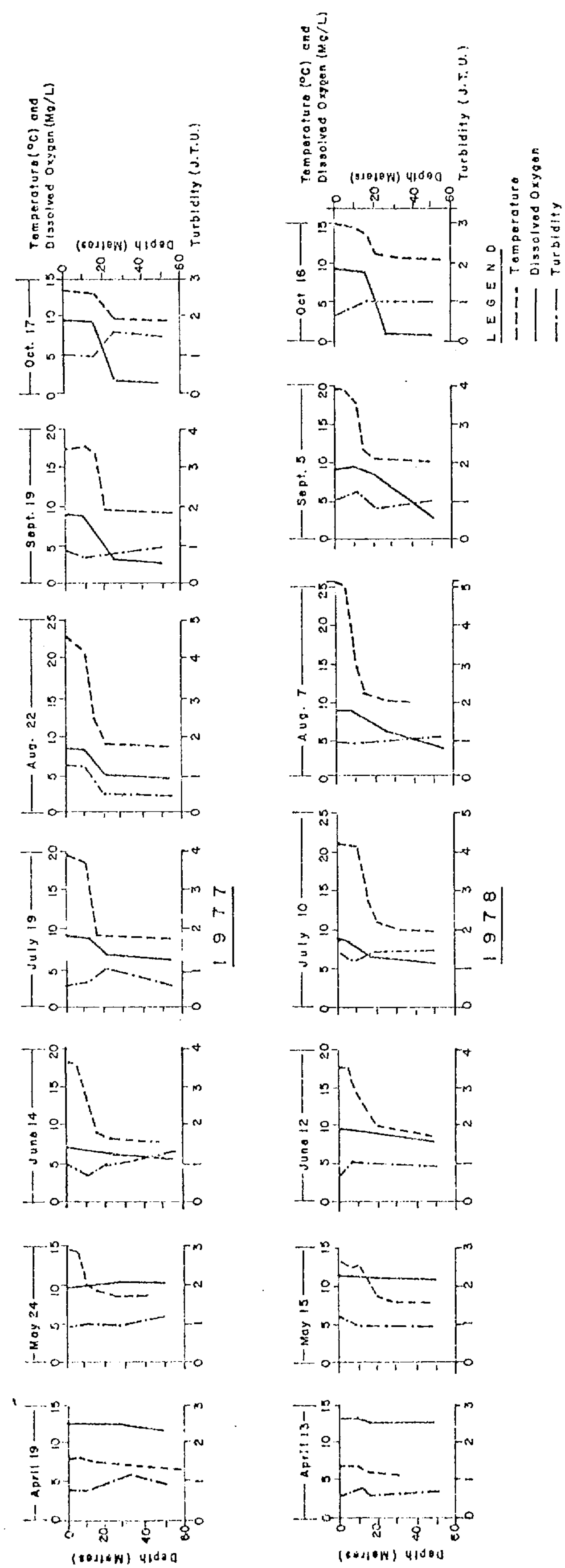

FIGURE I PROFILES OF TEMPERATURE, DISSOLVED OXYGEN AND TURBIDITY FOR OSOYOOS LAKE (O-1), 1977 AND 1978

APPENDIX III

CALCULATIONS TO DETERMINE THE POTENTIAL 1977/78 SPRING TO FALL OXYGEN DEMAND CREATED IN THE SKAHA LAKE HYPOLIMNION BY *MYRIOPHYLLUM SPICATUM* CARBON BIOMASS

APPENDIX III CALCULATIONS TO DETERMINE THE POTENTIAL 1977/78 SPRING TO FALL OXYGEN DEMAND CREATED IN THE SKAHA LAKE HYPOLIMNION BY *MYRIOPHYLLUM SPICATUM* CARBON BIOMASS

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1. 1977 Infestation Data (Tables A, B, and C below, provided by B.C. Ministry of the Environment).

Infestation			
Dense (70%)	: 26.7 Ha = 2.67×10^5 m^2	x 400 g Dry Wt.*	= 10.68×10^7
Moderate (50%)	: 13.9 Ha = 1.39×10^5 m^2	x 286 g Dry Wt.*	= 3.97×10^7
Sparse (16%)	: 29.4 Ha = 2.94×10^5 m^2	x 91 g Dry Wt.*	= 2.68×10^7
		Total DWT	17.33×10^7

2. Carbon Content = $.4 \times 17.33 \times 10^7$ = 6.93×10^7 g C in 1977
(Assumes Average Composition of 40% from Table 2)
4.88×10^7 g C in 1978

3. DO Content of Hypolimnion at Spring Overturn : V of Hypolimnion[T] = 22.346×10^{10}L
DO in April, 1977 = 13.8 mg/L
Total Amount = 3.08×10^9 g of O_2 in 1977

DO April, 1978, 14.0 mg/L 3.12×10^9 g in 1978

4. Oxygen Demand
Each molecule of CO_2 contains 12 gram atoms of C and 16 gram atoms of O .

in 1977 the weight of O_2 required to oxidize all the above C to CO_2

is $6.93 \times 10^7 \times \frac{16}{12} = 9.24 \times 10^7$ g O_2

in 1978 this value = $4.88 \times 10^7 \times 16/12 = 6.50 \times 10^7$ g O_2.

in 1977, 100% of the carbon would demand 3% of the O_2.
in 1978, 100% of the carbon would demand 2% of the O_2.

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* Dry weights based on density of infestation.
T From Basin Study Technical Supplement V.

TABLE A B.C. WATER INVESTIGATIONS BRANCH BIOMASS DATA - MEAN DRY WEIGHTS (g/m^2)

Lake	Date	Plant	$\bar{x}$	
Okanagan - Kin Beach	May 16, 1972	Myriophyllum spicatum	199.2	
	May 24, 1972	" "	314.95	
	July 14, 1972	" "	429.13	
	July 17, 1972	" "	308.35	
	May 27, 1975	" "	30.54	
	June 13, 1975	" "	36.66	
	June 21, 1975	" "	54.66	
	July 21, 1975	" "	501.35	
	Aug. 19, 1975	" "	779.37	
	Oct. 14-15, 1975	" "	138.66	
	June 11, 1976	" "	446.6	
Okanagan-Kelowna Foreshore	July 8, 1975	M. spicatum - stem & leaf	244.3	
	Aug. 14, 1975	"	595.7	
	Oct. 2, 1975	"	401.0	
	May 29, 1975	Myriophyllum spicatum	110.0	
	June 18, 1975	" "	88.0	
	July 2, 1975	" "	224.0	
	July 29, 1975	" "	374.6	
	Aug. 28, 1975	" "	138.6	
	Oct. 2, 1975	" "	302.0	
Skaha - NE end	July 9, 1972	Various plants - No M. spicatum	68.1	
SE end	June 15, 1972	"	6.75	
S end	June 14, 1972	"	6.70	
Kalamalka - S end	Aug. 6, 1972	"	243.6	
N end	Aug. 7, 1972	P. crispus	58.0	
M end	July 20, 1974	P. crispus - dense	101.25	
Osoyoos - NE end	July 26, 1972	Various plants - No M. spicatum	99.5	
NW end	July 27, 1972	" "	12.62	
Okanagan - North Arm	May 20, 1976	Myriophyllum spicatum	Stems	Roots
			9.45	9.74
	June 7, 1976	" "	54.30	25.93
	June 23, 1976	" "	92.60	18.99
	July 15, 1976	" "	71.56	14.51
	Aug. 13, 1976	" "	100.16	11.82

TABLE B CHEMICAL COMPOSITION

Species	Lake	Date	% C	% N	% Ash	C/N
Myriophyllum spicatum	Okanagan-Kin Beach	May 24/72	23.35	1.629	54.10	14.33
			25.86	2.101	40.85	12.31
		July 17/72	42.30	1.683	25.69	25.13
			43.78	1.601	19.88	27.34
		July 14/72	24.86	1.111	51.34	22.37
		July 15/72	43.83	1.850	19.21	23.69
Myriophyllum exalbescens	Osoyoos-N end	July 26/72	38.76	1.836	28.79	21.11
	Skaha	July 9/72	20.46	1.520	56.5	13.46
Elodea canadensis	Osoyoos	July 26/72	38.80	1.503	28.77	25.8
	Skaha	June 15/72	42.24	2.133	34.15	19.80
	Skaha	July 9/72	13.24	1.099	78.3	12.05
Potamogeton crispus	Kalamalka	Aug. 7/72	37.85	1.273	32.44	29.7
	Skaha	July 9/72	41.34	1.203	30.20	34.36
Potamogeton richardsonii	Skaha	July 9/72	44.53	2.176	15.27	20.46
	Skaha	June 14/72	50.0	2.269	18.32	22.04
Various Potamogetons	Skaha	June 14/72	39.67	0.842	34.87	47.11
Chara	Skaha	June 14/72	13.50	0.858	54.30	15.73
Various Aquatic Plants	Skaha	June 14/72	33.8	1.947	39.62	17.36

TABLE C SKAHA LAKE - MYRIOPHYLLUM SPICATUM AFFECTED AREA 1975-78
(as supplied by R. Nijman)

Total Affected Area (ha)			1977 Density Breakdown (ha)			Total Affected Area (ha)	1978 Density Breakdown (ha)			
1975	1976	1977	Dense	Mod.	Sparse	1978	Dense	Mod.	Sparse	Present
4.1	14.2	70.0	26.7	13.9	29.4	61.5	13.7	14.5	28.4	4.9

Criteria for density Breakdown

	1977		1978
Dense*:	70% bottom cover *M. spicatum*	Dense:	70%
Moderate:	31-69% " " " "	Moderate:	31-69%
Sparse:	30% " " " "	Sparse:	2-30%
		Present:	2%

Note the introduction of the density category "present" in 1978 to describe the very sparsely affected areas.

The first macrophyte survey conducted in 1975 identified two *M. spicatum* sites. RCMP scuba divers noted increasing stands of "weeds" at one of these sites in 1973 and 1974, northwest of Skaha beach. In 1975 this was a dense *M. spicatum* site. The introduction source was probably *M. spicatum* fragments from Okanagan Lake (upstream) as that area has experienced rapid growth of *M. spicatum* populations since the turn of the decade.

1975 and 1976 *M. spicatum* affected area figures are estimates, not based on aerial photographs. Large format aerial photographs (verticals) have been used since 1977 to more accurately determine M. spicatum affected area. Density breakdown figures are only available for 1977 and 1978.

Affected area decreases noted for Skaha Lake in 1978 are attributed to a combination of mechanical removal and lake drawdown effects.

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* Dense growth can be assumed to represent a biomass of about 400 g dry weight per square meter. Other densities are percentages of that.

APPENDIX IV

STUDY TO DISCOVER POSSIBLE EXPERIMENTAL SOURCES OF VARIATION BETWEEN 1971 CHLOROPHYLL-A DATA AND THOSE OF 1976/77/78

APPENDIX IV STUDY TO DISCOVER POSSIBLE EXPERIMENTAL SOURCES OF VARIATION BETWEEN 1971 AND 1976/77 CHLOROPHYLL-A DATA

In an attempt to determine if the difference between the 1971 and 1976/77/78 chlorophyll-a results was experimental, a small comparison test was done.

This test was on a phyptoplankton sample taken from Burnaby Lake. The sample was split and duplicate analyses were done on one half of the sample in John Stockner's laboratory (Pacific Biological Station in Nanaimo, B.C.) using the method of Yentsch and Menzel (1963). Triplicate analyses were done on the other half of the sample at the Environmental Protection Service laboratory (West Vancouver, B.C.) using the method of Lorenzen (1967). The results are shown below:

Stockner Laboratory (ug/l)	Environmental Protection Service Laboratory (ug/l)		
Fluorometric Chlorophyll-a	Chlorophyll-a	Pheopigments	Chlorophyll-a + Pheopigments
16.6	11.7	7.9	19.6
15.2	12.2	5.6	17.8
	13.2	3.2	16.4
Average 15.9	12.4	5.6	17.9

It would appear from these limited results that when the EPS laboratory chlorophyll-a and pheopigment data are added together, the resultant figure is over 10% greater than that obtained by Stockner's laboratory. When the chlorophyll-a and pheopigment values are not added together, the EPS chlorophyll-a value is over 20% less than that obtained by Stockner's laboratory.

One possible source of difference is that at Stockner's laboratory the samples were hand-ground in a tissue grinder. Possibly this resulted in fewer algal cells being disrupted than in the EPS Polytron Ultrasonic Disrupter and therefore less chlorophyll being extracted.

Dr. Ralph Daley (personal communication) of the Canadian Centre for Inland Waters stated that the acidification technique for extracting pheopigments which was used at the Environmental Protection Service laboratory might result in some chlorophyll-a being converted to pheopigments.

From an observation of these results, the methodologies, and a survey of the literature, it appears that in this case Stockner's results might be slightly too low because of the hand grinding technique and the EPS chlorophyll-a + pheopigment values might be slightly too high because of some chlorophyll-a being converted to pheopigment. It was decided that the most comparable EPS value was that of the chlorophyll-a + pheopigment concentrations.

We therefore conclude that the two methods have not produced extremely close results. However, the variation between methods (about 10%, when the EPS chlorophyll-a and pheopigment values are combined) is small enough to permit a general comparison.

APPENDIX V

GRAPHICAL RELATIONSHIP BETWEEN 1977/78 SEASONAL DEEP STATION PHYTOPLANKTON CHLOROPHYLL-A AND VARIOUS NUTRIENTS

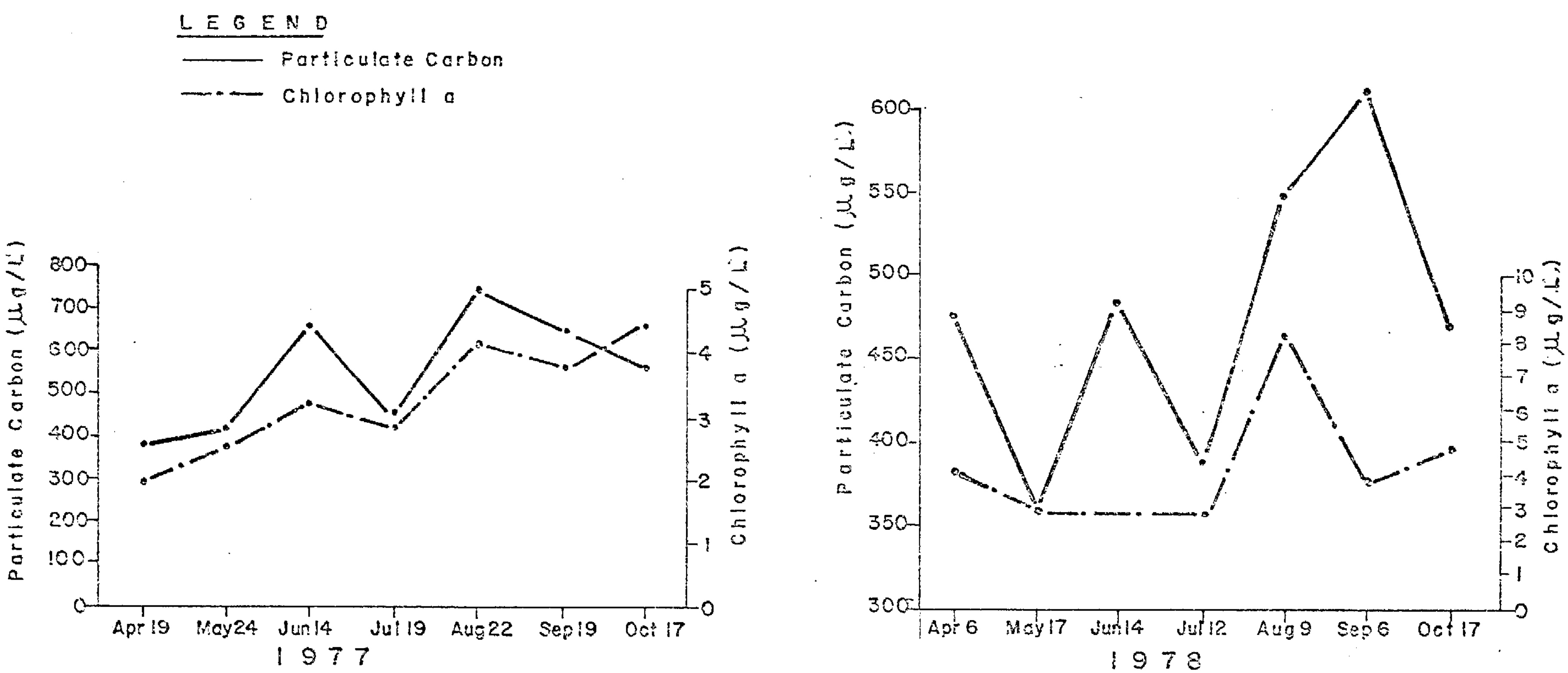

FIGURE A
PHOTIC ZONE CHLOROPHYLL a AND EPILIMNETIC PARTICULATE CARBON VALUES FOR SKAHA LAKE (S-1) - 1977 AND 1978

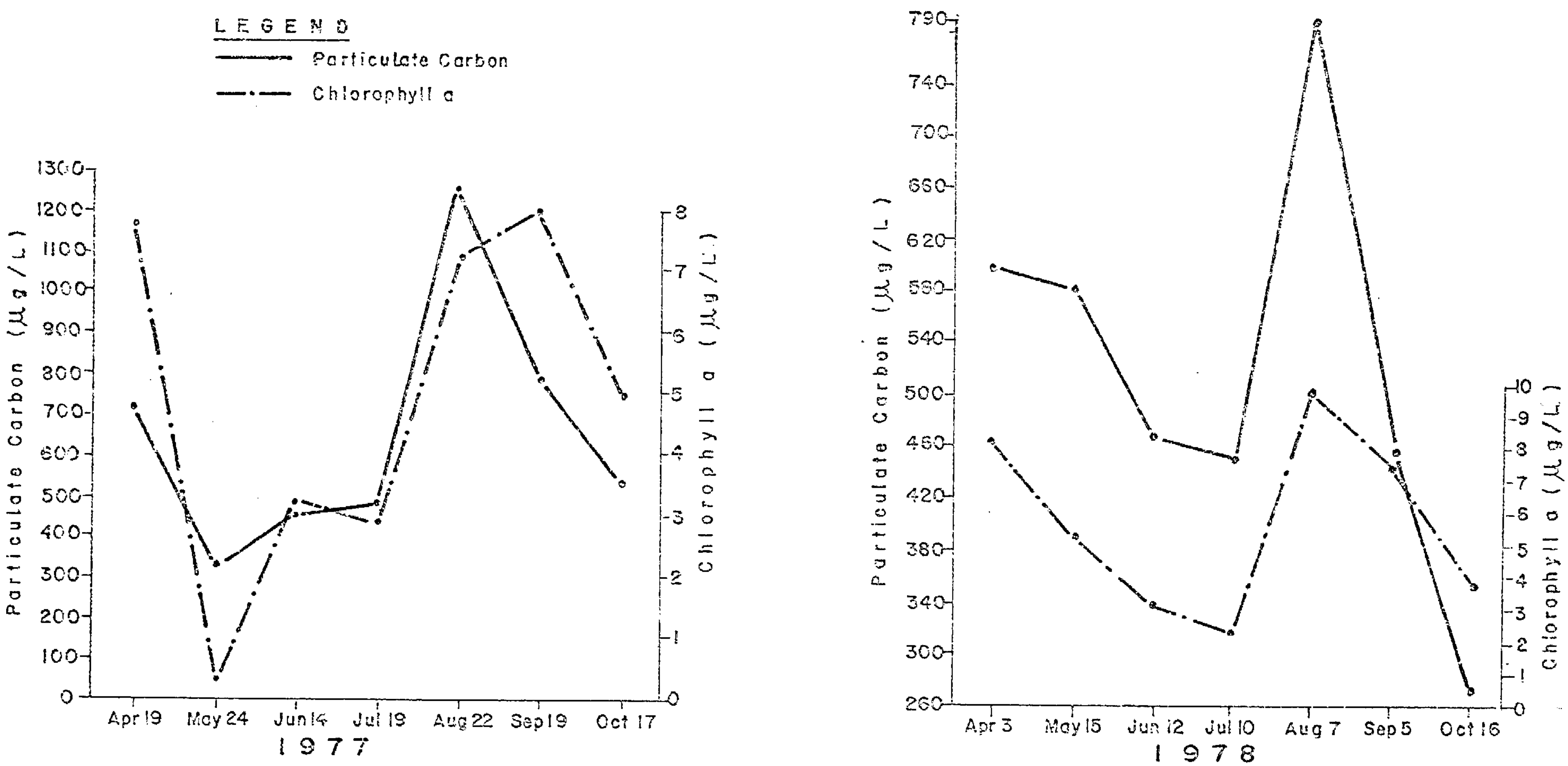

FIGURE 8
PHOTIC ZONE CHLOROPHYLL a AND EPILIMNETIC PARTICULATE CARBON VALUES FOR OSOYOOS LAKE (O-1) - 1977 AND 1978

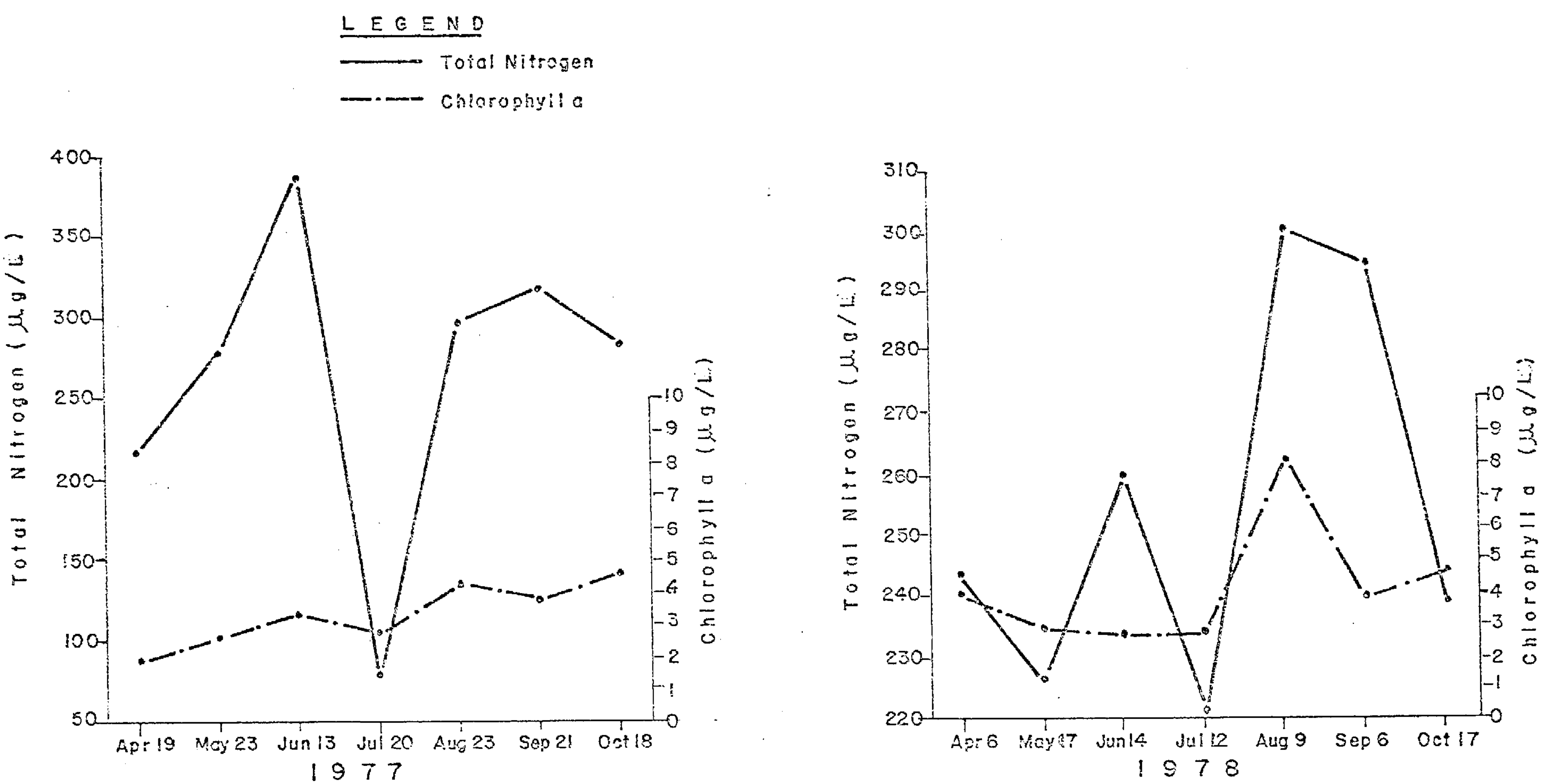

FIGURE C
PHOTIC ZONE CHLOROPHYLL a AND EPILIMNETIC TOTAL NITROGEN VALUES FOR SKAHA LAKE (S-1) - 1977 AND 1978

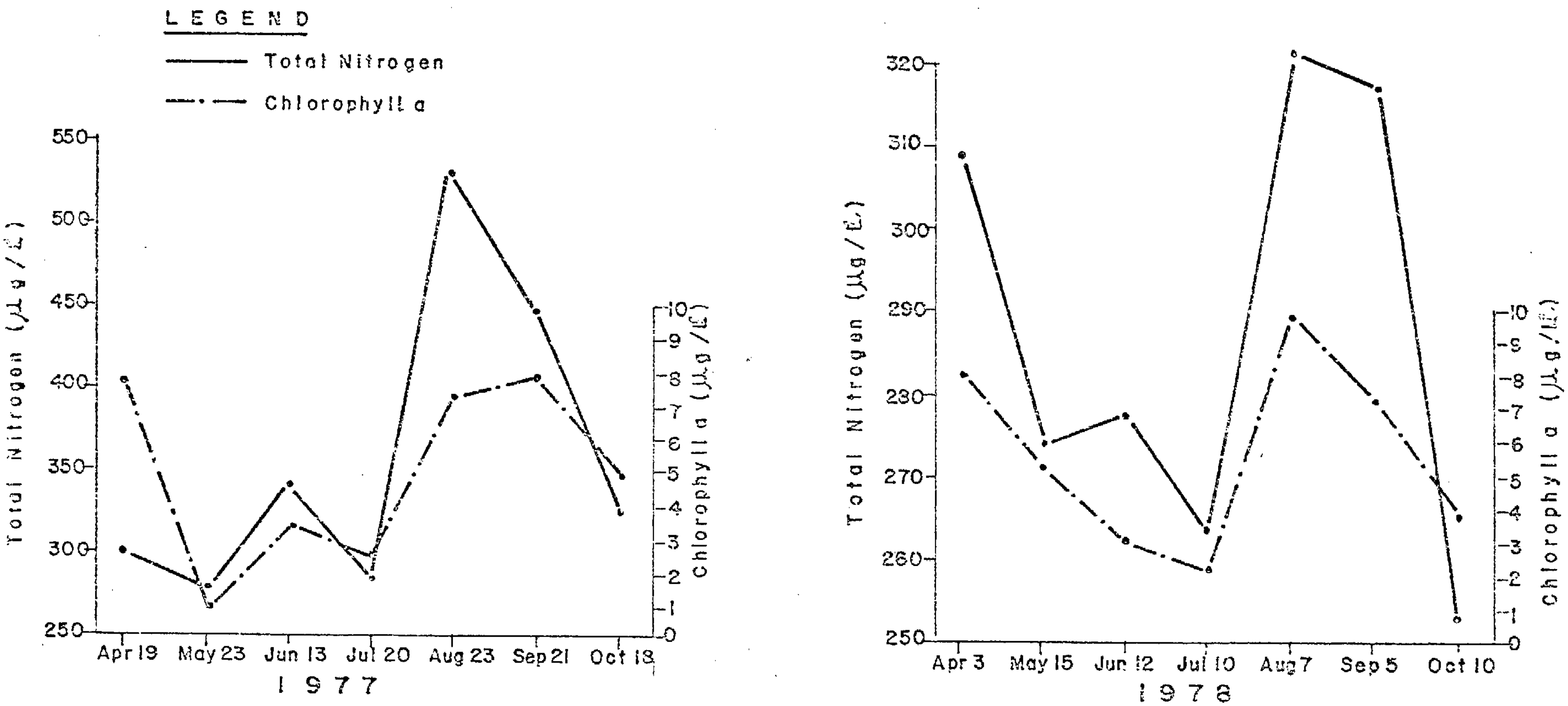

FIGURE D
PHOTIC ZONE CHLOROPHYLL a AND EPILIMNETIC TOTAL NITROGEN VALUES FOR OSOYOOS LAKE (O-1) - 1977 AND 1978

APPENDIX VI

EXPERIMENT COMPARING THE GLASS SLIDE AND ROUGHENED PLEXIGLASS PLATE PERIPHYTON SAMPLERS

APPENDIX VI EXPERIMENT COMPARING THE GLASS SLIDE AND ROUGHENED PLEXIGLASS PLATE PERIPHYTON SAMPLERS

PURPOSE:

To determine if the 1971 periphyton data (chlorophyll-a, pheopigment dry weight and phytoplankton identification) obtained from glass slides are comparable to 1977/78 data obtained from plexiglass plates.

METHODS:

For three months of the 1976 field season and for two months of the 1977 field season, replicate samples were taken on lakes Okanagan and Skaha using glass slide samplers [see Figures 1 and 2 in Stockner et al, 1972, and plexiglass samplers (Figure 2)] at the same stations for the same 14 day sampling periods. At the end of each sampling period, the glass slides were removed and placed in distilled water and the growth scraped off at the laboratory. The growth on the roughened plexiglass plates was scraped off into the distilled water in the field. The rest of the preparation and analysis procedures for dry weight, ash-free dry weight, chlorophyll-a, and identification and enumeration were the same for both samples and were identical to those methods described on page 15 for the 1977/78 periphyton samples.

When the results returned from the laboratories, statistical tests were applied to the data to determine if there was a significant variation between the results from the two samplers.

Linear regression analyses were performed on the chlorophyll-a, pheopigment, dry weight and ash-free dry weight results from the glass slides and plexiglass plates to see if they were correlated and therefore comparable (Sokal and Rohlf, 1969). Z-tests were applied to the results to determine if the correlation coefficients were significant (Alder and Poessler, 1968) to the $P = .01$ or $.05$ level.

RESULTS:

The correlation for chlorophyll-a was quite high between the two samplers (r = .8044) and was significant at the P = .05 level. Interestingly, when chlorophyll-a and pheopigments were added together, the correlation, though fair (r = .7458) was not significant at the P = .05 level. The ash-free dry weight parameter showed a poor correlation between samplers (r = .5493). The correlation for dry weight was again fair (r = .7481) but not significant at the P = .05 level. Therefore it appears that the chlorophyll-a data from the two samplers are comparable whereas the opposite is true for the ash-free dry weight data. It also appears that a fair correlation is present with the dry weight and chlorophyll-a plus pheopigment data, permitting perhaps a very general comparison between results from the two samplers.

Why chlorophyll-a results are comparable and ash-free dry weight results are not is unclear, and the periphyton identification and enumeration data only tend to make the question more perplexing. The identification data show that there was a variation to some degree in the dominant species colonizing each substrate. The species which were found on both substrates were present in different biovolumes per unit area. One can only speculate that because different organisms possess different quantities of chlorophyll-a, the total variation in chlorophyll-a between samplers was decreased by virtue of different species colonizing each sampler. It would require a complex study of this situation to come up with a definitive answer.

In the design of the 1977/78 program, it was decided to use roughened plexiglass plates to provide greater sturdiness to the substrate and to reduce sloughing. It was thought that there would be a more stable growth of periphyton on the plexiglass, because presumably the roughened surface would provide a more suitable surface for attachment than smooth glass. As the following table shows, the periphyton enumeration and identification data appear to disagree with this expectation:

TABLE B MEAN PERIPHYTIC DIATOM BIOVOLUMES (cm^3/m^2) AND ESTIMATED PERCENTAGE BY VOLUME OF NON DIATOMS: ROUGHENED PLEXIGLASS SAMPLER VS. GLASS SLIDES (PERIOD AUGUST 31 TO OCTOBER 19, 1977)

Station	1 All Dominant Diatoms	2 All Dominant Non-Diatoms	1 + 2 Total Dominants
a) S-S1 (Plexi)	.653 (44%)*	3%	47%
b) S-S1 (Glass)	1.766 (58%)*	7%	65%
a) S-S2 (Plexi)	.206 (44%)*	4%	48%
b) S-S2 (Glass)	.335 (38%)*	24%	62%
a) S-S3 (Plexi)	.103 (36%)*	17%	53%
b) S-S3 (Glass)	.254 (46%)*	18%	64%

* (These figures are back-calculated from volume data.)

These results show two things. Firstly, despite the fact that the glass slides yielded a less diverse assemblage than plexiglass, the total dominant diatom biovolumes produced by the glass slides are greater than those produced by the plexiglass plates. This difference in volume might be influenced by degree of eutrophication. The difference appears to decrease as the distance from the Penticton sewage outfall increases.

The higher biovolumes produced by the glass slide substrates probably result from of one or all of three possible situations:

(a) The plexiglass plate is roughened; therefore, the scratches harbour significant volumes of organisms which are not removed in the scraping-off process;

(b) The glass is a more inert material than plexiglass; therefore, the periphyton prefer the glass substrate and larger numbers attach to it than the plexiglass;

(c) The glass is more slippery than roughened plexiglass; therefore, only organisms equipped to attach to slippery surfaces colonize glass plates. With less competition than on plexiglass, these suitably adapted organisms are able to flourish and produce a greater volume than the organisms on the plexiglass plates.

A higher percentage of the assemblage on glass slides is composed of dominants than plexiglass plates. This suggests a greater selectivity on the part of the glass slides.

CONCLUSION:

This comparison study provides the conclusions that the periphyton identification, biovolume and ash-free dry weight data from the glass and roughened plexiglass samplers are not comparable. It also was found that the chlorophyll-a data from the two samplers are directly comparable whereas dry weight and chlorophyll-a pheopigments are generally comparable. Beyond these conclusions, there is a limitation which will not allow answering of further questions such as why some parameters are comparable and others are not, as well as if degree of nutrient enrichment of an area is directly related to the degree of difference between biovolumes from these two types of sampler.

Because a more diverse assemblage colonizes the plexiglass plates, it is felt that this sampler probably is more representative of the periphytic community. Possibly the reason for the glass slide sampler's greater selectivity is that only organisms equipped to attach themselves to a slippery surface are most successful.

APPENDIX VII

ALGAL ANALYTICAL PROCEDURES - OKANAGAN LAKES RESPONSE PROJECT

1976, 1977, 1978

a) Periphyton

b) Phytoplankton

APPENDIX VII ALGAL ANALYTICAL PROCEDURES - OKANAGAN LAKES RESPONSE PROJECT - 1976, 1977, 1978

(Prepared by Gordon Ennis, Inland Waters Directorate, Vancouver, B.C.)

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a) Periphyton

Diatom Enumeration

Periphytic diatom identification and cell counts were made on subsamples which were cleaned in hydrogen peroxide or in nitric acid (Patrick and Reimer, 1966). Diatoms were then evaporated onto cover slips (Battarbee, 1973) and then mounted on microscope slides with Hyrax media. Microscope transects were examined using a phase contrast microscope at 1000 times magnification and all diatoms in the sample were identified and counted until there was a total count of 200 frustules. Because this high magnification could produce errors in the counts of large diatoms, the sample was re-examined at 400 times magnification and only the large diatoms counted. Suitable conversion factors were used to transform counts to cells per square cm. In addition to diatom counts, diatom volumes were calculated. For each species, dimensions of ten separate cells were microscopically measured and used to determine average cell measurements for each species. Surface areas of diatom species drawings (to scale) were then measured with a polar planimeter. This area value was then multiplied by the cell's depth to determine the average cell volume in cubic micrometers. Volumes of individual samples were finally determined by multiplying each species cell count by its average cell volume.

The works of Patrick and Reimer (1966), Cleve-Euler (1951-1955), Hustedt (1930, 1931-1959), Huber-Pestalozzi (1942), Sreenivasa and Duthie (1973), and Weber (1966) were consulted for identification of the diatoms. The species classification outlined by Van Landingham (1967-1971) was followed except that *Cymbella caespitosa* was recognized as a distinct species. For genera not covered by Van Landingham (starting after the genus Melosira), the species taxonomy of Patrick and Reimer (1966), Cleve-Euler (1951-1955), Hustedt (1930), and Huber-Pestalozzi (1942) was followed.

Community Composition and Non-Diatom Enumeration

The relative abundance of each algal phyla was measured in the other subsample with an inverted microscope using methods detailed in Northcote, Ennis, and Anderson (1975).

In the inverted microscope sample, Cyanophyta and Chlorophyta species were qualitatively measured for relative abundance and identified using Prescott (1962), Hoek (1963), and Bourelly (1966, 1968, 1970).

b) Phytoplankton

Planktonic algae were enumerated using the Utermohl technique (Utermohl, 1958). Samples were transferred to 5, 10, or 25 cc settling chambers (depending upon algal density) and enumerated with an inverted phase contrast microscope. Microscope transects were examined at 400 times magnification and all phytoplankters identified and counted until there was a total count of 200 cells (except; lengths of filaments were measured and colonies composed of small cells were counted as individual colonies). Because this high magnification could produce errors in the counts of large phytoplankton species, the sample was re-examined at 200 times magnification and only large phytoplankters counted. Suitable conversion factors were used to transform counts to cells per milliliter. Phytoplankton volumes were also calculated. For each species, dimensions of ten separate cells were microscopically measured and used to determine average cell measurements for each species.

Planktonic diatom volumes were then determined using the method described in the periphytic diatom enumeration section. Volumes of phytoplankton from the other algal classes were calculated by the use of geometric formulae.

Planktonic diatoms in the samples were identified using the reference works of Patrick and Reimer (1966, 1975), Cleve-Euler (1951-1955), Hustedt (1930, 1931-1959), Huber Pestalozzi (1942), Sreenivasa and Duthie (1975), and Weber (1966). The works of Bourrelly (1966, 1968, 1970), Geitler (1932), and Prescott (1962) were used to identify planktonic algae from other classes.

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APPENDIX VIII

PERCENTAGE COMPOSITION
OF THE BENTHIC MACROINVERTEBRATE COMMUMITY
IN THE OKANAGAN RIVER AT PENTICTON IN 1977

U = Unclassified
T = Tolerant
F = Facultative
I = Intolerant

Pollution Status from Servizi and Burkhalter (1970)* and Resh and Unzicker (1975).

Figures in brackets are all over 10% and therefore signify a dominant organism.

APPENDIX VIII PERCENTAGE COMPOSITION OF THE BENTHIC MACROINVERTEBRATE COMMUNITY IN THE OKANAGAN RIVER AT PENTICTON IN 1977

Taxa	May 26		June 22		July 29		September 2		September 27		Pollution Status
	OK-R1	OK-R2	OK-R1	OK-R2	OK-R1	OK-R2	OK-R1	OK-R2	OK-R1	OK-R2	
Ph. Coelenterata											
Colonial Hydroid	-	-	-	-	0.1	-	0.3	-	0.2	-	U
Hydra sp	(28.1)	0.9	1.5	1.5	(16.0)	4.6	2.7	2.0	(75.6)	(18.8)	U
Cl. Turbellaria	-	-	-	-	-	-	-	1.3	1.2	1.4	
Duquesia sp	0.9	-	-	-	-	-	-	-	-	-	U
Ph. Nematoda	0.9	1.8	0.7	0.2	0.2	0.5	-	1.5	0.4	-	
Class Oligochaeta	-	-	-	-	-	-	-	-	0.3	-	
F. Enchytraeidae	1.8	-	-	-	0.7	0.5	1.7	-	0.5	-	*T
Nais variabilis	(10.9)	3.4	(85.0)	(12.0)	9.6	(18.0)	2.4	0.8	9.1	3.3	T
Ophidonais serpentina	-	-	-	0.1	-	-	-	-	-	-	*T
Tubificidae (juvenile)	-	-	-	0.6	-	-	-	-	-	-	T
Nais sp	-	-	-	-	-	-	0.3	-	-	-	*T
Chaetogaster sp	-	-	-	0.1	-	-	-	-	-	-	*T
S. Class Copepoda											
Diaptomus ashlandi	(15.1)	1.5	-	0.1	3.3	-	-	-	0.8	-	U
Harpacticus sp	-	-	-	-	-	0.9	-	-	-	-	U
Episcura nevadensis	0.9	0.9	7.8	(22.8)	(45.2)	3.6	(85.1)	(61.7)	(17.8)	(15.1)	U
Cyclopoid sp	-	-	-	0.1	-	-	-	-	-	-	U
Cyclopoida (juvenile)	-	-	-	-	-	-	-	-	0.5	0.5	U
Order Cladocera											
Alona sp	0.9	-	0.4	-	-	2.0	-	-	-	-	U
Sida crystalina	-	-	-	0.1	1.0	-	-	0.2	0.3	-	U
Daphnia thorata	-	-	-	-	1.7	-	-	0.2	-	0.2	U
Bosmina coregoni	-	-	-	-	2.1	-	-	-	-	-	U
S. Class Ostracoda											
F. Cypridae	-	-	-	-	-	0.5	-	0.3	0.2	0.7	U
Lymnocythere sp	-	-	-	-	-	-	-	-	1.5	0.8	U
Order Lepidoptera											
Cataclysta sp	3.9	(11.8)	-	1.6	-	1.6	-	(12.2)	-	(19.8)	
Order Coleoptera											
Elmis sp	-	1.5	-	1.1	-	2.0	-	2.2	-	2.9	
Haliplus sp	-	-	-	-	-	-	-	0.2	-	-	
Order Trichoptera											I
F. Hydroptilidae	-	-	-	-	-	1.0	-	-	-	-	I
F. Hydropsychidae	3.0	2.5	-	-	0.2	-	-	-	-	-	F/I
Hydroptila sp	0.9	-	-	-	0.1	0.9	0.6	0.8	2.7	-	I
Cheumatopsyche sp	0.9	2.8	-	0.4	0.9	8.8	0.3	5.5	0.4	(18.6)	I
Rhyacophila sp	-	-	-	-	-	-	-	-	-	0.5	I
Order Ephemeroptera											
Ephemerella sp	-	0.3	0.4	0.4	4.5	9.4	-	-	0.2	0.2	*I
Pseudocleon sp	-	0.9	-	0.2	0.1	0.9	-	-	0.5	0.3	*I
Paraleptophlebia sp	-	-	-	0.4	-	0.9	-	-	-	-	*I
Baetis sp	-	1.8	-	0.1	-	0.5	-	0.2	0.1	-	*I
Cinygmula sp	-	0.3	-	-	-	-	-	-	-	-	*I

(continued)

Taxa	May 26		June 22		July 29		September 2		September 27		Pollution Status
	OK-R1	OK-R2	OK-R1	OK-R2	OK-R1	OK-R2	OK-R1	OK-R2	OK-R1	OK-R2	
Order Diptera											
F. Empididae	-	-	-	0.2	-	1.6	-	0.3	-	-	*F
F. Orthocladinae	0.3	-	-	-	-	-	-	-	-	-	*F
F. Tanypodinae	0.3	-	-	-	-	-	-	-	-	-	*F
F. Simuliidae	-	-	0.2	1.2	-	-	-	-	0.2	1.0	*F
Simulium sp	-	-	-	-	0.7	0.9	0.2	-	0.2	-	F/I
F. Chironomidae	1.8	(10.9)	0.6	3.4	1.2	2.5	0.3	-	-	-	*F
Microspectra sp	-	1.8	0.3	3.3	-	1.6	-	0.2	-	0.1	*F
Orthocladius sp	4.8	(28.5)	2.0	(37.9)	-	(21.8)	0.3	-	-	-	F/I
Endochironomus sp	-	-	-	0.6	-	-	-	-	-	-	*F
Eukiefferiella sp	-	(11.3)	0.5	4.0	-	2.5	-	-	-	-	*F
Cricotopus sp	0.9	8.7	0.1	2.4	-	1.6	-	-	-	-	T/F/I
Psectrocladius sp	-	0.6	-	0.1	-	0.5	-	-	-	-	F/I
Procladius sp	-	0.3	-	0.5	-	0.5	-	-	-	0.1	T/F
Diamesa sp	-	-	-	0.2	-	-	-	-	-	-	I
Thienemanniella sp	-	-	0.3	-	-	-	-	-	-	-	*F
Cardiocladius sp	-	-	-	0.1	-	0.5	-	-	-	-	*F
Trichocladius sp	1.8	0.6	-	1.3	-	0.9	-	-	-	-	*F
Smittia sp	-	-	-	0.2	-	-	-	-	-	-	*F
Palpomyia sp	-	-	-	0.1	-	0.5	-	-	-	-	F
Hemerodromia sp	3.9	0.6	-	-	0.1	7.2	-	0.2	-	-	*F
Tanypus sp	-	-	-	-	-	-	-	0.3	-	-	T/F/I
Tabanus sp	-	-	-	-	0.1	-	-	-	-	-	T/F/I
Heterotrissocladius sp	-	0.6	-	-	-	-	-	-	-	-	*F
Order Homoptera											
Family Aphididae	-	-	-	0.3	-	-	-	-	-	-	U
Order Plecoptera											
Paraperla Frontalis	-	-	-	0.2	-	0.5	-	0.2	-	-	*I
Order Odonata											
Enallagma sp	-	-	-	-	-	-	-	-	0.1	-	F/I
Order Acarina											
Hermannia sp	-	0.9	-	-	6.5	-	0.6	0.8	(18.8)	(15.0)	U
Tyrellia sp	-	-	-	0.4	-	-	-	-	-	-	U
Teutonia sp	-	-	-	-	-	-	-	1.0	1.8	0.9	U
Acari sp	-	0.3	-	-	-	0.9	-	-	-	-	U
Testudacarus sp	-	-	-	-	-	0.5	0.3	0.2	-	-	U
Oxus sp	-	-	-	-	-	-	-	0.3	-	-	U
Malaconothrus sp	-	-	-	-	-	-	-	0.5	-	-	U
Porohalacarus sp	-	-	-	-	0.6	-	-	-	-	-	U
Libertia sp	-	-	-	-	0.6	-	-	-	-	-	U
Corticacarus sp	-	-	-	-	0.1	-	-	-	-	-	U
Limnesia sp	-	0.6	-	-	-	-	-	-	-	-	U
Order Collembola											
Family Poduridae	-	0.3	-	-	-	-	-	-	-	-	U
Class Gastropoda											
Family Planordidae	0.9	-	-	-	-	-	0.3	-	-	-	U
Lymnaea sp	1.8	-	-	-	3.1	5.1	3.1	5.5	3.4	9.4	T/F/I
Valvata sp	-	-	-	-	0.1	-	-	-	-	-	F/
Heliosoma sp	-	-	-	-	-	-	0.3	0.2	0.2	0.1	T/F