CHAPTER 7

Biological Characteristics of the Main Valley Lakes.

7.1 NUTRIENT BIOASSAY

The nutrient bioassay program involved a number of different approaches. Nutrient enrichment bioassay, pure culture bioassay, sewage enrichment and trace metal enrichment studies were all a part of the program. In this section, the results of each aspect are reported independently and an attempt to link them meaningfully is made at the conclusion.

It should be noted that the nutrient bioassay program went through an ongoing developmental process, thus the experiments of 1970 were of a "survey nature" in an effort, primarily, to define the problems and develop adequate techniques. To this end, methodology both in the field and laboratory, varied in the two years of the study. Only the data of the 1971 portion of the program is presented here to avoid duplication and confusion. Results of 1970 and 1971 showed general agreement within bounds expected when one considers the developmental nature of the 1970 program. Trends from both years experiments were very similar and it is in that context that the 1970 results are discussed.

7.1.1 Nutrient Enrichment Bioassay

(a) Osoyoos Lake

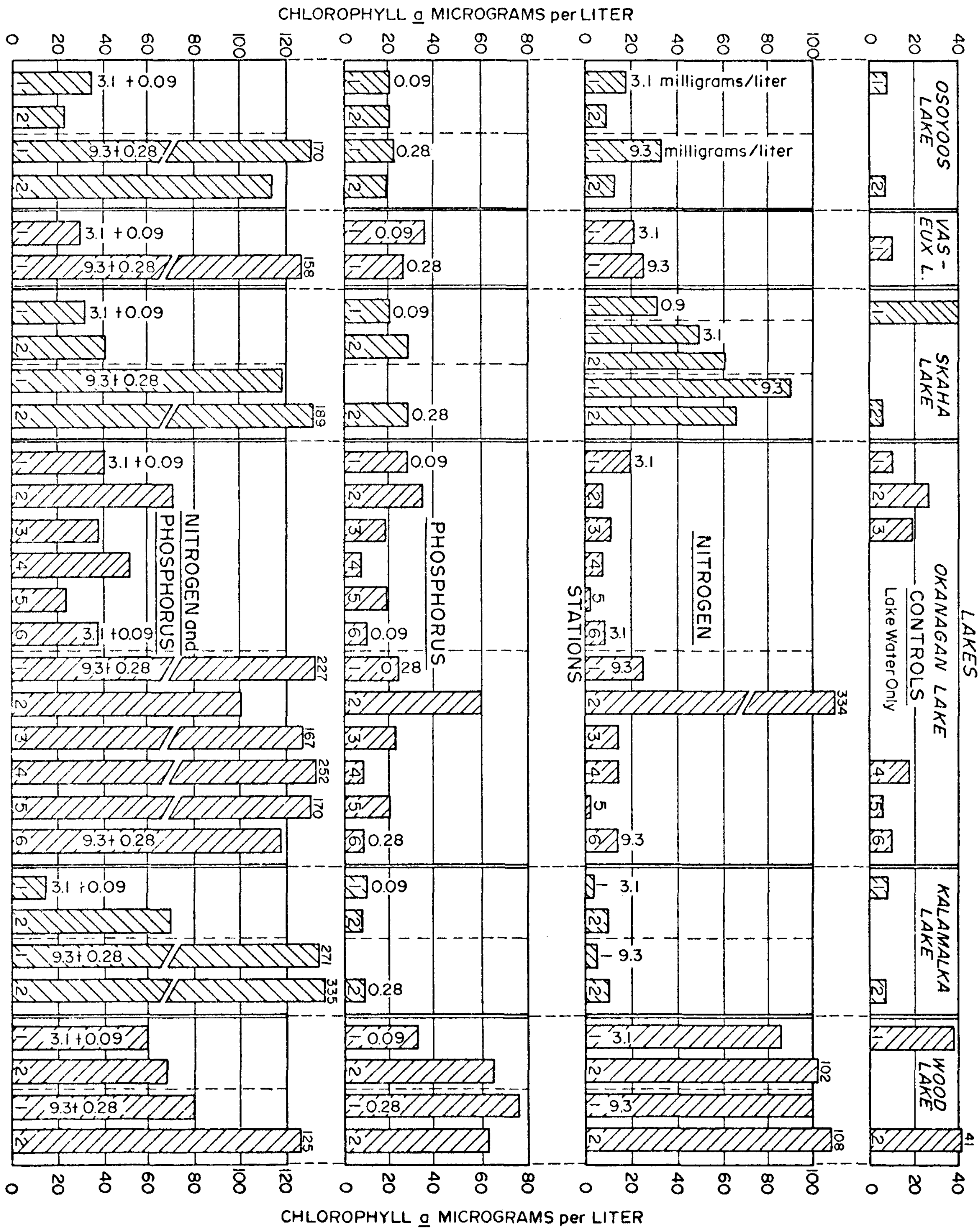
Phytoplankton growth in this lake was stimulated by addition of a small amount of phosphorus (0.09 mg/l), as PO_4(P) and increasing nitrogen concentration from 0.90 to 30.5 mg/l (NO_3(N)). Growth tended to be proportional to amount of nitrogen added, although increasing phosphorus alone or with low NO_3, alone there was no notable stimulation. The highest growth rate was achieved (Figure 7.1), when 9.3 mg/l of NO_3(N) and 0.28 mg/l of PO_4(P) were added. Increasing CO_2 concentrations also increased the growth rate with the greatest yield at 44 mg/l CO_2.

(b) Vaseux Lake

Additions of NO_3(N) alone at both concentrations produced algal growth slightly greater than observed in the control (Figure 7.1). PO_4(P) when added alone promoted more growth than NO_3(N) alone, with a yield about twice that noted in the control. NO_3(N) and PO_4(P) added together at the lowest concentrations had little stimulatory effect, but at the highest concentrations, growth was about ten times that of the control (Figure 7.1).

(c) Skaha Lake

Water samples from one station (mouth of Okanagan River) in 1970, and two stations (mouth of Okanagan River and near Okanagan Falls), in 1971 were used



RESULTS OF THE NUTRIENT ENRICHMENT BIOASSAY EXPERIMENTS,
OKANAGAN MAIN VALLEY LAKES, 1971. Figure 7.1

in the nutrient enrichment bioassay. Results from 1970 and 1971 at Station 1 showed similar results, so only the 1971 data are discussed here.

In the Station 1, (Okanagan River mouth) sample, additions of NO_3(N) at three concentrations - 0.9, 3.1, and 9.3 mg/l - were stimulatory, while a single PO_4(P) addition was not (Figure 7.1). Additions of NO_3(N) and PO_4(P) together at low concentrations had little effect, but at higher concentrations stimulated growth to about three times that of the control (Figure 7.1).

Samples from Okanagan Falls (Station 2) grew up to four times as quickly as the control when NO_3(N) at either of the two concentrations was added (Figure 7.1). Addition of PO_4(P) did not stimulate growth.

(d) Okanagan Lake

Two nutrient enrichment bioassays were performed in 1970 on water samples taken from one station; mid-lake off Summerland Trout Hatchery. Results of both bioassays in 1970 showed similar trends and are therefore discussed as a single experiment.

Additions of NO_3(N) and PO_4(P) alone had no stimulatory effect on the growth of algae in test samples. Flasks given constant amounts of PO_4(P) but varying amount of NO3(N), showed an increase of algal growth with an increase in the amount of nitrogen added. When concentrations of NO_3(N) were held constant and the amounts of PO_4(P) varied, growth remained constant throughout the series. Bicarbonate additions produced results similar to those discussed for Osoyoos Lake.

Six stations were selected for the nutrient enrichment bioassay experiment in 1971. In samples from Station 1; Vernon Arm, additions of NO_3(N) and PO_4(P) alone at two concentrations had little effect on the growth of algae. Nutrient additions of NO_3(N) and PO_4(P) together in lowest concentrations promoted growth to three times that of the controls, whereas NO_3(N) and PO_4(P) together at the highest concentrations stimulated growth to approximately fifteen times that of the controls (Figure 7.1).

Addition of NO_3(N) in the lowest concentrations to the Station 2, Armstrong Arm sample had no effect on the growth of test samples, whereas the addition of NO_3(N) at the highest concentration stimulated growth beyond that of the highest concentration of NO_3(N) and PO_4(P) together. The growth with NO_3(N) alone was equivalent to ten times that of the controls (Figure 7.1). Addition of PO_4(P) alone and NO_3(N) and PO_4(P) together at both concentrations, stimulated growth to only two times that of the controls (Figure 7.1).

In the Station 3, Kelowna Bridge samples, NO_3(N) and PO_4(P) additions by themselves, growth of algae was in most cases below that of the controls.

NO_3(N) and PO_4(P) additions together at the lowest concentrations, stimulated growth to about twice that of the controls; while with additions at the highest concentrations, growth was greater than five times the controls (Figure 7.1).

Station 4 (off Peachland) sample, flasks with NO_3(N) and PO_4(P) additions alone at both concentrations showed less growth than seen in the controls. Flasks with NO_3(N) and PO_4(P) additions together at both concentrations, stimulated growth to from ten to fifteen times that of the control flasks (Figure 7.1).

Growth inhibition was observed with additions of NO_3(N) at both concentrations to Station 5 samples, whereas stimulation of growth to a little beyond that of the control was evident with PO_4(P) additions alone. Additions of nitrogen and phosphorus together at both concentrations promoted growth of algae to three and ten times that of the control flasks (Figure 7.1).

In samples from Station 6 (off Penticton), only a little growth beyond that observed in the controls was evinced when NO_3(N) and PO_4(P) were added alone. Additions of NO_3(N) and PO_4(P) together in the lowest and highest concentrations, showed similar trends to the other stations tested; namely, stimulation up to two and ten times respectively, the growth of the control flasks (Figure 7.1).

(e) Kalamalka Lake

Two nutrient enrichment experiments were performed on water samples taken from one mid-lake station; off Crystal Waters Resort in 1970. Both sets of experiments showed similar trends, thus are treated as one for discussion. Addition of NO_3(N) and PO_4(P) alone, as well as with the addition of a constant amount of NO_3(N) and varying amounts of PO_4(P) together, showed essentially the same growth as seen in the controls. When PO_4(P) additions were kept constant but NO_3(N) varied, growth was up to three times greater than the controls.

Two stations were selected for the nutrient enrichment water sample sources in 1971. Station 1, located in the southern region, showed inhibition when NO_3(N) was added alone, and only slight growth with PO_4(P) alone (Figure 7.1). Similarly, when NO_3(N) and PO_4(P) were added together at the lowest concentration, growth was only slightly more than that of the controls, whereas NO_3(N) and PO_4(P) added together at the highest concentration promoted growth to twelve times that of the controls (Figure 7.1).

The other station, located in the northern region, showed growth of algae three times higher than the controls when NO_3(N) was added alone, while the addition of PO_4(P) at both concentrations had little effect on growth (Figure 7.1). At the lowest concentration of NO_3(N) and PO_4(P) together, growth was promoted to six times that of the controls, but at the highest concentration it was stimulated to twenty-five times the controls (Figure 7.1).

(f) Wood Lake

Two stations were used in Wood Lake. Station 1 located in the northern region showed a growth of algae twice that of the controls with NO_3(N) additions (Figure 7.1). At the lowest concentration of PO_4(P), no growth was observed beyond that of the controls, whereas growth doubled at the higher concentration of PO_4(P). In both cases, with the addition of nitrogen and phosphorus together, growth was only twice the controls, a phenomenon quite different from that observed in the other Okanagan Lakes.

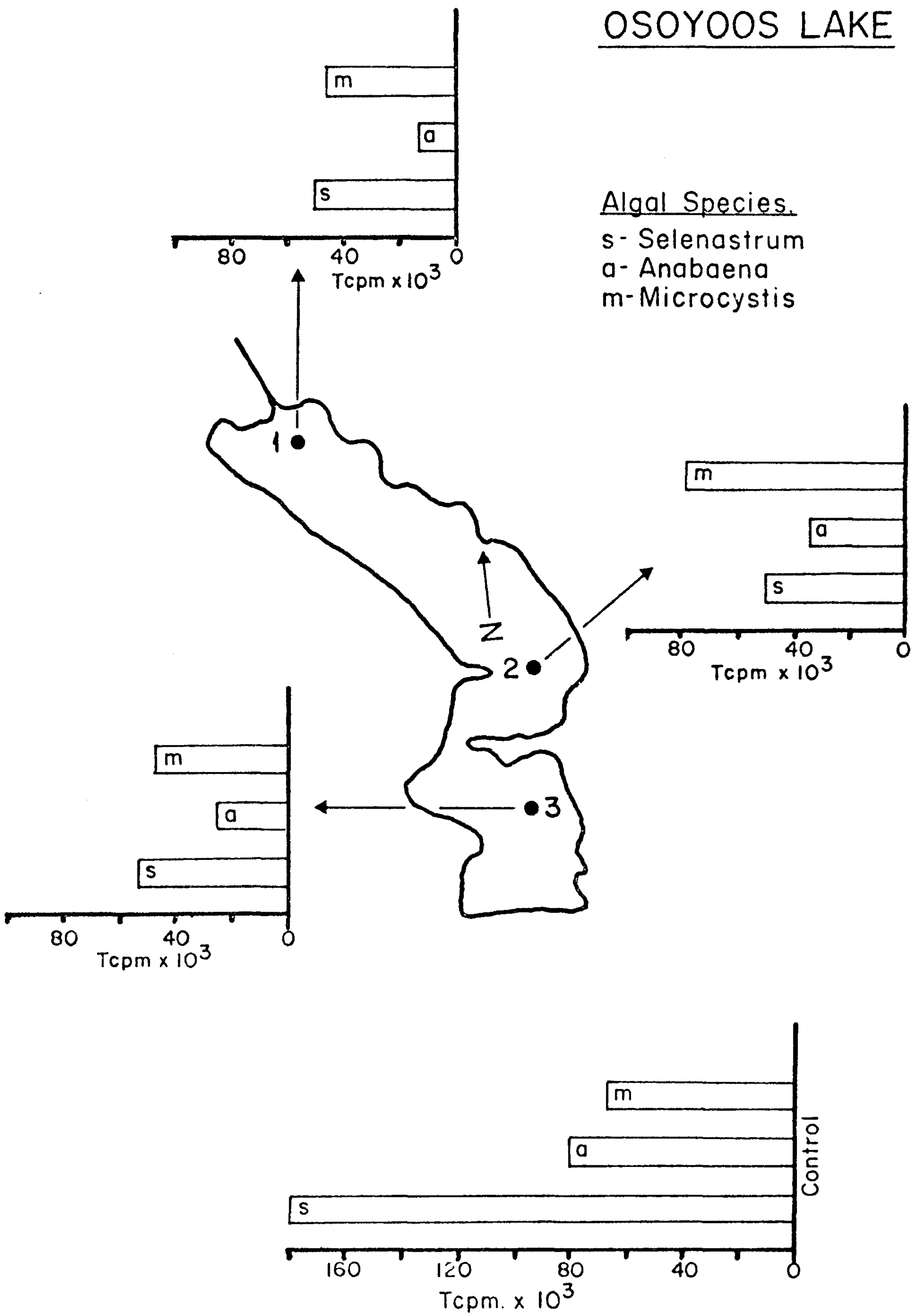
Station 2, located in the southern region of the lake, showed stimulation of growth twice that of the controls with additions of both concentrations of NO_3(N), whereas additions of PO_4(P) only stimulated growth slightly above the controls (Figure 7.1). Addition of NO_3(N) and PO_4(P) together at the lowest concentration, showed stimulation of growth similar to the addition of PO_4(P) alone, whereas at the highest concentration of NO_3(N) and PO_4(P), growth was promoted to three times that of the controls (Figure 7.1).

7.1.2 Pure Culture Bioassay

Three test organisms were used in the experiments; *Selenastrum capricornutum, Anabaena flos-aquae* and *Microcystis aeruginosa*. These species were used because they represented a good cross-section of the various types of algae likely to be found in lakes of different nutritional status. *Selenastrum* is a unicellular or loosely aggregated colonial green alga *(Chlorophyceae),* and the two remaining species are blue-green algae *(Chlorophyceae). Anabaena* is a filamentous species that is capable of fixing nitrogen. *Microcystis* is either unicellular or loosely aggregated colonial and cannot fix nitrogen. As far as is known, only *Anabaena* occurs commonly in lakes of the Okanagan Basin. Some *Microcystis,* has been noted, but its specific identity is uncertain. To our knowledge, *Selenastrum* does not occur in the main valley lakes. Intra and inter lake comparisons are made on the basis of yield of maximum growth as measured by total radioactive counts per minute (TCPM). Chlorophyll-*a.* determinations were also made in 1971, but the sample size was small (35 ml.) and results so variable they could not be used.

(a) Osoyoos Lake

Results of a single pure culture bioassay conducted in 1970 on mid-lake water near the city of Osoyoos, produced the highest yield of *Anabaena* of any of the five lakes tested. Growth of *Microcystis,* and *Selenastrum* was relatively low. Available nutrients at the time of the test run were 0.01 mg/l for both NO_3(N) and PO_4(P) respectively. The excellent response of *Anabaena* in Osoyoos Lake at this time may be related to its ability to fix nitrogen in the presence of insufficient external supply. In 1971 the pure culture bioassay was repeated using three stations (Figure 7.2). Growth of *Anabaena* and *Microcystis* was high at Station 2, but relatively low at Stations 1 and 3. *Selenastrum* showed moderate growth at all stations with little variability in growth among stations. *Anabaena* exhibited comparatively low growth but was most abundant in the mid-basin sample, as was the case with *Microcystis.*



RESULTS OF PURE CULTURE BIOASSAY EXPERIMENTS FROM THREE OSOYOOS LAKE STATIONS.(1971) Figure 7.2

(b) Vaseux Lake

A single pure culture bioassay experiment was performed in 1971 using surface water obtained from a mid-lake station (Figure 7.3). Growth of all three species was very similar to that generally observed in Osoyoos Lake waters.

(c) Skaha Lake

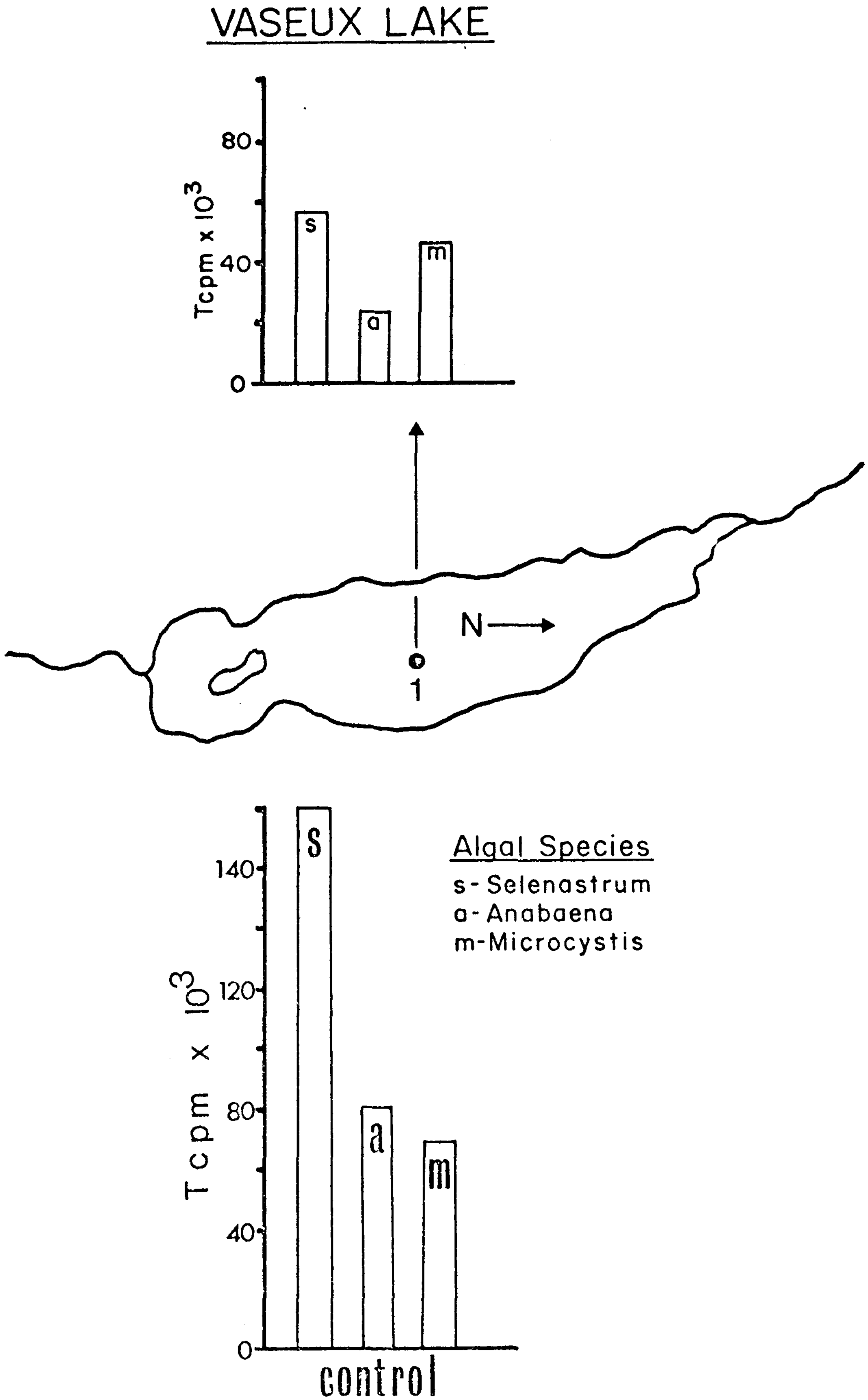
In 1970, two pure culture bioassay experiments were performed with samples from each of two stations. The greatest yield of *Selenastrum* was obtained in the first test station just off the mouth of the Okanagan River. Growth of the other test algae was low at both stations. Chemical analysis of the water showed nutrient concentrations of 0.01 NO_3(N) and 0.01 PO_4(P) mg/l, which substantiates, to some degree, the results obtained in the bioassay. Despite the apparent low nutrient concentrations, there was obviously sufficient nutrients to support the observed heavy growth of *Selenastrum* noted at this station. In the second test, a high yield of all three algae was observed at Station 1, just off the mouth of the Okanagan River. Growth of the test algae at Station 2 off Okanagan Falls was good, but not exceptional. Available nutrients at Station 1 were very high at the time of this test; 0.11 NO_3(N) and 0.16 PO_4(P) mg/liter, while at Station 2, concentrations of NO_3(N) and PO_4(P) were 0.01 and 0.01 mg/ liter respectively. The observed algal yield at each of the stations is in agreement with the noted nutrient levels.

In the 1971 pure-culture bioassay, water from four stations was tested. The results are presented graphically in Figure 7.4. Stations 1, 2 and 3 were similar in yield with *Anabaena* growing best at Station 3, and *Selenastrum* at Station 2. Station 2 at the mouth of the Okanagan River, tended to promote the highest algal growth, further substantiating results obtained in the 1970 experiment, and indicating considerable nutrient availability at this station located in the plume of the Okanagan River.

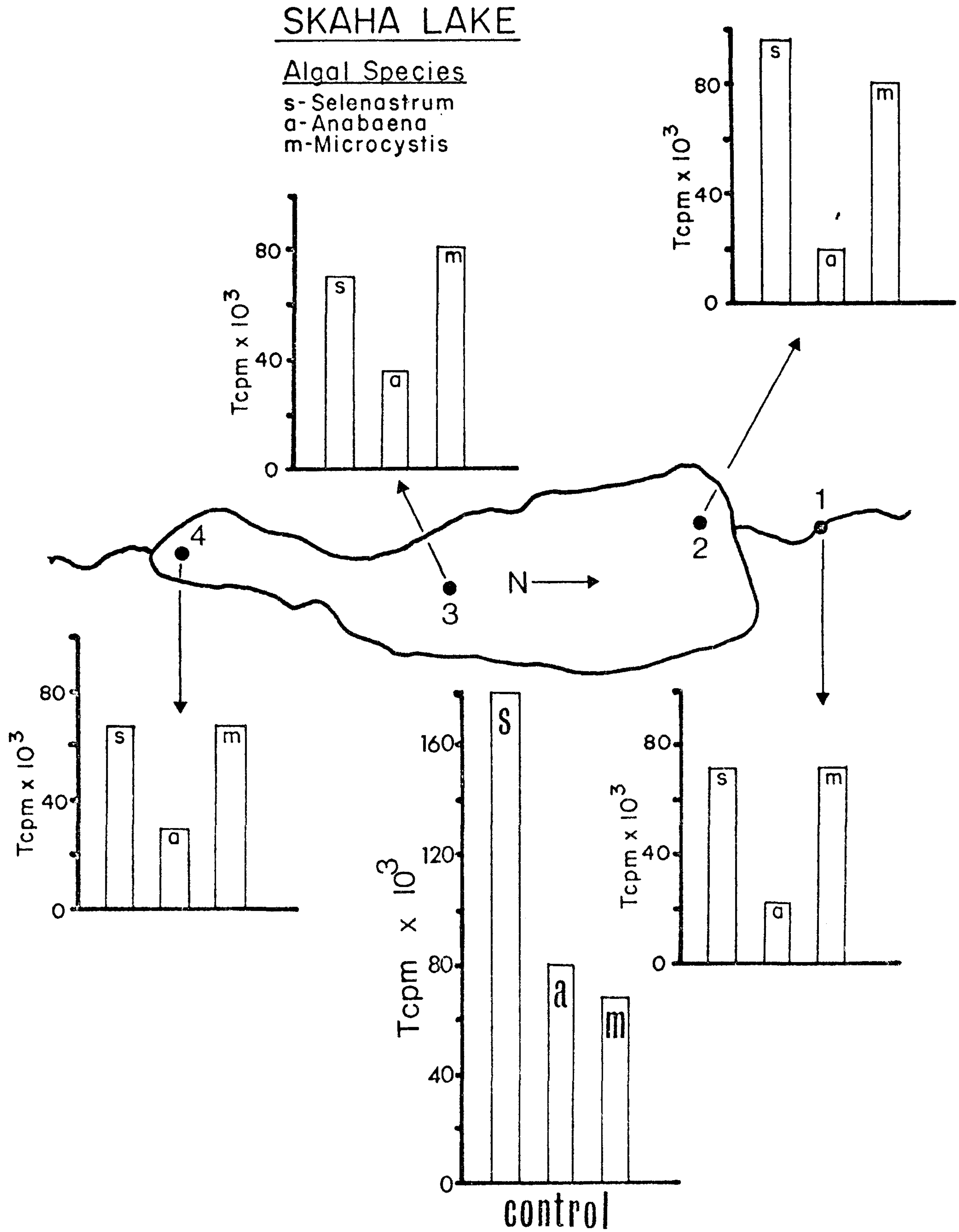
(d) Okanagan Lake

In 1970, two pure culture bioassay experiments were conducted on water obtained from three stations: Vernon Arm, Kelowna Bridge and off Summerland Trout Hatchery. In the first experiment, water from the Vernon Arm and off Summerland Hatchery promoted good growth of all test algae. Results of chemical analyses of water from these stations showed low nutrient levels at all stations; 0.01 mg/liter NO_3(N) and PO_4(P), with the exception of 0.08 mg/liter NO_3(N) at the Kelowna Bridge Station. The high rankings of algal growth at these Okanagan Lake stations does not correlate well with the chemical analyses, but this is not surprising when one considers the sensitivity levels of these nutrient determinations.

Results of the second experiment conducted in August were very similar to results of the first test, with water in the Vernon Arm and off Summerland



RESULTS OF PURE CULTURE BIOASSAY EXPERIMENTS FROM ONE VASEUX LAKE STATION. (1971) Figure 7.3



RESULTS OF PURE CULTURE BIOASSAY EXPERIMENTS FROM FOUR SKAHA LAKE STATIONS. (1971) Figure 7.4

Hatchery exhibiting higher yields than water off the Kelowna Bridge. Nutrients were again at low levels; 0.01 mg/liter, but total P values were high in the Vernon Arm; 0.08 mg/liter.

In 1971, one pure culture bioassay experiment was performed on water samples from 10 stations. The data presented in Figure 7.5 and 7.6 indicate there was little variability in growth among stations, and a very low growth of all test algae. Among the six lakes tested in 1971, Okanagan Lake ranked lowest in yield.

(e) Kalamalka Lake

A surface water sample from mid-lake served as the medium for two pure culture bioassay experiments conducted in 1970. In the first run, *Anabaena* and *Microcystis* exhibited moderate growth, while the growth of *Selenastrum* among the lowest recorded in any lake. In the second test, results were similar to those just described. Available nutrients were low at both periods; 0.03 mg/liter in NO_3(N) and 0.01 mg/liter in PO_4(P) in the first experiment; and 0.01 mg/liter for both nutrients in the second experiment. In 1971, five stations in Kalamalka Lake were tested (Figure 7.7). There was little difference in yield among stations for the alga *Selenastrum* and next to Okanagan Lake, its yield was one of the lowest recorded. Growth of *Anabaena* and *Microcystis* was moderate, ranking fourth among six lakes tested in 1971 (Figure 7.7).

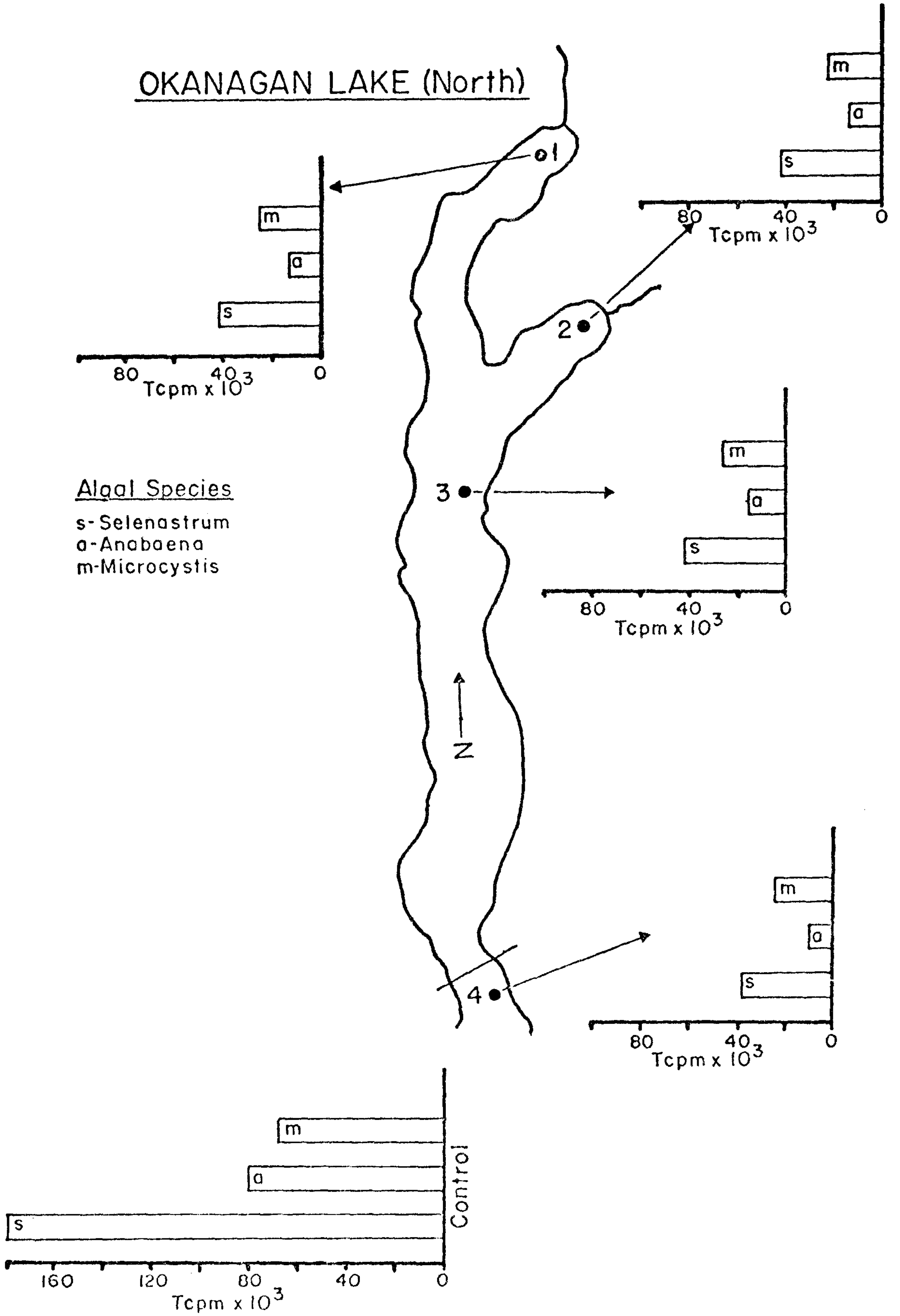
(f) Wood Lake

In 1970, only one pure culture bioassay experiment was performed on a surface sample from mid-lake. Yield of *Microcystis* was the highest recorded in any of the five lakes tested, and very similar to the algal yield obtained in Okanagan Lake off Summerland hatchery. Growth of *Anabaena* was high. Growth of *Selenastrum* was the lowest observed in any lake. Chemical analysis showed low nutrient availability; 0.01 mg/liter for both NO_3(N) and PO_4(P). In 1971, water from three stations was tested (Figure 7.8). and the yield of *Selenastrum* was second only to Skaha Lake. Growth of the other species was moderate, but not exceptional. There was little difference in yield among the three stations tested. At the time of the 1971 sampling, Wood Lake was between blooms and available nutrients low.

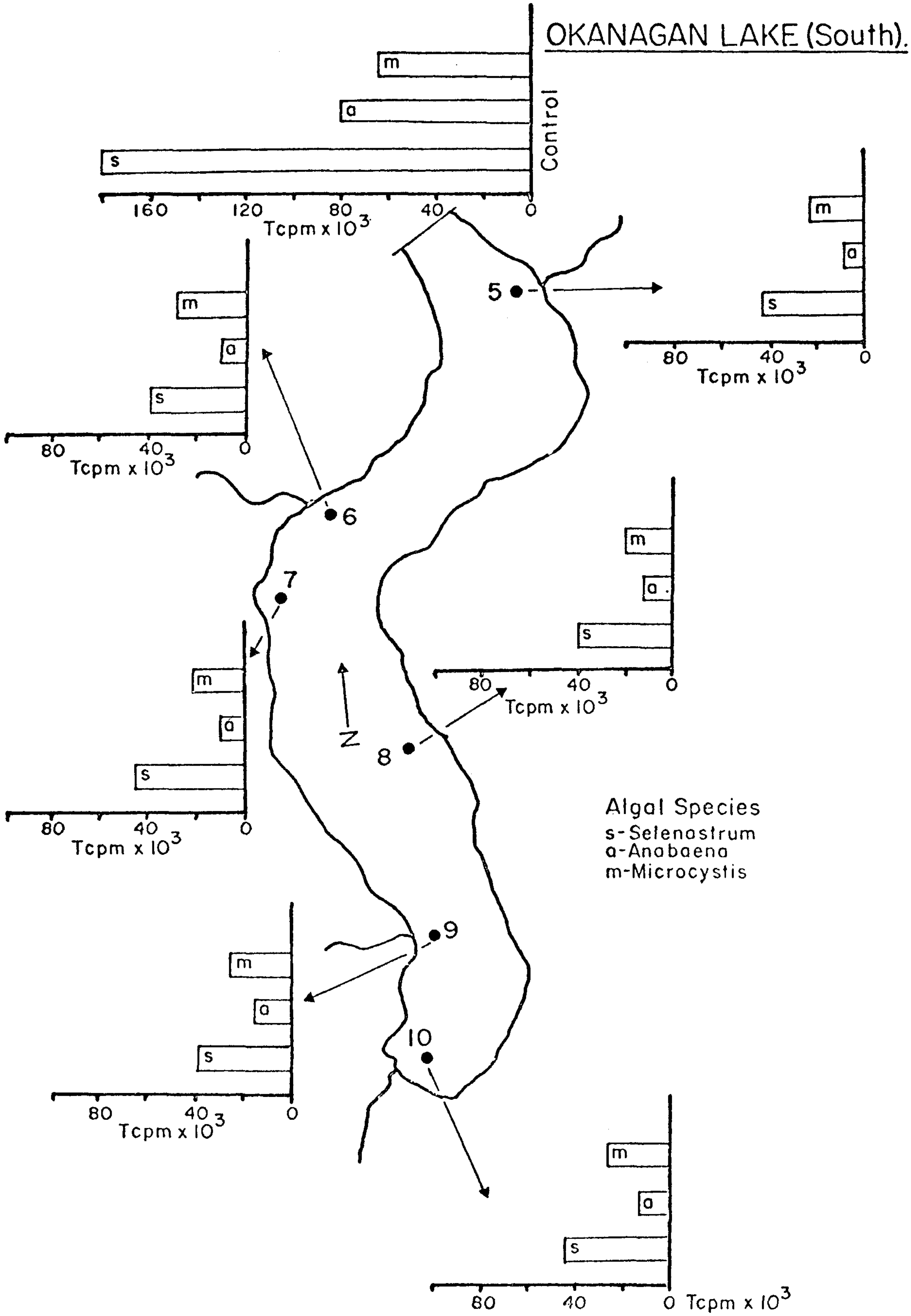
7.1.3 Sewage Enrichment Experiments

Since a chief source of PO_4(P) in the basin lakes is municipal sewage, a series of experiments were designed to demonstrate the fertilizing capacity of both raw and treated sewage when added to the uncontaminated lake water. It was also interesting to note the short term response of phytoplankton and the shift of dominant species in the algal assemblage. Results from the five lakes tested were similar with respect to growth, but different in absolute yield and final species succession. These differences are not surprising since the standing stock of phytoplankton in each lake differed at the time of sampling.

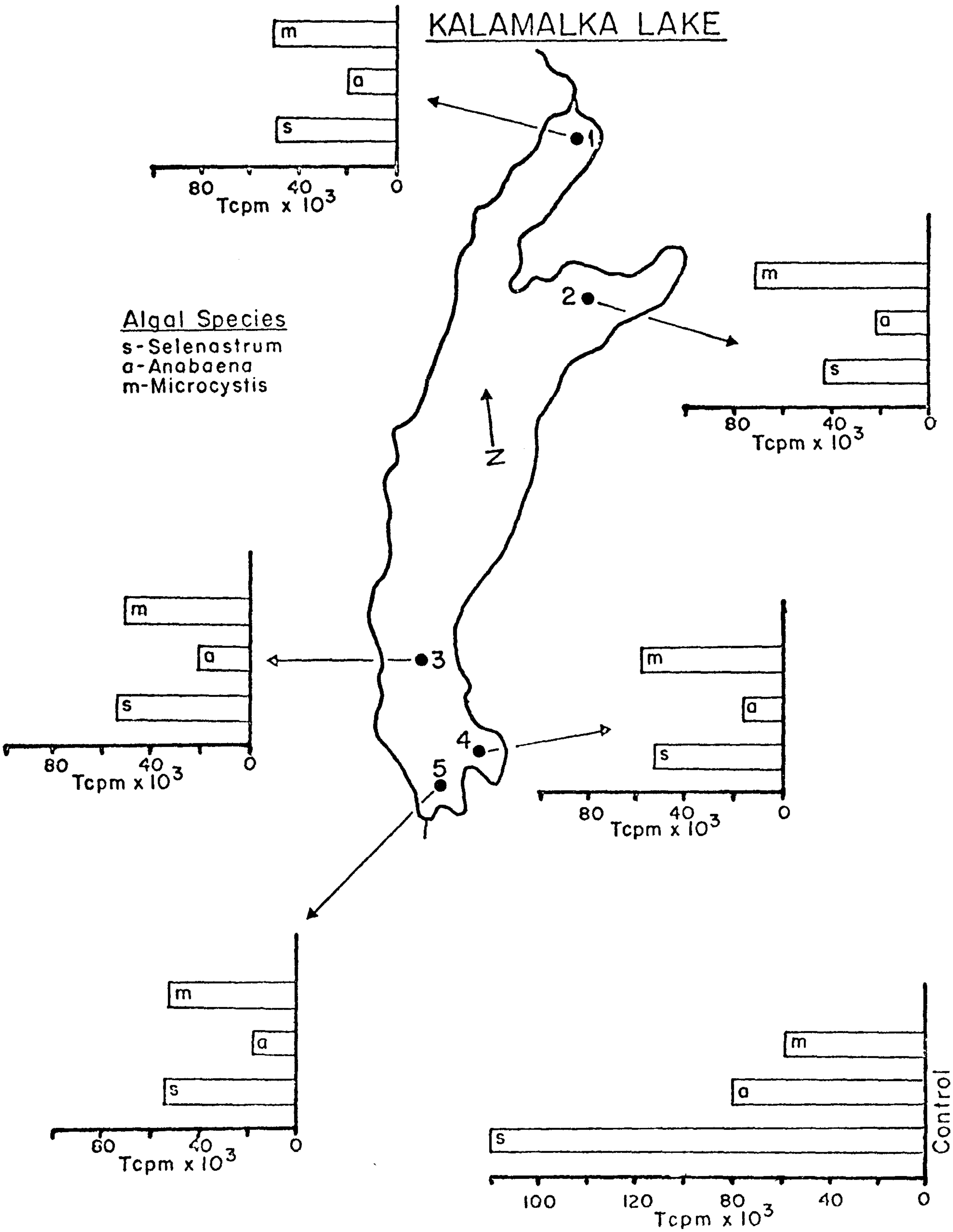
It is noted that these laboratory experiments were not designed to duplicate the actual lake situation and certain differences did exist. For example, the



RESULTS OF PURE CULTURE BIOASSAY EXPERIMENTS FROM FOUR NORTH OKANAGAN LAKE STATIONS. (1971) Figure 7.5

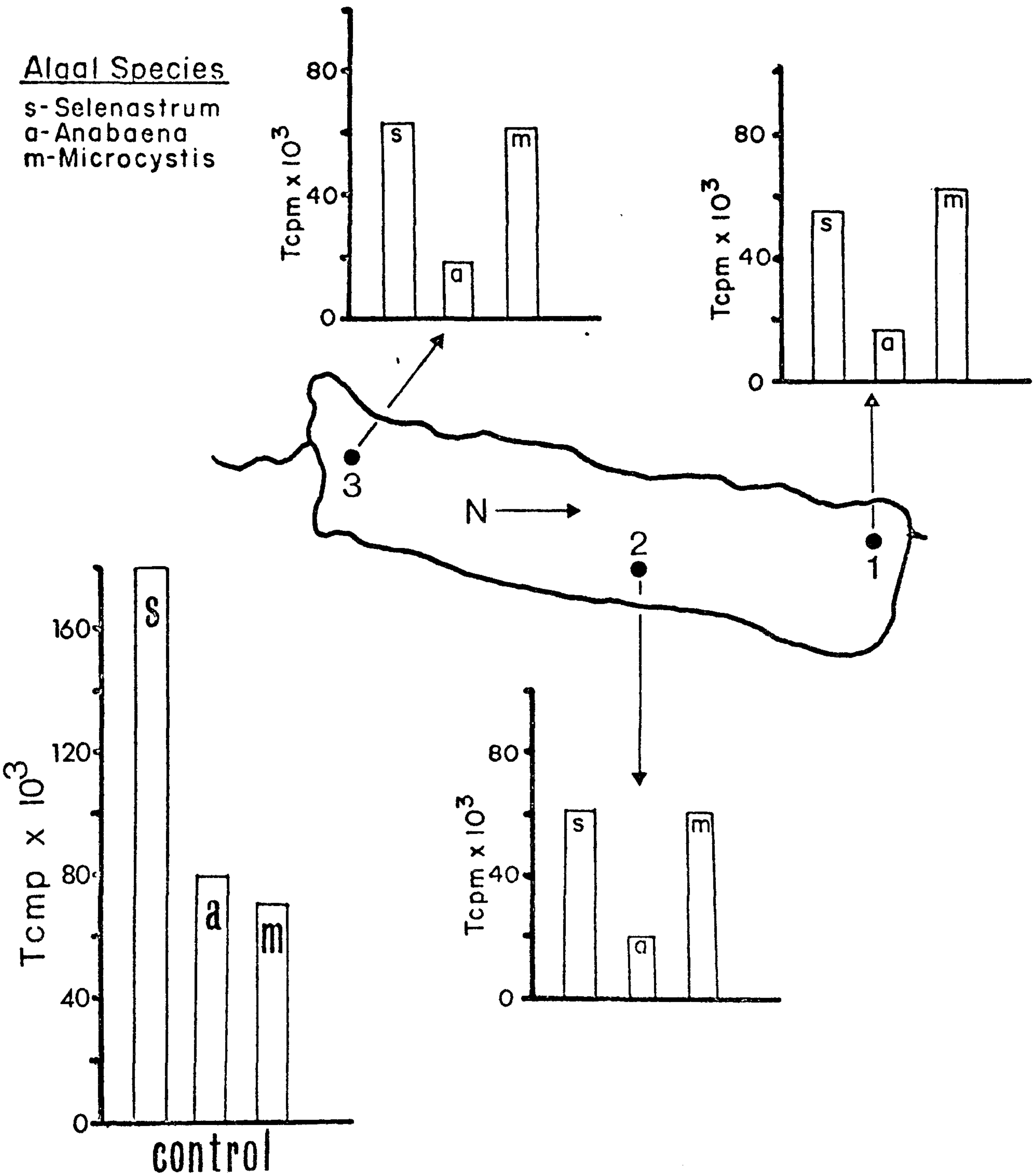


RESULTS OF PURE CULTURE BIOASSAY EXPERIMENTS FROM SIX SOUTH OKANAGAN LAKE STATIONS.(1971) Figure 7.6



RESULTS OF PURE CULTURE BIOASSAY EXPERIMENTS FROM FIVE KALAMALKA LAKE STATIONS. (1971) Figure 7.7

WOOD LAKE



RESULTS OF PURE CULTURE BIOASSAY EXPERIMENTS FROM THREE WOOD LAKE STATIONS. (1971) Figure 7.8

flasks were shaken regularly and there was no stratification or settling in the flasks, thus the nutrients were constantly available to algae. This is not necessarily the case in the lake where several physical forces may separate nutrients and algae. These experiments were intended to be informative examples rather than definitive extrapolations to the natural situation.

The general effects of the sewage enrichment experiments on the phytoplankton of each lake are discussed below.

(a) Osoyoos Lake (Figure 7.9)

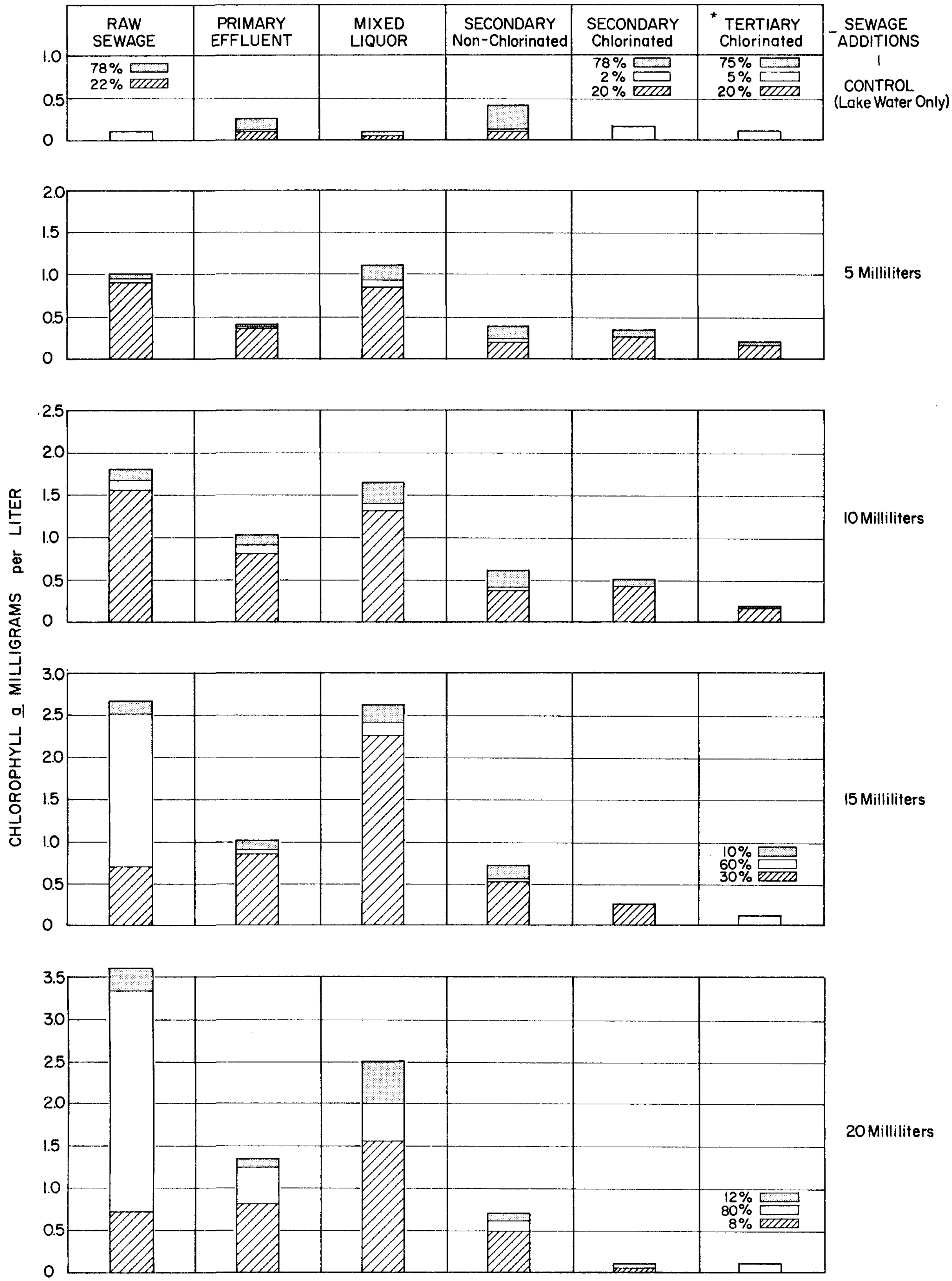
The control flasks, after nine days incubation, contained a mixture of the blue-green alga *Lyngbya* sp. and the diatom *Fragilaria crotonesis*. With the addition of raw sewage, the succession changed to green algal dominance; *Chlorella* spp. with the remainder being several genera of diatoms. With primary treated sewage addition, the succession changed to diatom dominance, chiefly *Navicula* sp., *Nitzschia* sp., and *Fragilaria* spp. The addition of mixed liquor to flasks produced results similar to that of primary treated sewage except the production of algae was much greater. Addition of secondary, non-chlorinated sewage showed similar trends and species composition to the above, but algal production was reduced. The addition of final chlorinated effluent led to a mixture dominated by the diatom *Fragilaria crotonesis* , and the green alga *Scenedesmus* sp. Tertiary treated sewage additions gave way to a final succession of almost exclusively *Scenedesmus* sp.

(b) Skaha Lake (Figure 7.10)

The controls after nine days contained almost exclusively the diatoms *Fragilaria crotonesis* , *Asterionella formosa*, and *Tabellaria fenstrata*, and the blue-green *Anabaena* sp. The flasks receiving raw sewage after nine days contained considerably more *Anabaena* sp., with *Fragilaria crotonesis* and *Synedra* sp. being the dominant diatoms. Additions of primary treated sewage showed similar results to that of the flasks with raw sewage additions, except that *Anabaena* sp. was more abundant, 60%. Mixed liquor additions decreased the amount of *Anabaena* sp. and *Fragilaria crotonesis* , but stimulated the growth of *Navicula* sp. Flasks receiving secondary non-chlorinated and final chlorinated sewage, had an increased growth of *Anabaena* sp. of 50% and 75% respectively. Flasks with tertiary treated sewage additions contained a heavy growth of *Anabaena* sp. with some *Fragilaria crotonesis* still present.

(c) Okanagan Lake (Figure 7.11)

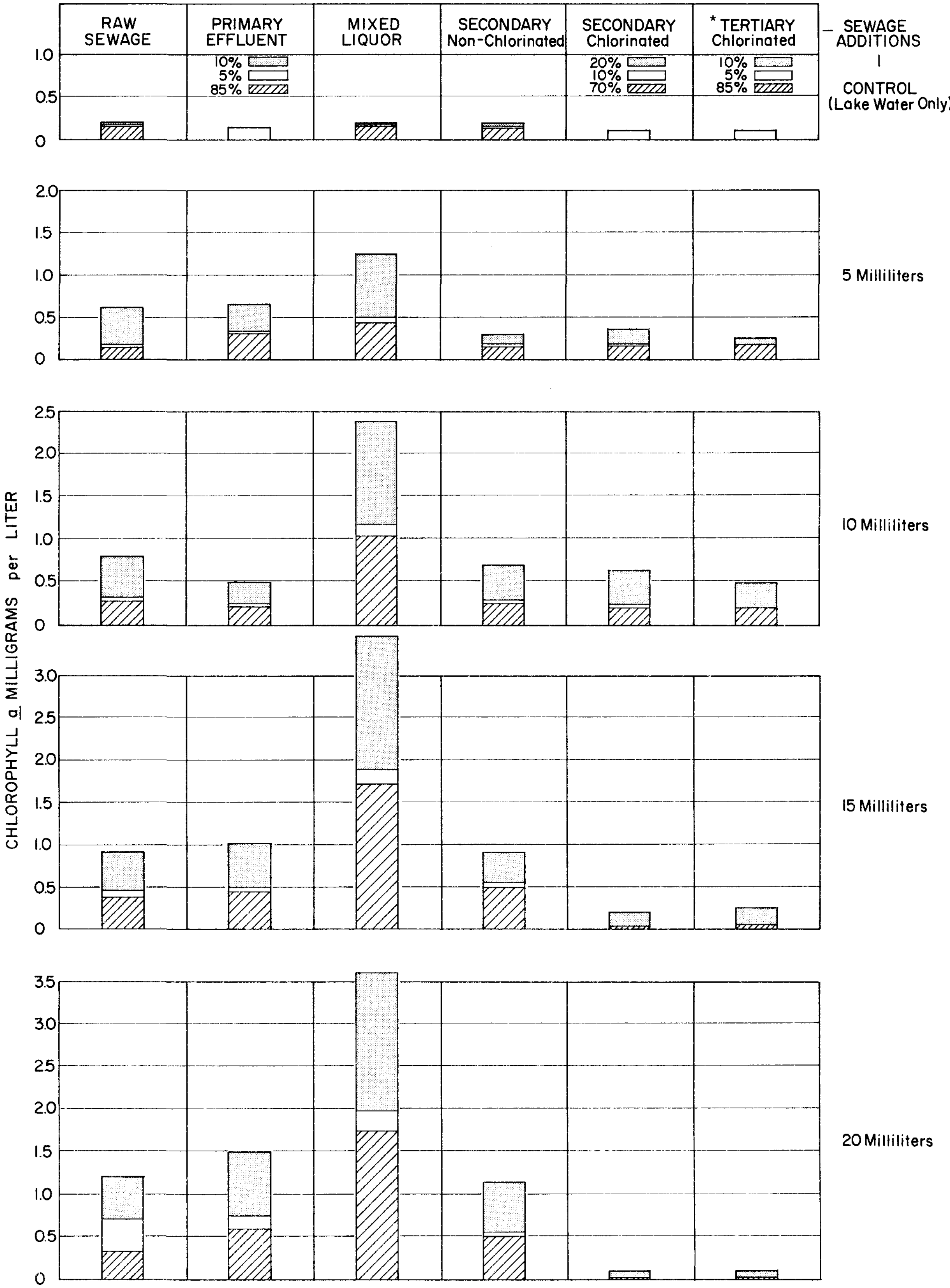
The control flasks after nine days growth contained mostly the diatoms *Asterionella formosa* and *Synedra* sp. With the addition of raw sewage, species composition changed from diatoms to that of green algal dominance, *Shorella* sp. and *Scenedesmus* sp. With the addition of primary treated sewage, *Scenedesmus* sp. became the dominant alga, but with some *Navicula* sp. present. With the



* Assumes 45% Reduction at Penticton plant during the sampling period.

The major alga groups: Diatoms, Green Alga, and Blue-Green Alga, are shown as a percentage of the total bar height.

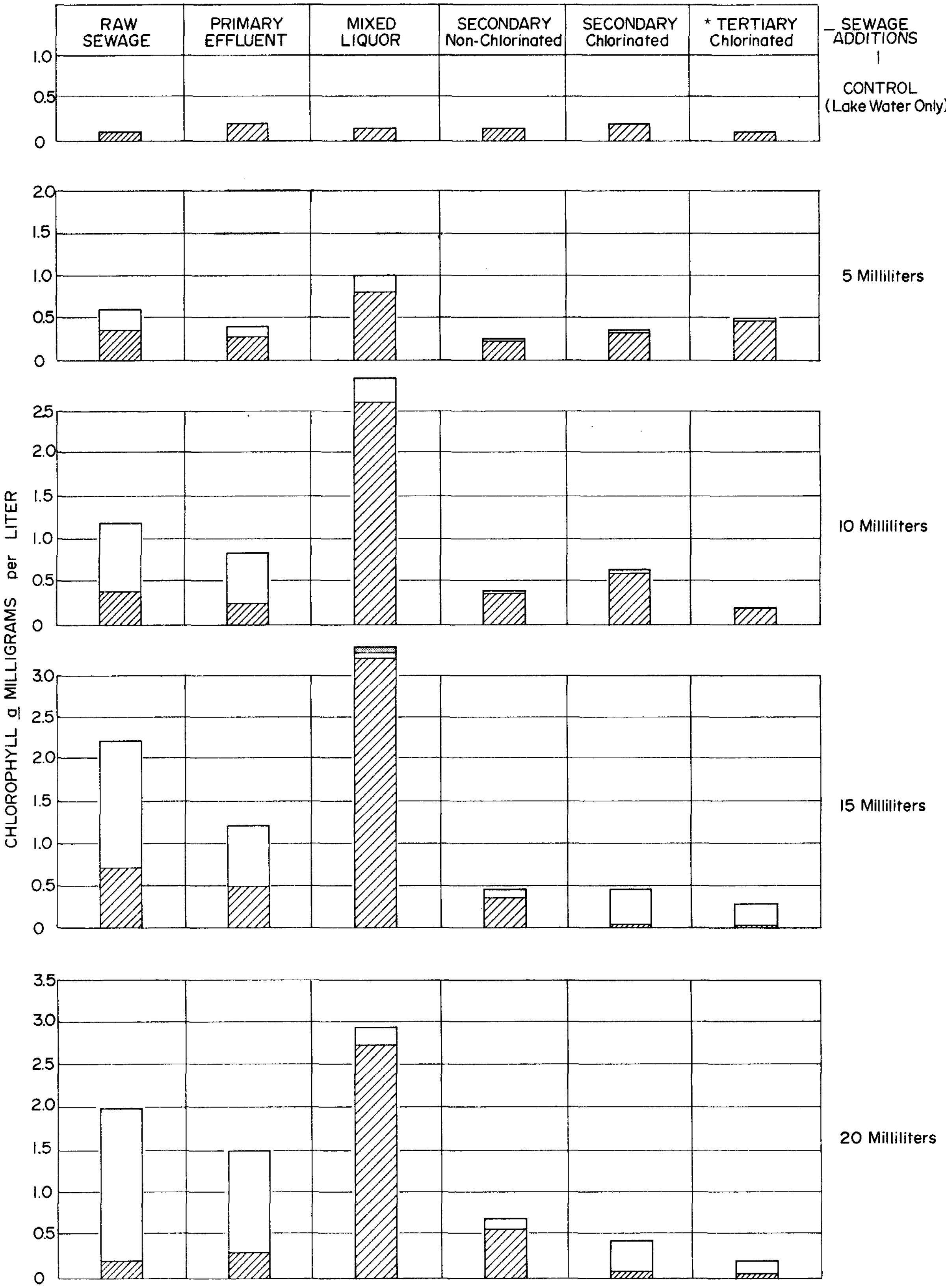
BIOASSAY RESULTS, SEWAGE ENRICHMENT EXPERIMENTS AFTER NINE DAYS GROWTH ON OSOYOOS LAKE WATER, 1971. Figure 7.9



* Assumes 45% Reduction at Penticton plant during the sampling period.

The major alga groups: Diatoms, Green Alga, and Blue-Green Alga, are shown as a percentage of the total bar height.

BIOASSAY RESULTS, SEWAGE ENRICHMENT EXPERIMENTS AFTER NINE DAYS GROWTH ON SKAHA LAKE WATER, 1971. Figure 7.10



*Assumes 45% Reduction at Penticton plant during the sampling period.

The major alga groups: Diatoms, Green Alga, and Blue-Green Alga, are shown as a percentage of the total bar height.

BIOASSAY RESULTS, SEWAGE ENRICHMENT EXPERIMENTS AFTER NINE DAYS GROWTH ON OKANAGAN LAKE WATER, 1971. Figure 7.11

addition of mixed liquor, *Navicula* sp. became dominant (90%). Secondary non-chlorinated sewage additions promoted the dominance of *Navicula* sp. again, but to a lesser degree than that of mixed liquor additions. A slight increase in the yield of the green alga *Scenedesmus* sp. was also noted in flasks with secondary non-chlorinated sewage additions. Enrichment of flasks with final chlorinated and tertiary treated sewage led to a green algal dominance, mainly *Scenedesmus* sp. and *Chlorine* sp., with some *Navicula* sp. present.

(d) Kalamalka Lake (Figure 7.12)

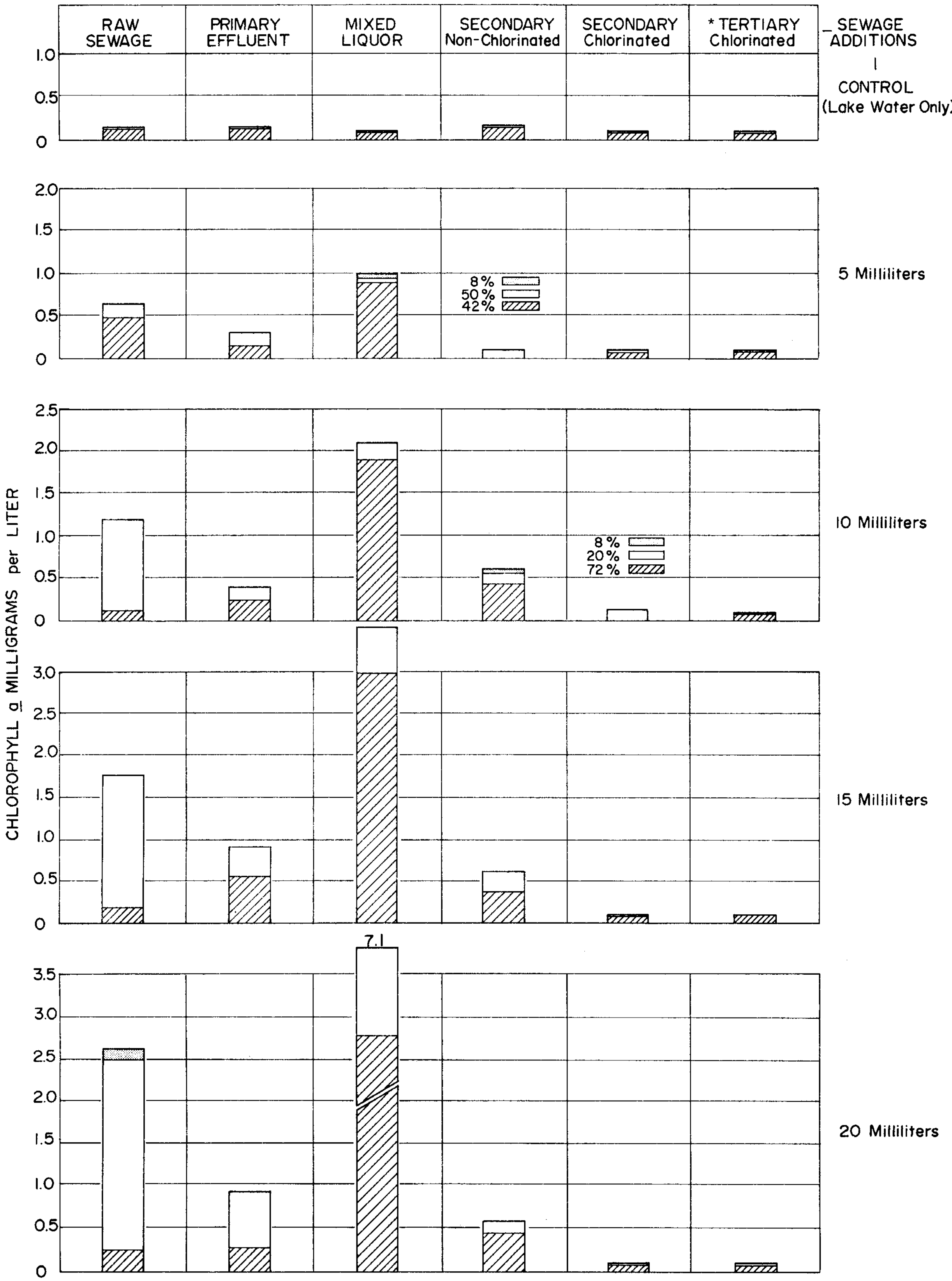
The controls after nine days contained almost exclusively diatoms, chiefly *Synedra* spp. and *Navicula* spp. Flasks receiving raw sewage promoted a complete species shift to that of green algal dominance, mainly *Scenedesmus* sp. and *Chlorine* sp. Primary treated sewage additions gave similar results to that of raw sewage additions, but with less algal growth. With the addition of mixed liquor and secondary non-chlorinated sewage, the diatoms remained dominant, chiefly *Navicula* spp. but with some *Scenedesmus* sp. present. Flasks with final chlorinated and tertiary treated sewage showed a diatom dominance again, but this time consisting of *Synedra* sp. in final chlorinated sewage, and *Synedra* sp. again, along with *Fragilaria crotonesis*, in flasks with primary treated sewage.

(e) Wood Lake (Figure 7.13)

The controls after nine days were made up chiefly of Cyanophyta species, mainly *Lyngbya* sp. and *Oscillatoria* spp. Flasks inoculated with raw sewage showed a succession of green algal dominance, chiefly *Scenedesmus* sp. and *Chlorella* sp. Flasks receiving primary treated sewage again showed Cyanophyta dominance, mostly *Oscillatoria* spp. Mixed liquor additions promoted more growth of diatoms, chiefly *Navicula* spp., but still had a high dominance of *Oscillatoria* spp. Flasks enriched with secondary non-chlorinated sewage again promoted total dominance of diatoms, mainly *Navicula* spp. whereas the addition of final chlorinated and tertiary treated sewage, perpetuated a Cyanophyta dominance, chiefly *Oscillatoria* spp.

7.1.4 Trace Metal Experiments

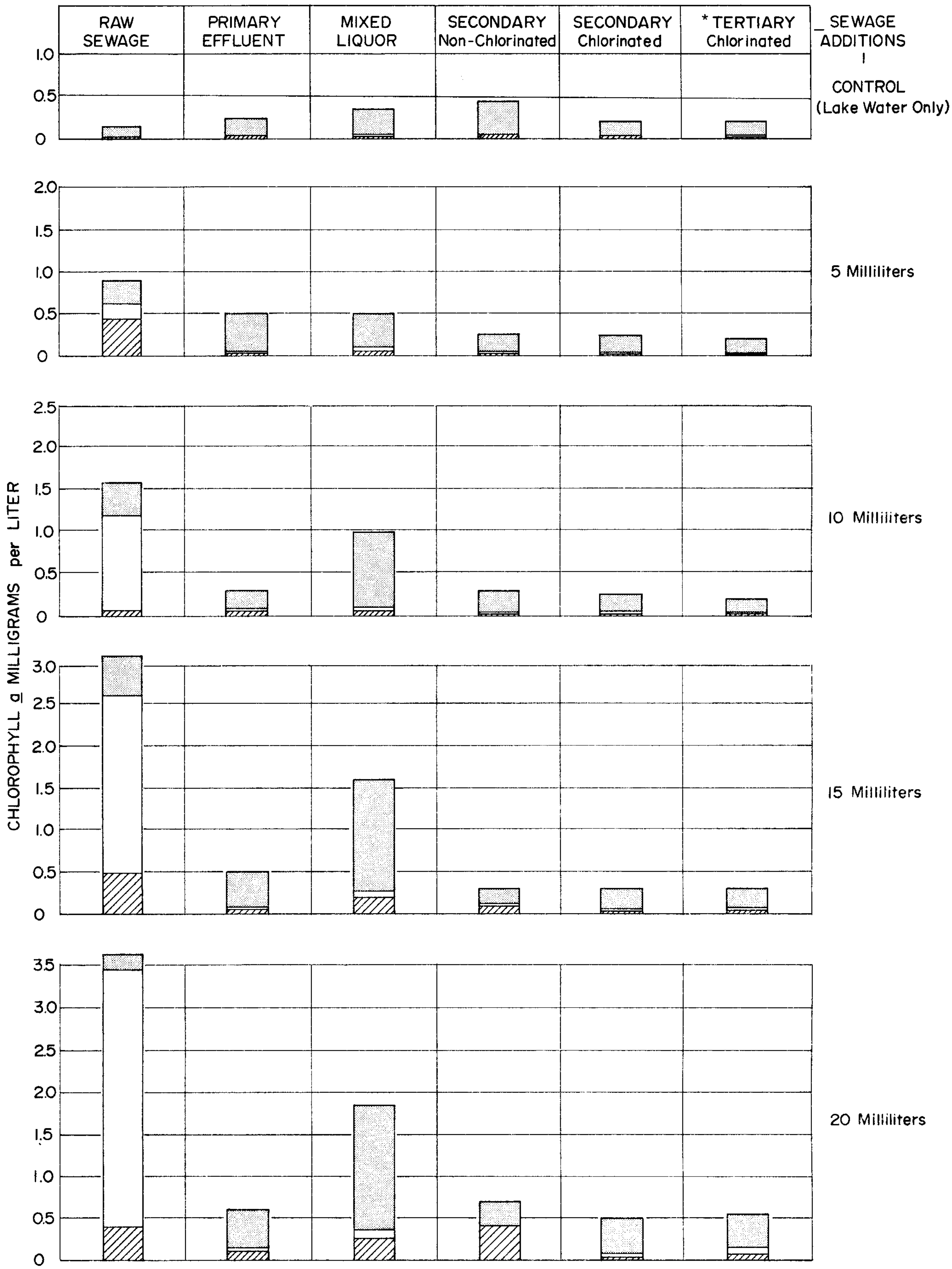
The fall run of the nutrient enrichment bioassay was incorporated into the trace metal experiments. The first seven flasks of each series received nutrient additions equivalent to those in the spring nutrient enrichment bioassay, 1971. The remaining flasks received combinations of nutrients [NO_3(N) and PO_4(P)]; trace metals; boron, iron and molybdenum, and the chelator, EDTA. The results obtained from the trace metal experiments will be discussed on the basis of uptake of radioactive carbon, because samples allotted for chlorophyll analysis were too small to yield accurate growth trends. Results will be discussed on a comparative basis, that is the effect of the addition of a nutrient and trace metal or chelator, will be compared to that of the nutrient addition alone.



*Assumes 45% Reduction at Penticton plant during the sampling period.

The major alga groups: Diatoms, Green Alga, and Blue-Green Alga, are shown as a percentage of the total bar height.

BIOASSAY RESULTS, SEWAGE ENRICHMENT EXPERIMENTS AFTER NINE DAYS GROWTH ON KALAMALKA LAKE WATER, 1971. Figure 7.12



*Assumes 45% Reduction at Penticton plant during the sampling period.

The major alga groups: Diatoms, Green Alga, and Blue-Green Alga, are shown as a percentage of the total bar height.

BIOASSAY RESULTS, SEWAGE ENRICHMENT EXPERIMENTS AFTER NINE DAYS GROWTH ON WOOD LAKE WATER, 1971. Figure 7.13

(a) Osoyoos Lake

The fall run of the nutrient enrichment bioassay showed similar growth trends to that seen in the spring run. NO_3(N) additions of 0.7 mg/liter showed growth equal to that of the control, whereas at the higher concentration of 1.2 mg/liter, growth was observed to be less than that of the control. Phosphorus addition at the lowest concentration (0.03 mg/liter) showed growth inhibition, whereas at the higher concentration (0.09 mg/liter) growth was stimulated beyond that of the control. Addition of NO_3(N) and PO_4(P) together at both concentrations, showed the greatest growth.

Stimulation of algal growth was evident with boron additions at the lowest concentration, whereas at higher concentrations growth was inhibited (Table 7.1) An increase in algal growth was noted when boron and NO_3(N) were added to test samples. Additions of PO_4(P) at the lower concentration with boron at both concentrations, 10 and 100 g/l, stimulated growth beyond that of phosphorus additions alone, but to a lesser degree than with nitrogen and boron additions. Phosphorus additions at the highest concentration and nitrogen and phosphorus additions together at both concentrations, together with boron at both concentrations, all showed algal growth less than that of the controls (Table 7.1).

Addition of EDTA at the lowest concentration showed growth less than the control, whereas at the highest concentration algal growth was much higher than the control (Table 7.1). Nitrate additions at both concentrations along with both levels of EDTA showed stimulation of algal growth when compared with flasks with NO_3(N) additions alone. Flasks receiving PO_4(P) at the lower concentration along with EDTA at both concentrations, showed growth stimulation, but to a lesser degree than that of NO_3(N) and boron additions. Phosphorus additions at the highest concentration along with both concentrations of EDTA proved to be inhibitory to algal growth (Table 7.1). Addition of NO_3(N) and PO_4(P) together at the lowest concentration and with EDTA at the lowest concentration showed no increase in algal growth, whereas the highest concentration of NO_3(N) and PO_4(P) together and EDTA showed marked increases in growth (Table 7.1).

Additions of EDTA and iron, stimulated growth in all flasks, with the greatest response noted with the addition of higher concentrations of EDTA and iron and NO_3(N) and PO_4(P) together (Table 7.1).

Growth was stimulated in most flasks with the addition of molybdenum. The greatest response occurred with the addition of the highest concentration of molybdenum along with the addition of the higher concentration of NO_3(N) and PO_4(P) together (Table 7.1).

(b) Skaha Lake

The fail run of the nutrient enrichment bioassay on one mid-lake station in Skaha Lake showed similar results to that of the spring run, except that the

TABLE 7.1
RESULTS OF TRACE METAL EXPERIMENTS 1971 - OSOYOOS LAKE

Trace Metal Additions \ Nutrient Additions	Control	Nitrogen		Phosphorus		Nitrogen & Phosphorus	
	0	0.7	2.1	.03	.09	0.7 + .03	2.1 + .09
Boron .01	+ 1.3	e 1.0	+ 1.5	+ 1.3	- 0.9	- 0.8	- 0.7
Boron .11	- 0.5	+ 1.3	+ 1.6	+ 1.5	- 0.9	- 0.9	+ 0.5
EDTA .01	- 0.8	+ 1.4	+ 1.6	+ 1.5	- 0.9	- 0.5	+
EDTA .02	+ 1.3	+ 1.3	+	+ 1.7	- 0.9	+ 1.2	+ 1.2
EDTA + Iron .01 .01	+ 1.3	+ 1.2	+ 1.4	+ 1.7	+ 1.3	+ 1.1	+ 1.2
EDTA + Iron .08 .11	+ 1.3	+ 1.3	+ 1.2	+ 1.5	+ 1.3	+ 1.2	+ 1.4
Molybdenum .01	+ 1.4	+ 1.2	+ 1.4	+ 1.5	e 1.0	+ 1.1	e 1.0
Molybdenum .11	+ 1.1	+ 1.3	+ 1.7	+ 1.2	e 1.0	e 1.0	+ 1.2

TABLE 7.2
RESULTS OF TRACE METAL EXPERIMENTS 1971 - SKAHA LAKE

Trace Metal Additions \ Nutrient Additions	Control	Nitrogen		Phosphorus		Nitrogen & Phosphorus	
	0	0.7	2.1	.03	.09	0.7 + .03	2.1 + .09
Boron .01	+ 1.4	+ 1.1	- 0.8	- 0.8	e 1.0	e 1.0	e 1.0
Boron .11	- 0.9	+ 1.1	- 0.2	- 0.3	e 1.0	- 0.7	+ 1.1
EDTA .01	- 0.9	- 0.7	+ 1.1	- 0.9	+ 1.1	e 1.0	+ 1.2
EDTA .08	+ 1.3	+ 1.2	e 1.0	+ 1.1	- 0.9	e 1.0	+ 1.3
EDTA + Iron .01 .01	- 0.8	+ 1.1	- 1.2	+ 1.1	= 0.9	+	+ 1.4
EDTA + Iron .08 .11	- 0.9	+ 1.2	+ 1.1	- 0.8	- 0.9	+ 1.1	+ 1.2
Molybdenum .01	+ 1.4	+ 1.2	+ 1.4	+ 1.5	e 1.0	+ 1.1	e 1.0
Molybdenum .11	+ 1.1	+ 1.3	+ 1.7	+ 1.2	e 1.0	e 1.0	+ 1.2

Results of Trace Metal Experiments, 1971.
+ (1.0) growth greater than controls.
- (1.0) growth less than controls.
e (=1.0) growth equal to controls.

addition of nitrogen at the highest concentration (2.1 mg/liter) showed the greatest production of algae (Table 7.2),

With the addition of boron at the lowest concentration, algal growth was stimulated beyond that of the control, whereas with the higher addition of boron, growth was inhibited (Table 7.2). Nitrate additions at the lowest concentration with boron at both concentrations and NO_3(N) and PO_4(P) together at higher concentration of boron were all stimulatory to algal growth. All other nutrient additions with boron additions were inhibitory to algal growth (Table 7.2).

With the addition of EDTA at the lowest concentration, growth was less than the control, whereas at the highest concentration, growth was stimulated beyond that of the control (Table 7.2). Nitrate addition at both concentrations with EDTA additions, were inhibitory to algal growth, whereas growth was stimulated with all other NO_3(N) and EDTA additions. Phosphate and EDTA additions together in the lower concentrations showed growth less than that of PO_4(P) additions alone. Addition of the lowest concentrations of phosphate along with the higher concentration of EDTA promoted growth slightly above that of PO_4(P) addition alone. The opposite trend occurred for the highest addition of phosphorus with slight growth stimulation and inhibition with the lower and the higher concentrations of EDTA respectively. Additions of NO_3(N) and PO_4(P) together at the highest concentrations along with EDTA at the higher concentration, produced the greatest production of algae as compared to all other nutrient additions with boron (Table 7.2).

The controls and flasks receiving additions of PO_4(P) at the lowest concentration, and EDTA and iron at higher concentration, together with flasks inoculated with PO_4(P) highest concentration and iron at both concentrations, all produced algal growth less than the flasks without EDTA and iron. In all other flasks. Growth was greater than the controls, with the greatest response being with the additions of the highest concentration of NO_3(N) and both concentrations of NO_3(N) and PO_4(P) together, along with EDTA and iron at both concentrations (Table 7.2).

In all cases, the addition of Molybdenum was inhibitory to algal growth, except for the addition of NO_3(N) and PO_4(P) together at the highest concentration along with the lowest concentration of molybdenum. In this instance, growth was stimulated a little beyond the flask with NO_3(N) and PO_4(P) alone (Table 7.2)

(c) Okanagan Lake

The fall run of the nutrient enrichment bioassay, 1971, showed stimulation of growth with all nutrient additions. Nitrate additions at the highest concentration showed the greatest production of algae. Flasks inoculated with PO_4(P) at the lowest concentration showed the next highest production of algae. Nitrate additions at the lowest concentration produced good growth, but to a lesser degree than PO_4(P) additions at the lowest concentration (Table 7.3). Addition of PO_4(P) at the highest concentration and additions of NO_3(N) and PO_4(P) together at both concentrations, all showed equal growth promotion to slightly above that of the controls (Table 7.3).

Some stimulatory effect on algal growth was evident with boron additions alone at both concentrations (Table 7.3). Growth inhibition was observed with the additions of NO_3(N) and boron in all combinations. PO_4(P) additions in the lowest concentration and the highest concentration along with additions of boron in the lowest and highest concentrations were stimulatory to growth, whereas all other PO_4(P) and boron additions were inhibitory to algal growth. Additions of NO_3(N) and PO_4(P) together at both concentrations along with both concentrations of boron, all promoted the greatest algal growth (Table 7.3),

Addition of EDTA in most all cases showed greater growth than that of the controls. EDTA additions alone showed increased growth with the increased concentration of EDTA. NO_3(N) additions along with both concentrations of EDTA showed growth stimulation with the greatest response with the addition of the lowest concentration of NO_3(N) along with the highest concentration of EDTA. All PO_4(P) additions along with EDTA showed approximately the same amount of growth stimulation except for the addition of PO_4(P) at the highest concentration along with EDTA at highest concentration, which was only slightly above the others Flasks receiving additions of NO_3(N) and PO_4(P) together showed a similar trend to other flasks with the addition of EDTA (Table 7.3).

Additions of EDTA and iron alone showed growth stimulation with the greatest response being the addition at the highest concentration. In all cases, NO_3(N) additions alone with EDTA and iron were inhibitory to algal production, except for the addition of NO_3(N) at the highest concentration along with the lowest concentration of EDTA and iron (Table 7.3). PO_4(P) additions along with EDTA and iron showed growth inhibition whereas additions of NO_3(N) and PO_4(P) together, along with EDTA in all combinations showed the greatest growth stimulation (Table 7.3).

(d) Kalamalka Lake

The effects of trace metals on algal growth could not be observed on the sample taken from Kalamalka Lake as initial phytoplankton populations were too low to yield distinguishable effects. These results lend support to the statement that Kalamalka Lake is the most Oligotrophic lake in the Okanagan Basin.

(e) Wood Lake

The fall run of the nutrient enrichment bioassay, 1971 showed growth stimulation with all nutrient additions, with the greatest algal growth in flasks with NO_3(N) at highest concentrations, and NO_3(N) and PO_4(P) together at highest concentrations (Table 7.3).

TABLE 7.3
RESULTS OF TRACE METAL EXPERIMENTS 1971 - OKANAGAN LAKE

Trace Metal Additions \ Nutrient Additions	Control	Nitrogen		Phosphorus		Nitrogen & Phosphorus	
	0	0.7	2.1	.03	.09	0.7 + .03	2.1 + .09
Boron .01	+ 1.2	e 1.0		+ 1.1	e 1.0	+ 1.3	+ 1.3
Boron .11	+ 1.1	e 1.0	- 0.7	- 0.8	+ 1.3	+ 1.3	+ 1.1
EDTA .01	+ 1.2	+ 1.1	e 1.0	+ 1.1	+ 1.1	- 0.7	- 0.8
EDTA .08	+ 1.4	+ 1.3	+ 1.1	+ 1.1	+ 1.2	+ 1.3	+ 1.5
EDTA + Iron .01 .01	+ 1.2	- 0.9	+ 1.2	e 1.0	- 0.7	+ 1.2	+ 1.1
EDTA + Iron .08 .11	+ 1.3	e 1.0	e 0.9	- 0.8	e 1.0	+ 1.2	+ 1.2
Molybdenum .01	+ 2.2	- 0.3	- 0.7	- 0.5	- 0.5	e 1.0	- 0.3
Molybdenum .11	e 1.0	- 0.4	- 0.5	- 0.4	- 0.5	- 0.5	- 0.4

TABLE 7.4
RESULTS OF TRACE METAL EXPERIMENTS 1971 - WOOD LAKE

Trace Metal Additions \ Nutrient Additions	Control	Nitrogen		Phosphorus		Nitrogen & Phosphorus	
	0	0.7	2.1	.03	.09	0.7 + .03	2.1 + .09
Boron .01	e 1.0	e 1.0	- 0.9	e 1.0	e 1.0	e 1.0	- 0.9
Boron .11	e 1.0	e 1.0	- 0.9	- 0.9	- 0.9	e 1.0	e 1.0
EDTA .01	+ 1.3	+ 1.2	e 1.0	e 1.0	- 0.9	+ 1.1	+ 1.1
EDTA .08	+ 1.2	+ 1.1	+ 1.1	e 1.0	+ 1.3	+ 1.2	+ 1.3
EDTA + Iron .01 .01	+ 1.2	+ 1.3	+ 1.1	- 0.9	+ 1.3	+ 1.3	+ 1.3
EDTA + Iron .08 .11	+ 1.2	+ 1.3	+ 1.1	e 1.0	- 0.9	+ 1.3	+ 1.6
Molybdenum .01	+ 1.4	+ 1.3	+ 1.4	+	+ 1.2	+ 1.3	+ 1.5
Molybdenum .11	+ 1.3	+ 1.2	+ 1.2	+ 1.1	e 1.0	+ 1.3	+ 1.4

Results of Trace Metal Experiments, 1971.
+ (1.0) growth greater than controls.
- (1.0) growth less than controls.
e (=1.0) growth equal to controls.

All additions of boron, alone or in combination with nutrients, showed growth equal to or less than that of the controls (Table 7.4).

Growth patterns with EDTA and nutrients followed different trends from those observed with boron additions. In this case, growth increased with all EDTA additions except for PO_4(P) at the highest concentration and EDTA at the lowest concentration. Additions of NO_3(N) and PO_4(P), together at the highest concentration, along with EDTA both concentrations showed the greatest algal growth (Table 7.4).

Similar growth patterns were observed with the addition of EDTA and iron to that of additions of EDTA, except there was greater production of algae in this series. Every flask was stimulated beyond that of a nutrient addition alone, except for the addition of PO_4(P) at the lowest concentration along with EDTA at the lowest concentration, and PO_4(P) at the highest concentration along with EDTA at the highest concentration, which were slightly below the control (Table 7.4).

The highest yield of algae was produced with the addition of nutrients and molybdenum as compared to all other trace metal and chelator additions in Wood Lake (Table 7.4). The greatest growth response was observed in flasks with additions of NO_3(N) at highest concentration and NO_3(N) and PO_4(P) together at the highest concentration along with both concentrations of molybdenum.

7.1.5 General Discussion

Results from four different experiments conducted on the six main lakes in the Okanagan Basin permitted an evaluation of the role of nutrients in regulating algal growth. Further information was gained on the causes of eutrophication of localized areas within lakes that are currently exhibiting nuisance conditions.

Kalamalka Lake and the main water mass of Okanagan Lake are currently in a nutrient deficient state. This was indicated by results from both the nutrient enrichment and pure culture bioassay experiments. In these lakes, NO_3(N) and PO_4(P) when added together, stimulated the greatest algal growth. When each nutrient was added alone, little algal growth occurred. Results from the pure culture bioassay experiments indicated a paucity of available nutrients, since little growth of the test algae was noted when added to filtered water.

Certain localities of Okanagan Lake exhibited nutrient-rich characteristics, namely in the Vernon Arm, Armstrong Arm and the near-shore water mass in the vicinity of Kelowna and Summerland. At these localities, NO_3(N) when added alone was in most instances, stimulatory to algal growth, while PO_4(P) additions were not. These results indicate a sufficient supply of PO_4(P) and a deficiency of NO_3(N). The growth of test algae in the pure culture bioassay experiments was moderate to high at all these localities, again indicating a 'residual' nutrient supply.

Skaha Lake appeared to be limited more by $NO_3(N)$ than $PO_4(P)$, for most additions of $NO_3(N)$ were stimulatory while $PO_4(P)$ additions were not. Currently, the most productive region of Skaha Lake is in the north end off the mouth of Okanagan River, where yields of test algae were the highest among lakes tested. Much of the main water mass of Skaha Lake exhibited nutrient-rich characteristics with no apparent $PO_4(P)$ limitation.

Vaseux and Osoyoos Lakes appeared to be limited by both $NO_3(N)$ and $PO_4(P)$, for the addition of both nutrients together, produced the greatest algal yield. The noted yield was considerably higher than that observed in Kalamalka and Okanagan Lakes, largely attributable to a much higher standing stock of phytoplankton in Vaseux and Osoyoos Lakes. The station located off the mouth of the Okanagan River in Osoyoos was more productive than the station located in the central portion of the lake, showing a greater response to $NO_3(N)$ than to $PO_4(P)$ additions. Results of the pure culture bioassay experiments also indicated that the most productive region of Osoyoos Lake was off the mouth of the Okanagan River, where moderate to high yields of the test algae were obtained. Vaseux Lake showed moderate yields of algae, indicating some nutrient availability at the time of the experiments.

Results from experiments conducted on Wood Lake water indicate it is one of the most productive (eutrophic) lakes in the valley. Additions of $PO_4(P)$ had no effect whatsoever, while $NO_3(N)$ additions promoted an excellent algal growth response. Results from the Pollution Control Branch experiments showed that an ample supply of available nutrients are present in Wood Lake throughout much of the growing season.

Historically, sewage treatment has been carried out primarily for community health reasons, and has not been concerned with aesthetic values such as increased plant growth. Only the water quality deterioration of many of the larger lakes to a point of aesthetic unacceptability has created the demand for research and control in this area.

Results from the sewage enrichment experiments strikingly illustrated the fertilizing capacity of domestic wastes when discharged to lakes in the Okanagan Valley. Preliminary results indicated that biological treatment of wastes often only increases the availability of plant nutrients, and hence does very little to ameliorate an algal nuisance problem. Increasing the amount of sewage added to lake water simply changed the direction of algal succession toward a blue-green algae dominance.

The trace metal experiments gave some dues as to the possible role of trace metals and a chelator in regulating phytoplankton growth, but no definitive conclusions can be drawn at this time from these preliminary experiments.

7.2 PHYTOPLANKTON

No detailed phytoplankton enumeration was conducted as part of the present study. Fortunately, the work of Stein and Coulthard (1971) included some enumeration data of dominant and sub-dominant phytoplankton in each of the main valley lakes (Table 7.5).

The phytoplankton populations in Wood Lake are characterized by the dominance of blue-green algae in most samples, at all depths, throughout the season. *Oscillatoria* sp. was the dominant species, while *Aphanaizomenon* was common during the summer. A few diatoms occur in early spring in Wood Lake, but these are quickly replaced by a blue-green algae dominated assemblage. The populations were among the largest recorded, averaging 7,900 cells per milliliter.

In Kalamalka Lake, phytoplankton populations are sparce - 700 cells per milliliter, and diatoms are the dominant form, chiefly *Asterionella formosa*, *Fragilaria crotonesis*, and *Synedra acus*. Green algae are not too prevalent in Kalamalka. However, the phytoflagellates comprise over 51% of the total population in early summer and early fall. The more important species are *Cryptomonas ovata*, *Chromulina* spp and *Dinobryon certularia*.

Okanagan Lake phytoplankton is dominated chiefly by diatoms with some blue-green algae, but there is considerable variation from station-to-station. Phytoplankton density is generally low, averaging approximately 1,500 cells per milliliter as compared to 7,000 to 8,000 cells in Wood and Osoyoos Lakes respectively (Table 7.5). Currently, the dominant diatoms in Okanagan Lake are *Fragilaria crotonesis* , *Asterionella formosa* and *Melosira italica*. The blue-green algae common in mid-summer and in the fall are chiefly *Aphanotheca nidulans, Anabaena flos-aquae* and *Lyngbya limnetica*. The dominant phytoflagellate is *Cryptomonas ovata*.

Phytoplankton of Skaha Lake is composed chiefly of diatoms with a blue-green algal pulse in late August and early September. Average phytoplankton density is about 3,700 cells per milliliter. The dominant diatoms in Skaha Lake are *Asterionella formosa*, *Fragilaria crotonesis* and *Cyclotella comta*. In the summer these diatom species are replaced by *Melosira italica*, and *Tabellaria* spp. The dominant blue-green algae are *Aphanizomenon flos-aquae*, *Aphanotheca microscopica* and *Anabaena circinalis*.

The phytoplankton succession in Osoyoos Lake is characterized by a spring pulse of diatoms, a summer bloom of blue-greens and phytoflagellates and a return to diatoms in the fall. The principal diatom species in Osoyoos Lake are *Asterionella formosa*, *Fragilaria crotonesis*, *Cyclotella comta* and *Melosira italica*. The dominant phytoflagellate was *Cryptomonas ovata*. The blue-green algae recorded commonly are *Oscillatoria* spp., *Lyngbya limnetica* and *Aphanizomenon flos-aquae*.

TABLE 7.5

PHYTOPLANKTON BY SEASONS*

STATION	ANNUAL AVERAGE NUMBER/ml	DOMINANT ORGANISMS BY GROUP EARLY SUMMER (May-July)	DOMINANT ORGANISMS BY GROUP LATE SUMMER (July) August-Sept.	SPRING (April)
W3	7900	--	BG	BG (Ph)
KA2	400	BG, D = Ph	Ph, BG, D	Ph = D
OK2	1925	BG, D	BG, D	D, Ph
OK5	1475	D, BG	BG, D	Ph = D
OK8	1650	D, BG	BG, D	D, Ph
OK11	1350	D, BG	BG, D	D, Ph
SK2	3825	D, BG	BG, D	D = Ph
SK5	3670	D	D, BG	D = Ph
OY2	3300	D	BG, Ph	D = Ph
OY5	7650	D, BG	BG, Ph	D, Ph

* Phytoplankton density, seasonal succession by group, and dominant phytoplankton species in the Okanagan main valley lakes (after Stein and Coulthard, 1971).

NOTE: Dominant group listed first: = means equal numbers of each.
BG - bluegreen algae: D - diatoms: Ph - phytoflagellates

DOMINANT PHYTOPLANKTON SPECIES

LAKE	
WOOD	*Oscillatoria* spp., *Aphanizomenon flos-aquae*
KALAMALKA	*Anabaena flos-aquae*, *Lyngbya limnetica*. *Asterionella formosa*, *Fragilaria crotonensis* *Cryptomonas ovata*, *Chromulina* spp. *Melosira italica*, *Synedra acus*
OKANAGAN	*Fragilaria crotonensis*, *Asterionella formosa*, *Anabaena flos-aquae*, *Aphanothece* spp. *Melosira italica*, *Coelosphaerium naegelianum*, *Cryptomonas ovata*.
SKAHA	*Asterionella formosa*, *Fragilaria crotonensis*, *Cyclotella* sp. *Melosira italica*, *Tabellaria* sp. *Aphanizomenon flos-aquae*, *Oscillatoria* sp., *Anabaena circinalis*, *Aphanothece microscopica*.
OSOYOOS	*Asterionella formosa*, *Fragilaria crotonensis* *Cyclotella* sp., *Melosira islandica* *Cryptomonas ovata*, *Lyngbya limnetica* *Oscillatoria* sp., *Aphanizomenon flos-aquae* *Phanothece microscopica*, *Synedra acus*

The previous paragraphs have outlined in some detail the more common phytoplankton species in the main valley Okanagan lakes. In those lakes exhibiting eutrophic characteristics, i.e. Wood, Osoyoos Lakes; blue-green algae tend to be dominant throughout much of the summer and fall periods. In those lakes exhibiting less eutrophic conditions, diatoms and phytoflagellates were the most abundant groups. In Skaha, Wood and Osoyoos Lakes, where a moderately high concentration of PO_4(P) occurs at spring overturn, there was a rapid growth of diatoms followed by a pulse of blue-green algae, whose density appeared to a large extent dependent upon the initial concentration of available PO_4(P). In Wood Lake where there was an over-abundance of PO_4(P) at spring overturn (80 *u*g/ liter), blue-green algae tended to dominate the phytoplankton assemblage from spring to early fall. In Okanagan and Kalamalka Lakes, where the concentration of PO_4(P) at spring overturn is low (<10 *u*g/liter), diatoms dominate the spring pulse, with phytoflagellates common during summer and with a return to diatom dominance in the fall. The observed seasonal succession of phytoplankton provides further evidence of the trophic character of the Okanagan main valley lakes.

7.3 ATTACHED ALGAE AND ROOTED AQUATIC VEGETATION

Since lake water quality changes are often reflected in growth of rooted aquatic vegetation and periphyton, which can in turn have a notable effect on people's use of the water body; the extent and magnitude of this growth was studied in 1972. Attention was focused upon the determination of biomass and relative growth rate of attached algae (periphyton). Also included in the study was a cursory examination of the nature of the substratum (sand, rock, gravel) of the littoral zone of the main valley lakes and documentation of the extent of use of this zone by aquatic macrophytes.

Vaseux Lake is most affected by littoral development, with approximately 50% of the lake area included in the 0 to 6 meter contour (Table 7.6). Okanagan Lake, North and Vernon Arms, had about 28% of their surface area comprised of littoral zone, and in Osoyoos Lake approximately 23% of its area was included in the 0 to 6 meter contour of the littoral zone. Skaha Lake had extensive littoral benches along the eastern shoreline which comprised approximately 15% of total lake area. The remaining basins of Okanagan, Wood and Kalamalka Lakes are steep sided and have a negligible littoral region, comprising about 5 to 9% of the total lake surface area. Emergent and submergent vegetation covers almost the entire littoral zone in Vaseux Lake, but in the other main valley lakes, epilithic and epipetic benthic diatoms are the dominant vegetation.

The dominant emergent macrophyte in all lakes was *Scirpus validus*. *Nymphaea odorata* and *Nuphar luteum* were dominant floating leaved plants, commonly found in the littoral zones of Vaseux and Osoyoos Lakes. The dominant submergent plants,

TABLE 7.6

LAKE AREA, LITTORAL AREA. AND PERCENT OF LAKE AREA COMPRISED OF LITTORAL

LAKE (MAP NUMBER)	A LAKE AREA		A_L LITTORAL AREA		% LITTORAL
	ACRES	KM^2	ACRES	KM^2	A_L/A
OSOYOOS (Canadian portion)	3,706	15.0	860	3.5	23.2
VASEUX	680	2.7	336	1.3	49.4
SKAHA	4,966	20.7	784	3.2	15.7
OKANAGAN - South	14,998	60.7	1,298	5.3	8.6
- Central	8,722	35.3	862	3.5	9.8
- North	9,142	37.0	2,612	10.6	28.5
KALAMALKA	6,398	25.8	359	1.5	5.6
WOOD	2,298	9.3	208	0.8	9.0

often causing nuisance conditions were *Myriophyllum exalbescens*, *Potomogeton richardsonii* and *Potomogeton crispus.* Areas currently exhibiting extensive weed beds, where harvesting has either been carried out or has been proposed, are Vernon Arm and Kelowna shoreline south of the floating bridge in Okanagan Lake; the south end of Wood Lake; patches along the east shore of Skaha Lake; Vaseus Lake, and along the west shore, north and middle basins of Osoyoos Lake (Table 7.7).

Results of periphyton studies indicate that Wood Lake produces the greatest yield of periphyton per meter squared of littoral zone, and the Vernon Arm of Okanagan Lake produces the second highest yield (Table 7.8). Yield of periphyton at both stations in Vaseux Lake and off the mouth of the Okanagan River in Skaha Lake, and in Osoyoos Lake were also high, ranking third and fourth respectively (Table 7.8). (See Maps 3 to 10). The average periphyton growth at other lake stations was substantially less than the above noted, with values varying from 0.3 to 0.8 mgm/cm^2. The heavy periphyton growth noted in Wood, Skaha, Vaseux and Osoyoos Lakes was, in most cases, at stations located either in the vicinity of direct known sewage effluent discharges, or very close to the plume of the Okanagan River. The lowest average yield of periphyton was noted in Kalamalka Lake and at 6 of the 8 stations in Okanagan Lake (Table 7.8). Low growth was also noted at stations along the east shore of Skaha Lake. This was thought to be due to a paucity of nutrients along the eastern shoreline, as the main flow of the Okanagan River is directed to the western shoreline by a small training dyke. The situation noted in Skaha Lake, where one station exhibits high growth and others very low growth, is similar to that noted in Okanagan Lake where 6 of the 8 stations showed very low growth, while those in more eutrophic situations, i.e. located adjacent to the Kelowna and Vernon Arm areas, showed much higher growth.

There were general trends observed in the seasonal growth and succession of periphyton assemblages in all main valley lakes (Maps 3 to 10).

1. The maximum growth occurred in May or early June and consisted chiefly of diatoms.
2. A second, smaller growth pulse occurred in late August and was dominated by green or blue-green algae.
3. Dominant species in spring algal assemblages tended also to be dominants in the fall assemblage.
4. Most peaks in the plot of chlorophyll-a values coincided with the second growth peak in mid-August.
5. The lowest periphyton production occurred in most lakes in the period from mid-July to early August
6. The summer algal assemblages at highly productive stations were generally dominated by *Cladophora glomerata* or *oscillatoria* spp.
7. There was a high rate of occurrence of blue-green algae at all stations located in nutrient-rich areas. In more Oligotrophic areas, diatoms were the principal group throughout the growing season.

TABLE 7.7

TENTATIVE IDENTIFICATION OF AQUATIC MACROPHYTES IN THE OKANAGAN MAIN VALLEY LAKES

LAKE	STATION NUMBER [a]	TENTATIVE IDENTIFICATION
KALAMALKA	1	*Potamogeton crispus* (3)
	1A	*Nymphaea odorata* (1)
	1B	*Nuphar luteum* (1)
	2	*Nymphaea tetragona*
	3	*Potamogeton crispus* (3), *Myriophyllum alterniflorum* (3), *Nymphara odorata* (1), *Potamogeton* spp. (3)
	4	*Chara* sp. (3)
	5	*Nuphar luteum* (1)
	9	*Chara* sp. (3), *Potamogeton praelongus* (3)
	12A	*Potamogeton vaginatus* (3)
	12B	*Potamogeton richardsonii* (3)
	13	*Potamogeton* sp.(3)
	14A	*Elodea canadensis* (3)
	14B	*Potamogeton filiformis* (3), *Potamogeton crispus* (3), *Myriophyllum* sp.(3)
WOOD	2 & 6	*Elodea canadensis* (3), *Potamogeton crispus* (3) *Myriophyllum* sp.(3)
	3	*Ceratophyllum demersum* (3)
	3B	*Potamogeton crispus* (3)
	4	*Potamogeton crispus* (3), *Potamogeton gramineus* (3)
	11	*Ranunculus aquatilis* (1) and (3), *Potamogeton* sp.(3)
OKANAGAN	1-Vernon Arm	*Myriophyllum exalbescens* (3), *Potamogeton richardsonii* (3), *Potamogeton cadillaceus* (3), *Chara* sp.(3), *Myriophyllum* sp.(3)
	North Arm	*Scirpus validus* (2)
SKAHA	Most areas	*Scirpus validus* (2)

(1) Floating leafed (2) Emergent (3) Submergent

[a] Numbers refer to sampling stations on original field maps filed with Pacific Environment Institute, Environment Canada, West Vancouver, B.C.

TABLE 7.8

AVERAGE NET PRODUCTION RATE OF PERIPHYTON FROM APRIL 19 TO SEPTEMBER 17 (152 DAYS) ON GLASS SLIDES IN THE OKANAGAN LAKES.

(SOME SELECTED VALUES FROM THE LITERATURE ARE GIVEN FOR COMPARISON)

PRESENT STUDY		SEASONAL AVERAGE	NET PRODUCTION RATE	ASH FREE	DEPTH
LAKE	STATION NO	($mg/cm^2/14$ days)	($mg/m^2/day$)	($mg/m^2/day$)	(meters)
OSOYOOS	1	1.40	1,000	500	1.5
	2	0.44	310	155	"
	3	0.58	410	205	"
	4	0.48	343	171	"
	Average			258	
VASEUX	1	1.40	1,000	500	"
	2	1.50	1,070	535	"
	Average			517	
SKAHA	1	1.40	1,000	500	"
	2	0.26	185	92	"
	3	0.29	207	103	"
	Average			231	
OKANAGAN	1	0.45	321	160	"
	2	1.70	1,214	607	"
	3	0.33	236	118	"
	4	0.37	265	132	"
	5	0.75	536	268	"
	6	0.52	371	185	"
	7	0.43	307	153	"
	8	0.44	314	157	"
	Average			225	
KALAMALKA	1	0.42	300	150	"
	2	0.28	200	100	"
	3	0.34	243	121	"
	Average			124	
WOOD	1	1.90	1,357	678	"
	2	0.80	571	285	"
	Average			481	
LITERATURE					
FALLS LAKE, Washington State (Castenholz, 1960)		--	--	148	0.4
ALKALI LAKE, Washington State (Castenholz, 1960)		--	--	131	0.4
SEDLICE RESERVOIR, Czechoslovakia (Sladechek and Sladechekova, 1963)		--	--	256	1.0
LAKE 240, Kenora, Ontario (Stockner and Armstrong, 1971)		--	--	250[2] 21[3]	1.0
BORAX LAKE, California (Wetzel, 1964)		--	--	700	-
LAKE SUPERIOR, (West shore), Minnesota (Fox *et al*, 1969)		--	--	61	-

1. Assumes a 50% ash content
2. maximum rate
3. minimum rate

A summary of dominant algal species and the annual succession of periphyton in lakes appears in Table 7.9.

Attempts were made to relate the concentrations of N and P contained in attached algal cells to available external supplies. Results indicated that the ratio of N:P in periphyton growing in eutrophic waters was half that found in less productive stations; 5:1 compared to 14:1 in more Oligotrophic stations. Highest phosphorus values were noted in the spring samples in eutrophic locations, while nitrogen concentrations tended to be higher in late summer and early fall in all lakes.

7.4 BOTTOM FAUNA

When assessing the relation between bottom fauna, lake enrichment and pollution, one must bear in mind that the distribution of benthic invertebrates cannot be explained completely without taking temperature regime, lake morphology, and zoogeographical distribution into consideration. Furthermore, among benthic animals, midges (chironomids) are better indicators of the oxygen level than of the trophic level. The oxygen level is not absolutely dependent on the primary production in the upper waters, but is strongly influenced by, (among others) the relative volume of the deep water in the hypolimnion to that in the epilimnion. This means that lakes with nearly identical communities of bottom organisms may be at different trophic levels. A strong correlation between trophic levels and bottom fauna composition thus cannot always be expected, especially in mesotrophic lakes. In such lakes, the number and weight of animals per area and the distribution with depth both of total bottom fauna and of forms characteristic for different trophic communities, may be more important.

Rawson (Clemens, *et al*, 1939) conducted a preliminary survey of the bottom fauna of Okanagan Lake in 1935, concluding that the lake was Oligotrophic, perhaps even ultra-oligotrophic. Northcote and Larkin (1956) included benthic grab samples from Kalamalka Lake in their survey of 100 B.C. lakes. Ferguson (1949) took grab samples from Skaha Lake. Apart from these three brief surveys, the bottom fauna of the Okanagan main valley lakes has not been studied in any detail.

7.4.1 Okanagan Lake

A total of 32 stations were sampled in Okanagan Lake in 1969. Species composition and average number of bottom organisms per square meter of sediment are presented in Table 7.10. When these data are compared with Rawson's findings, it is obvious that the lake has become more productive over the past 34 years. Rawson found only 15% of the bottom fauna comprised of oligochaetes, whereas currently they account for over 50% of the total fauna. There has also been a significant increase in the total number of chironomids, *Iridium*, and other miscellaneous groups. The increase in abundance of oligochaetes together with the occurrence of deformed chironomids in certain regions of Okanagan Lake is suggestive of some degree of insecticide pollution (Saether, 1970).

TABLE 7.9

SEASONAL SUCCESSION OF DOMINANT ALGAE IN THE PERIPHYTON OF THE OKANAGAN MAIN VALLEY LAKES

LAKE			
Osoyoos	*Synedra tenera*	*Cymbella cistula* *Melosira* sp. *Synedra tenera*	*Cymbella cistula*
Vaseux	*Cymbella cistula* *Anabaeua circinalis*	*Amphora* sp. *Nodularia* sp. *Aulosira laxa*	*Epithemia argus* *Amphora* sp. *Cymbella cistula*
Skaha	*Synedra radians* *Synedra tenera*	*Achnanthes* sp. *Nodularia* sp. *Aulosira laxa* *glomerata* *Cladophora*	*Cymbella cistula*
Okanagan (North basin)	*Synedra* spp. *Amphora* sp.	*Spirogyra* sp. *Epithemia argus* *Gomphonema ventricosum*	*Diatoma vulgare* *Amphora* sp. *Spirogyra*
Okanagan (South basin)	*Synedra acus* *Synedra tenera*	*Gomphonema ventricosum* *Diatoma* sp.	*Synedra tenera* *Diatoma* sp.
Wood	*Synedra* spp. *Gomphonema ventricosum*	*Cladophora glomerata*	*Lyngbya* sp.
Kalamalka	*Synedra tenera* *Diatoma hiemale*	*Gomphonema ventricosum* *Achnanthes* spp. *Spirogyra* sp.	*Synedra tenera*

TABLE 7.10

THE AVERAGE NUMBER OF FAUNA PER SQUARE. METER IN THE OKANAGAN MAIN VALLEY LAKES. FROM ALL DEPTHS SAMPLED

	OKANAGAN LAKE[a]		OKANAGAN		SKAHA		OSOYOOS		KALAMALKA		WOOD	
SPECIES / NUMBER OF SAMPLES	NUMBER	PERCENT	NUMBER	PERCENT	NUMBER	PERCENT	NUMBER	PERCENT	NUMBER	PERCENT	NUMBER	PERCENT
	135	--	25[b]	--	5[c] 18[d]	--	5[c]	--	24[d]	--	15[d]	--
Chironomidae	268	73.6	841	38.6	444 607	11.4 6.1	827	15.0	602	55.4	539	71.7
Oligochaeta	53	14.6	1127	51.7	3199 7288	82.2 73.4	4551	82.7	416	38.3	157	20.9
Ephemeroptera	15	4.1	11	0.5	-- --	-- --	--	--	--	--	--	--
Amphipoda	12	3.3	41	1.9	142 --	3.6 --	--	--	--	--	--	--
Tricoptera	6	1.6	4	0.2	-- --	-- --	--	--	--	--	--	--
Pisidium	2	6.5	62	2.8	89 --	2.3 --	--	--	9	0.9	--	--
Gastropoda	2	6.5	48	2.2	-- --	-- --	--	--	--	--	--	--
Nemetoda	--	--	--	--	-- 2025	-- 20.4	--	--	22	0.2	33	4.3
Miscellaneous	6	1.6	44	2.0	18 15	0.5 0.1	124	2.3	37	3.4	24	3.2

[a] Rawson, 1935

[b] September 9-11, 1969, excluding stations adjacent to known sources of pollution

[c] September 11, 1969

[d] May 10-12, 1971

The northern region (Vernon, Armstrong Arms), is presently mesotrophic, based on the distribution and abundance of benthic organisms. Evidence of the pollution of the Vernon Arm by the Vernon Sewage Treatment Plant effluent was obtained in a series of stations taken from the mouth of Vernon Creek west to the vicinity of Okanagan Landing. The character of the fauna changed from one dominated by oligochaetes; *Limnodrilus hoffmeisterii* (eutrophic), to more mesotrophic indicators in the station just adjacent to Okanagan Landing. The mid-portion of the north basin between Okanagan Landing and Kelowna showed little change from the condition observed by Rawson nearly 40 years ago, and can still be considered Oligotrophic. It is interesting that one station adjacent to the mouth of Shorts Creek, (See Map 8), contained a predominance of mesotrophic indicator species, as opposed to other stations nearby that showed Oligotrophic forms. It was Shorts Creek that contributed up to 40% of the total phosphorus loadings to Okanagan Lake in 1970-71. This high load was largely particulate matter, and was attributed to extensive logging carried out in this watershed over the past few years. The relationship seen here is suggestive of moderate nutrient pollution because of poor land-use practices.

Stations 1 to 6 in Okanagan Lake were close to the pipe which discharges sewage from the City of Kelowna to Okanagan Lake. One station located very close to the pipe contained no organisms. Other stations in the immediate vicinity of the pipe, contained few organisms, but in stations further removed from the pipe, there was a tremendously large number of organisms of the Oligotrophic type.

Station 29, situated off the boat landing in Summerland, contained a high number of *Limnodrilus hoffmeisterii* and together with a presence of *Chironomus thummi* type and *Procladius* indicated a source of pollution to Okanagan Lake at this station. Stations further south in the basin adjacent to Penticton, the deeper waters, were typically Oligotrophic in faunal composition.

The bottom fauna of Okanagan Lake has shown considerable change since Rawson's investigation some 38 years ago. However, the fauna in the deeper water sediments show no apparent change over the 1935 condition, and the lake as a whole must still be classified as Oligotrophic in terms of the distribution and abundance of benthic organisms.

7.4.2 Skaha Lake

The bottom fauna in Skaha Lake is complicated by the presence of both oligrotrophic and eutrophic indicator species. This type of distribution of benthic fauna is not unusual for formerly Oligotrophic lakes, which by the sudden introduction of nutrients, are rapidly eutrophicating. The perplexing occurrence of Oligotrophic forms may be explained by the high flushing rate from Okanagan Lake water with the possibility of re-colonization from this lake. This, in combination with relatively high oxygen levels in the hypolimnion, may account for the somewhat varied faunal distributions noted in Skaha Lake.

There was a predominance of oligochaetes in Skaha Lake, with *Limnodrilus hoffmeisterii* as the dominant species. There were over 9,000 invertebrates per square meter in 1971, which was the highest density recorded for all lakes sampled in 1971 (Table 7.10). In 1969, the density was 3,892 per square meter, which was second only to Osoyoos Lake (Table 7.10). Of six chironomid species found, very few were indicative of eutrophic conditions. The absence of more eutrophic-indicating species may be the result of currents near the bottom which wash away some potential food such as detritus, thus creating a situation where food content is not high enough to support chironomid populations. Hence, forms adapted to less nutrient-rich sediments predominate.

7.4.3 Osoyoos Lake

The north and central basins of Osoyoos Lake are, according to the composition of the bottom fauna, moderately eutrophic and strongly eutrohpic, respectively. The central basin appears to have been enriched by surrounding communities. The northern basin is divided into two sub-basins with a pronounced underwater ridge between. This ridge may explain the difference between samples taken between the two northern sub-basins. The average number of bottom fauna per square meter of sediment surface in Osoyoos Lake was the highest recorded in the main valley lake system in 1969 (Table 7.10).

7.4.4 Kalamalka Lake

In 1935 Rawson found Kalamalka Lake to be a typical Oligotrophic lake, slightly richer than Okanagan Lake. He also noted that chironomids made up over 95% of the benthic fauna in the lake. In 1971, chironomids made up only 55% of the fauna. Thus, a significant shift in the faunal composition has taken place over the past 38 years.

The abundance of organisms per square meter in 1935 was of the same order of magnitude as those found during the current survey. One station situated about 50 meters from the mouth of Coldstream Creek in the northern part of Kalamalka Lake, showed some degree of mild pollution. *Chironomus* f.l. *flumosus* and C.f.l. *anthracinus* together with oligochaetes at a density of over 1,000 per square meter, indicated some enrichment from this stream. This finding correlates well with observations of nuisance rooted aquatic plant growths off the mouth of Coldstream Creek in 1971-72. Coldstream Creek drains an extensive cattle range area and is currently under intensive agricultural development.

Kalamalka Lake, on the basis of the distribution and abundance of benthic invertebrates, remains a typical Oligotrophic lake. The changes that have occurred in Kalamalka Lake since Rawson's investigations in 1935, are of much smaller magnitude than those found in Okanagan Lake.

7.4.5 Wood Lake

In 1935, Rawson found the benthic fauna of Wood Lake to be characteristic of a eutrophic lake; very high densities of oligochaetes and chironomids. He noted that in all 8 samples he collected, there were always more than 1,000 oligochaetes per square meter, and at a depth of 23 meters he found as many as 23,000 per square meter. Today the lake has very few organisms in the sediment (Table 7.10). In most areas no oligochaetes occur at all, and only a few specimens of *Chironomus attenuatus*. Two stations located near the outlet are obviously influenced by water entering the lake from Kalamalka Lake, but never-the-less have fauna typical of a eutrophic lake. However, even at these stations the number of oligochaetes was very much less than 1,000 per square meter (Table 7.10). The current limnological condition of Wood Lake does not alone explain the disappearance of what was undoubtedly a formerly rich fauna. The rate and duration of oxygen depletion is not so high as to explain the apparent paucity of invertebrates in Wood Lake. Saether and MacLean (1972) conclude that the only explanation must be the existence of some toxic compound in the sediments.

The arthropods are much more resistant to toxic compounds than most soft-bodied invertebrates, with the exception of insecticides which have little influence on worms and molluscs (Liebmann, 1960). Thus, it is suggested that the alleged toxic compound is not an insecticide, thus giving chironomids something of a comparative ecological advantage. High levels of mercury in the sediments do not alone seem to be of sufficient toxicity to cause the apparent decline.

7.4.6 General Summary

In summary, the distribution and abundance of benthic invertebrates has provided a trophic characterization of the main valley lakes that is consistent with current understanding of the overall biological production in these lakes. On the basis of benthic invertebrate abundance and species composition, the lakes can be ranked as follows:

Abundance			Species Composition (% Eutrophic Indicator Species)
1. Skaha	HIGH ↑	1.	Wood
2. Osoyoos		2.	Osoyoos
3. Okanagan		3.	Skaha
4. Kalamalka		4.	Okanagan-Kalamalka
5. Wood	↓ LOW		

7.5 ZOOPLANKTON

The varying nutrient load to the Okanagan main valley lakes and wide spectrum of trophic conditions offer an excellent opportunity to assess the response of certain Zooplankton populations to varying trophic states. Rawson studied the Zooplankton in Okanagan Lake in 1935. Northcote and Larkin (1956) reported on collections from Kalamalka Lake and Ferguson (1949) from Skaha Lake. Little or no work has been done on the remaining main valley lakes. Zooplankton studies as a part of the Okanagan Basin Study program consisted of a survey of Okanagan, Skaha and Osoyoos Lakes in September of 1959, and of these three plus Wood and Kalamalka Lakes, in August/September of 1971. The salient findings of these studies are reported below. Details of the survey results are listed in Appendix F and summarized in Tables 7.11 and 7.12.

7.5.1 <u>Okanagan Lake</u>

In total, thirteen species of crustacean plankton were found in the main valley lakes, and all of them were presented in Okanagan Lake (Table 7.11). Of four copepod species found, *Cyclops bicuspidatus thomasi* and *Diaptomus ashlandi* were the most abundant, contributing to about 60 and 30 % respectively of the total number of plankton species. Out of nine cladoceran Zooplankton species, *Daphnia thorata* was the most abundant, but its contribution to the total number of crustaceans was no greater than 1 to 2%. The second most abundant cladoceran was *Daphnia longiremis*. The remaining cladoceran species were in low number and as a rule less than 0.3% of the total (Table 7.12).

On the basis of vertical series taken in September 1969, it was found that most species of Zooplankton were distributed in the upper-most 25 meter layer. The most abundant species, *Diaptomus ashlandi* and *Cyclops bicuspidatus thomasi* were distributed throughout the 0 to 50 meter layer. The only exceptions were the nauplii of C. *bicuspidatus thomasi* which showed a maximum density in the 25 to 50 meter layer of water. Of the total plankters, 89% were located above the 50 meter depth contour.

The horizontal distribution of plankton in Okanagan Lake was more or less uniform throughout the central and most of the northern part of the lake in 1969, with densities of between 100 to 200 individuals per square centimeter (Table 7.12). The lowest amount of Zooplankton was found in the north arm of Okanagan Lake and this may be explained by the shallow depth at this station. A significantly higher number of Zooplankton were found in the south end of Okanagan Lake in 1969, but not in 1971.

The wide variation of the horizontal distribution of plankton as measured by settled volume (mm^3/cm^2) can be seen in Map 2. The highest plankton volume were found in September 1969, in the southern basin transects 1 to 3, with 14-20 mm^3/cm^2. In the vicinity of Kelowna, there were between 9 to 17 mm^3/cm^2 settled volume of Zooplankton, while in the northern basin there were over 21 mm^3/cm^2. In most of the remaining lake area, the average volume of plankton was between 5 and 11 mm^3/cm^2. The very high density of settled plankton in the southern basin in 1969 was due, mainly, to the number of copepodids of C. *bicuspidatus thomasi* and *D. ashlandi*. In August 1971, the greatest density of settled plankton was, as in 1969, located in the vicinity of Kelowna, and in the most

TABLE 7.11

LIST OF SPECIES FOUND IN NET PLANKTON OF LAKES OKANAGAN AND KALAMALKA IN THE PERIOD FROM 1935 TO 1971. (1935 DATA TAKEN FROM RAWSON (1939) Identifications by Dr. G.C. Carl; 1951 Data, Identifications by Present Authors From Samples Kindly Provided by Dr. T.G. Northcote)

SPECIES	OKANAGAN				KALAMLKA		
LAKE / DATE	JULY-AUG. 1935	JULY 25 1951	SEPT. 9-16 1969	AUG. 24-26 1971	AUG. 14 1935	JULY 31 1951	AUG. 25 1971
Epischura nevadensis Lilljeborg	x	x	x	x	x	x	x
Diaptomus ashlandi Marsh	xx	xx	xx	xx	(xx)	xx	xx
Diaptomus sp.					xx		.
Cyclops bicuspidatus thomasi Forbes	(xx)	xx	xx	xx	(xx)	xx	xx
Cyclops bicuspidatus Claus	xx				xx		
Cyclops vernalis Fischer				.			
Daphnia longispina (O.F. Muller)	x				x		
Daphnia thorata Forbes	(x)	x	x	x	(x)	x	x
Daphnia longiremis Sars	(x)	x	x	x	(x)	x	x
Daphnia pulex Leydig				.		.	
Daphnia schoedleri Sars (x pulex)				.			
Scapholeberis mucronata (O.F. Muller)	.				.		
Bosmina longirostris (O.F.Muller)		.	x	x	x	x	x
Bosmina coregoni longispina Leydig	x[1]	x	x	x		x	x
Diaphanosoma brachyurum Lievin	x						
Diaphanosoma leuchtenbergianum Fischer	(x)	x	x	x		.	x
Sida crystallina (O.F. Muller)	.			.	.		
Leptodora kindtii (Focke)	.	.	.	.		.	.
Holopedium gibberum Zaddach	.						

[1] Listed as Bosmina longispina Leydig

xx Abundant species above 10 per cent of the total number of crustaceans

x Common but not abundant 0.1 - 10.0 per cent

. Rare - less than 0.1 per cent

The marks in parentheses denote the probable names according to presently used taxonomy.

TABLE 7.12

NUMBER PER cm^2 AND PERCENT OF TOTAL COMPOSITION OF ZOOPLANKTON SPECIES IN FIVE OKANAGAN MAIN VALLEY LAKES

	OKANAGAN, 1969		OKANAGAN, 1971		SKAHA, 1969		SKAHA, 1971		OSOYOOS, 1969		OSOYOOS, 1971		KALAMALKA 1971		WOOD 1971	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Epischura nevadensis	0.7	0.4	1.3	1.3	2.5	1.0	3.7	1.6	0.2	0.1	2.0	2.6	4.1	3.0	1.0	0.7
Diaptomus ashlandi, adult	0.7	0.4	0.2	0.2	23.9	10.0	10.3	4.4	14.	9.1	4.4	5.8	-	-	6.6	4.7
Diaptomus copepodid	71.5	38.0	29.1	29.0	58.6	24.6	24.8	10.6	47.4	29.3	8.1	10.6	41.1	30.3	43.7	31.4
Diaptomus nauplius	0.3	0.2	1.5	1.5	42.6	17.9	33.0	14.1	33.0	20.5	14.8	19.4	1.3	1.0	7.5	5.4
Cyclops bicuspidatus thomasi, adult	0.4	0.2	0.3	0.3	11.0	4.6	2.6	1.1	6.8	4.2	1.4	1.8	0.2	0.1	9.7	7.0
Cyclops bicuspidatus copepodid	30.9	16.4	20.8	20.8	33.1	13.9	53.2	22.8	15.4	9.5	9.5	12.5	49.3	36.3	21.4	15.4
Cyclops bicuspidatus nauplius	80.2	42.5	43.8	43.7	60.6	25.4	95.3	40.8	35.7	22.1	29.4	38.6	27.0	19.9	46.1	33.2
Cyclops vernalis	-	-	0.1	-	-	-	0.5	0.2	0.1	0.1	0.8	1.1	-	-	-	-
Daphnia thorata	1.8	1.0	1.3	1.3	0.6	0.3	0.9	0.4	0.7	0.4	0.2	0.3	2.1	1.5	-	-
Daphnia longiremis	0.3	0.2	1.0	1.0	3.0	1.2	2.2	0.9	0.3	0.2	1.2	1.6	8.6	6.3	0.4	0.3
Daphnia schoedleri	-	-	.01	.01	0.1	0.1	-	-	0.1	0.1	-	-	-	-	-	-
Daphnia pulex	-	-	0.1	-	0.1	0.1	1.6	0.7	-	-	0.3	0.4	-	-	-	-
Bosmina longirostris	0.6	0.3	0.3	0.3	0.1	0.1	-	-	0.3	0.2	0.1	0.1	1.2	0.9	-	-
Bosmina coregoni longispina	0.2	0.1	0.1	0.1	-	-	0.1	0.1	-	-	-	-	0.6	0.4	-	-
Diaphanosoma leuchtenbergianum	0.4	0.2	0.3	0.3	2.1	5.17	5.2	6.8	6.8	4.2	4.0	5.3	0.3	0.2	2.6	1.9
Leptodora kindtii	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sida	-	-	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	188.1		100.99		238.1		233.5		161.4		75.9		135.8		139.0	

northern basin (Map 2). No above average volumes of Zooplankton were found in the southern basin, as in September 1969. In both 1969 and in 1971, the higher number of adults and lower number of copepodids in the northern end of the lake indicated a more advanced stage of population development in this region.

There were significant differences between the density of plankton in the 0 to 5 meter layer between inshore and offshore waters. The concentration of planktonic crustaceans in the inshore waters was, on the average, only 50% of that found in offshore waters in Okanagan Lake.

7.5.2 Skaha Lake

No significant difference was found in species composition and relative abundance of these species between Skaha and Okanagan Lakes. of the thirteen crustacean plankton found in Okanagan Lake, twelve were present in Skaha Lake with C. *bicuspidatus* and *D. ashlandi* being the dominant species (Table 7.12). Among the cladoceran plankton, *D. leuchtenbergianum* and *D. longiremis* were the most abundant. Between 15 to 19% of the population of Zooplankton consisted of adults in Skaha Lake, while only 0.7 to 1.0 were adults in the population in Okanagan Lake, (Table 7.12). Because of this, there were high settled plankton volumes found in Skaha Lake in both years, explainable in part by structural differences in the population. In addition to more adults in the population, there were a greater number of individuals per square cm. in Skaha Lake in both years (Table 7.12).

7.5.3 Osoyoos Lake

The crustacean plankton of Osoyoos Lake resembled that found in Skaha Lake, both in species composition and in population structure (Table 7.12). The total number of zooplankters averages 161 individuals per square cm. in September 1969, and only 76 per square cm. in August 1971, (Table 7.12). These densities were much lower than the numbers found in Skaha Lake and even lower than those found

in Okanagan Lake. The corresponding settled volumes of plankton were much higher (Map 2), approximately 25.9 and 10.9 mm^3/cm^2 in 1969 and 1971 respectively.

This difference in density and settled volume is related to the high percentage of copepodids and adults in the populations of *C. bicuspidatus* and *thomasi*, and *D. ashlandi* in Osoyoos Lake.

7.5.4 Kalamalka Lake

Nine species of crustacean plankton were found in Kalamalka Lake with C. *bicuspidatus thomasi* and *D. ashlandi* the dominant species, representing 56.3 and 31.3% of the population respectively (Tables 7.11 and 7.12) Very few *C. bisucpidatus* adults were found in Kalamalka Lake. 98% of the population of *D. ashlandi* was composed of copepodids. This age structure was very similar to that found in Okanagan Lake.

The number of cladocerans found in Kalamalka Lake were much more numerous here than in Okanagan Lake. *Daphnia longiremis* was the most abundant cladoceran in Kalamalka Lake.

The distribution of crustacean plankton throughout the lake was uniform, ranging from 101 to 169 individuals per square cm., with a lake average of 136 per square cm. (Table 7.12). Correspondingly, the settled volume ranged from 7.8 to 13.3 mm^3/cm^2 with a lake average of 10.9 (Map 2).

7.5.5. Wood Lake

Only six Zooplankton species were found in Wood Lake with *C. bicuspidatus thomasi* and *D. ashlandi* being dominant. Their percentage contribution to the total population were 55.6 and 41.5% respectively. Only three species of cladocerans were encountered in this lake, and together constituted no more than 2.2% of the total crustacean population. The average number of individuals per square cm. was 139 in 1971 (Table 7.12). The high settled plankton volume of 31.3 mm^3/cm^2, when compared to the low number of adults in the population and to the large amount of phytoplankton that could not be removed (Map 2).

7.5.6 General Discussion

It is interesting to compare the present study findings with those of Rawson in 1935. Additional data gathered in 1951 about the crustacean Zooplankton of Okanagan Lake is presented for comparison (Table 7.11). *Diaptomus ashlandi* and *C. bicuspidatus thomasi*, currently the dominant forms in both Okanagan and Kalamalka Lakes were also dominant forms in both 1951 and 1935 (Table 7.11). By perusal of this table, it can be seen that little change has occurred since 1935 in the species composition of crustacean plankton. The only significant difference between 1935 and 1969/71 samples seems to involve Zooplankton abundance.

The average volume of settled plankton from eleven vertical hauls taken by Rawson between July and August 1935 in the southern, central and northern regions of Okanagan Lake was 1.4 cm /haul or 2.8 mm^3/cm^2. Samples taken in September 1969 and in August 1971 using a comparable net showed an average density of 13.3 and 7.8 mm^3/cm^2, respectively, or approximately 4.8 and 2.8 times more Zooplankton now than were present in 1935. Even assuming some sampling error or incompatability of methods, these values are a valid indication that there has been an increase in the abundance of Zooplankton in Okanagan Lake since Rawson's 1935 studies. As noted previously, this increase in the density of Zooplankton is paralleled by an eight-fold increase in the total abundance of bottom organisms from 1935 to 1969 (Saether, 1970). (See also Section 7.4.1).

It is also interesting to compare the number of crustacean Zooplankton in the Okanagan Lakes to those of several Laurentian Great Lakes (Table 7.13). Lakes of the Okanagan Valley appear richer in plankton than Lake Superior, but certainly poorer than Lakes Erie and Ontario. Figures for Skaha, Osoyoos and Wood Lakes can be interpreted as being quite high if one bears in mind that the very high flushing rate of Skaha and Osoyoos Lakes do not favor the accumulation of poankton produced in the lake. In addition, very low oxygen concentrations in the hypolimnion of Osoyoos and Wood Lakes restricts the inhabitable layer to approximately the upper 20 meters as compared to 50 meters in the remaining lakes.

TABLE 7.13

AVERAGE NUMBERS OF ZOOPLANKTONIC CRUSTACEANS IN THE GREAT LAKES AND OKANAGAN BASIN LAKES

GREAT LAKES	INDIVIDUALS PER SQUARE CENTIMETER	OKANAGAN BASIN LAKES	INDIVIDUALS PER SQUARE CENTIMETER
Superior	43	Okanagan	101-188
Huron	167	Skaha	236-238
Ontario	306	Osoyoos	76-161
Erie	400	Wood	139
		Kalamalka	136

7.6 FISHES

Fish serve as convenient indicators, both temporally and spatially, of the sum of general effects of eutrophication in lakes. It has been known for some time that fishes respond to changes in the trophic nature of lakes, but their use as indices of eutrophication has only recently been considered (Larkin and Northcote, 1969). One of the objectives of the fishery program was to examine the present state of eutrophication using fish as indices, and to check selected species of fish for chlorinated hydrocarbons, heavy metals and other possible contaminants. Only aspects pertaining to the current state of eutrophication of these lakes is reviewed in this report. The heavy metal content of fish flesh and consideration of the abundance of kokanee spawning stocks will be part of two other technical supplements; Water Quality (VI) and Fisheries (IX) respectively.

A total of 26 species of fish were taken during the 1971 sampling program on Okanagan Basin lakes (Table 7.14). Nine of the 26 species were caught in all lakes sampled. These nine include mountain whitefish, rainbow trout, kokanee, largescale sucker, carp, squawfish, peamouth chub, chiselmouth, and prickly sculpin. Representatives of the catfish, perch, bass and sunfish families were confined to the lower two lakes in the system - Vaseux and Osoyoos, with the exception of the pumpkinseed, which were found in Skaha Lake as well.

TABLE 7.14

SPECIES[1] OF FISH FROM OKANAGAN BASIN LAKES AT DESIGNATED STATIONS[2] DURING THE 1971 SURVEY

FAMILY	COMMON NAME	SCIENTIFIC NAME	WOOD	KALAMALKA			OKANAGAN									SKAHA			VASEUX	OSOYOOS
			I	S	N	Σ	N	W	C	K	M	P	H	S	Σ	N	S	Σ		
Whitefishes (Coregonidae)	Mountain Whitefish	*Prosopium williamsoni*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Pygmy Whitefish	*Prosopium coulteri*															✓	✓		✓
	Lake Whitefish	*Coregonus clupeaformis*					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Trout and Salmon (Salmonidae)	Lake Trout	*Salvelinus namaycush*		✓	✓	✓														
	Rainbow Trout	*Salmo gairdneri*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Chinook Salmon	*Oncorhynchus tshawytscha*																		✓
	Sockeye Salmon	*Oncorhynchus nerka*																		✓
	Kokanee	*Oncorhynchus nerka*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Suckers (Catostomidae)	Largescale Sucker	*Catostomus macrocheilus*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Longnose Sucker	*Catostomus catostomus*			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Minnows (Cyprinidae)	Carp	*Cyprinus carpio*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Redside Shiner	*Richardsonius balteatus*	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓	
	Northern Squawfish	*Ptychocheilus oregonensis*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Peamouth Chub	*Mylocheilus caurinus*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Chiselmouth	*Acrocheilus alutaceus*	✓	✓		✓	✓	✓	✓						✓	✓	✓	✓	✓	✓
	Leopard Dace	*Rhinichthys falcatus*							✓						✓					
	Longnose Dace	*Rhinichthys cataractae*			✓	✓														
Catfishes (Ictaluridae)	Black Bullhead	*Ictalurus melas*																	✓	✓
Codfishes (Gadidae)	Burbot	*Lota lota*					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Perches (Percidae)	Yellow Perch	*Perca fluviatilis*																	✓	✓
Basses and Sunfishes (Centrarchidae)	Smallmouth Bass	*Micropterus dolomieui*																		✓
	Largemouth Bass	*Micropterus salmoides*																		✓
	Pumpkinseed	*Lepomis gibbosus*														✓		✓	✓	✓
	Black Crappie	*Pomoxis nigromaculatus*																		✓
Sculpins (Cottidae)	Prickly Sculpin	*Cottus asper*	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Slimy Sculpin	*Cottus cognatus*		✓	✓	✓		✓	✓			✓			✓					
TOTAL	26	26	10	12	12	14	12	14	15	12	10	12	11	12	15	14	14	15	15	20

[1] Listed as given in Carl *et al.*(1967) except for kokanee which herein is recognized as a distinct form.

[2] See Figure 1 for name and location.

7.6.1 Within-Lake Comparisons of Relative Abundance

In larger lakes where a number of sampling stations were established, some interesting intra-lake differences were noted pertaining to relative abundance of fishes. These data (Table 7.15), point out some of the intra-lake variations of productive capacity, particularly in the larger lakes, as illustrated by fishes which provide a good total view of the effects of trophic level. Kalamalka, Okanagan and Osoyoos Lakes are discussed below in this regard.

(a) Kalamalka Lake

Two stations were sampled in Kalamalka Lake (Figure 3.4). The south station consistently showed larger catches than did the northern station for each of the seasons and most of the species, especially peamouth chub (Table 7.15). Statistical analysis (Chi-square) indicated that the differences in relative abundance between stations was highly significant in Kalamalka Lake ($p < 0:001$)

(b) Okanagan Lake

Eight stations (Figure 3.4), were sampled in the spring, summer and fall in Okanagan Lake. The north station had the highest total catch (Table 7.15) which was chiefly the result of large kokanee catches in the autumn and lake whitefish throughout the netting period. Centre, Kelowna and Peachland stations were among the lowest in total catch. Catches of rainbow trout, mountain whitefish and lake whitefish were generally higher in the southern stations than in the northern or central stations.

After excluding kokanee and peamouth chub (schooling species, probably not caught in gill nets as independent individuals), a series of Chi-square and F. tests (by Chi-square ratios; $p = 0.05$) were run on Okanagan Lake stations to determine validity within lake groupings. The results indicated combinations of northern (N,W,C), central (K,M,P) and southern (H,S) - (see Figure 3.4), gave the best representation of the varying trophic areas within Okanagan Lake.

(c) Skaha Lake

Although there were not large differences in total catch between north and south stations in Skaha Lake, catches of rainbow trout, largescale sucker and squawfish were higher in the north while in the south there was a greater preponderance of mountain whitefish and lake whitefish (Table 7.15). Relative abundance of species was significantly different between the two stations.

7.6.2 Comparisons of Selected Fish Population Parameters Amongst Lakes

Throughout previous chapters, attempts have been made to discuss the data from each lake individually and avoid between-lake comparisons wherever possible during presentation of results. However, fishes - being summators of trophic level as discussed previously, have a vast number of variables acting upon them - thus the level of sensitivity in the culminatory role is much lower. It was therefore decided that results from this program could be most meaningfully discussed

TABLE 7.15

NUMBER OF FISH TAKEN IN COMBINED SPRING. SUMMER AND AUTUMN (STANDARD) NET SETS AT DESIGNATED STATIONS IN KALAMALKA, OKANAGAN AND SKAHA LAKES.

SPECIES	KALAMALKA		OKANAGAN								SKAHA	
	N	S	N	W	C	K	M	P	H	S	N	S
Kokanee	173	130	429	276	241	189	303	430	184	104	247	126
Rainbow trout	16	51	16	6	4	12	19	10	61	35	15	8
Lake trout	30	61										
Mountain whitefish	3	2	17	7	9	26	53	27	120	69	28	50
Lake whitefish			119	54	55	86	84	29	105	95	197	275
Largescale Sucker	20	37	81	57	34	45	45	45	73	49	169	137
Longnose Sucker	2			9	7	6	12	6	2	3	4	8
Peamouth Chub	98	219	175	235	95	134	195	80	267	304	338	653
Squawfish	44	52	115	128	86	94	51	59	72	105	211	167
Carp	3	16	13	15	1	5	6	1	8	5	30	19
Chiselmouth		1	38	1	1						97	1
Burbot			27	12	20	6	5	20	13	7	2	2
Prickly Sculpin						2		2	9		1	
Pumpkinseed											2	
TOTAL	389	569	1030	800	553	605	773	709	914	776	1341	1446
Spring	106	212	329	346	165	179	157	100	269	381	438	320
Summer	93	139	212	181	89	190	131	73	401	271	213	485
Autumn	190	218	489	273	299	236	485	536	244	124	690	641

in a comparative or 'ranking amonst lakes' manner. With the above in mind, the relative abundance of numbers and species, average length, weight-length relationship and growth rate are discussed.

(a) Total Catch

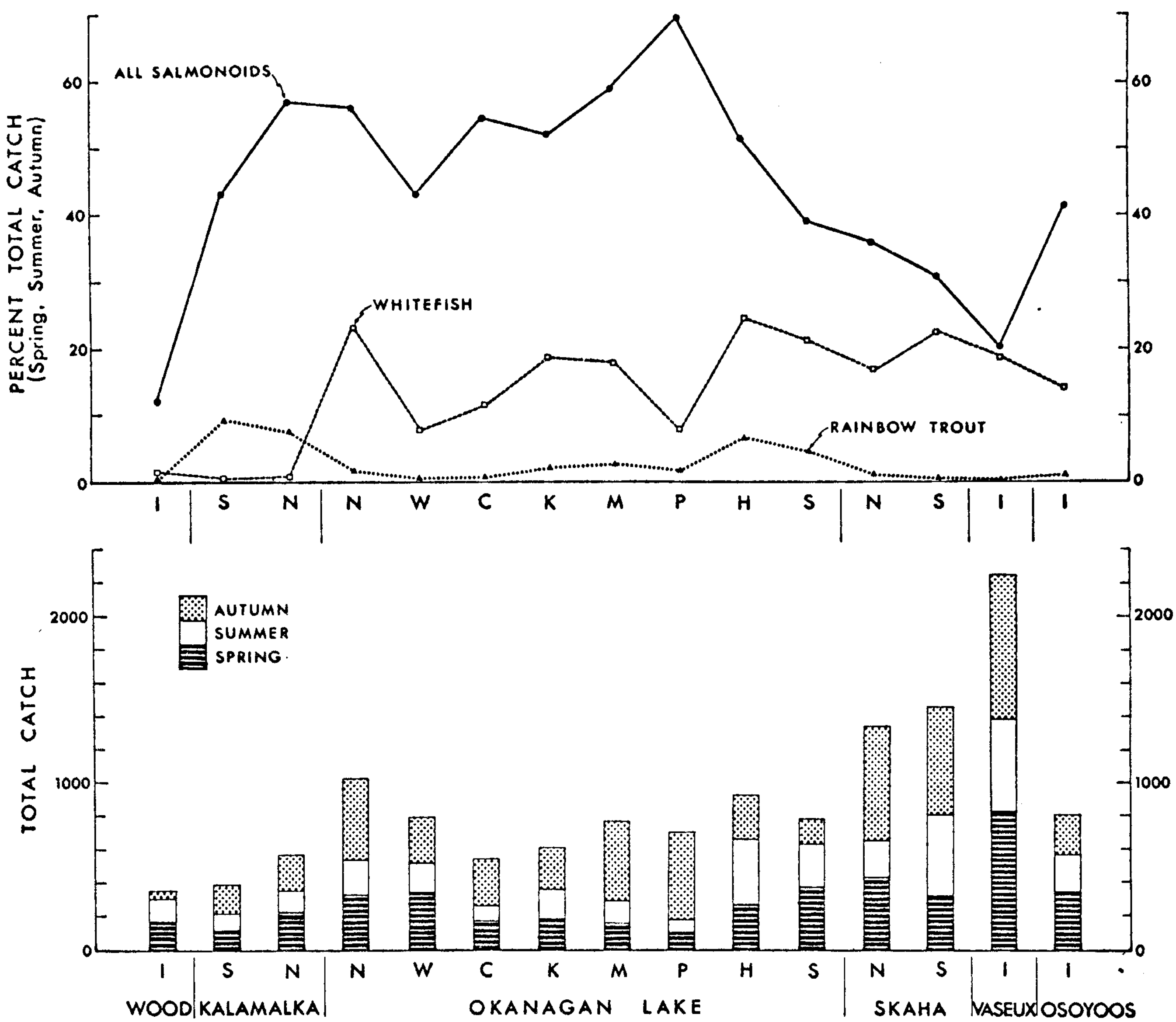
There were marked differences among lakes in the total number of fish caught in the standard net sets (Figure 7.14). The lowest total catch was from Wood Lake, followed by the catch noted at the south Kalamalka Lake station. Catches at Kalamalka north station and at stations C and K in Okanagan Lake were only slightly higher than those previously noted, while the highest catches in Okanagan Lake itself came from the northerly and southerly stations (Figure 7.14). Catches at both stations in Skaha Lake were among the highest in the system, with the exception of Vaseux Lake. Catches in Skaha and Vaseux Lakes were nearly double those from most of the other Okanagan main valley lake stations. Catches in Osoyoos Lake were lower than those noted in Skaha or Osoyoos Lakes, but were considerably higher than most from Okanagan Lake.

The seasonal distribution showed some variation in catch with summer catches tending to be much lower than those in either spring or autumn. In some cases, notably from central Okanagan stations, autumn catches far exceeded those in spring and summer combined, chiefly because of the domination of mature kokanee in the catch.

(b) Relative Catch

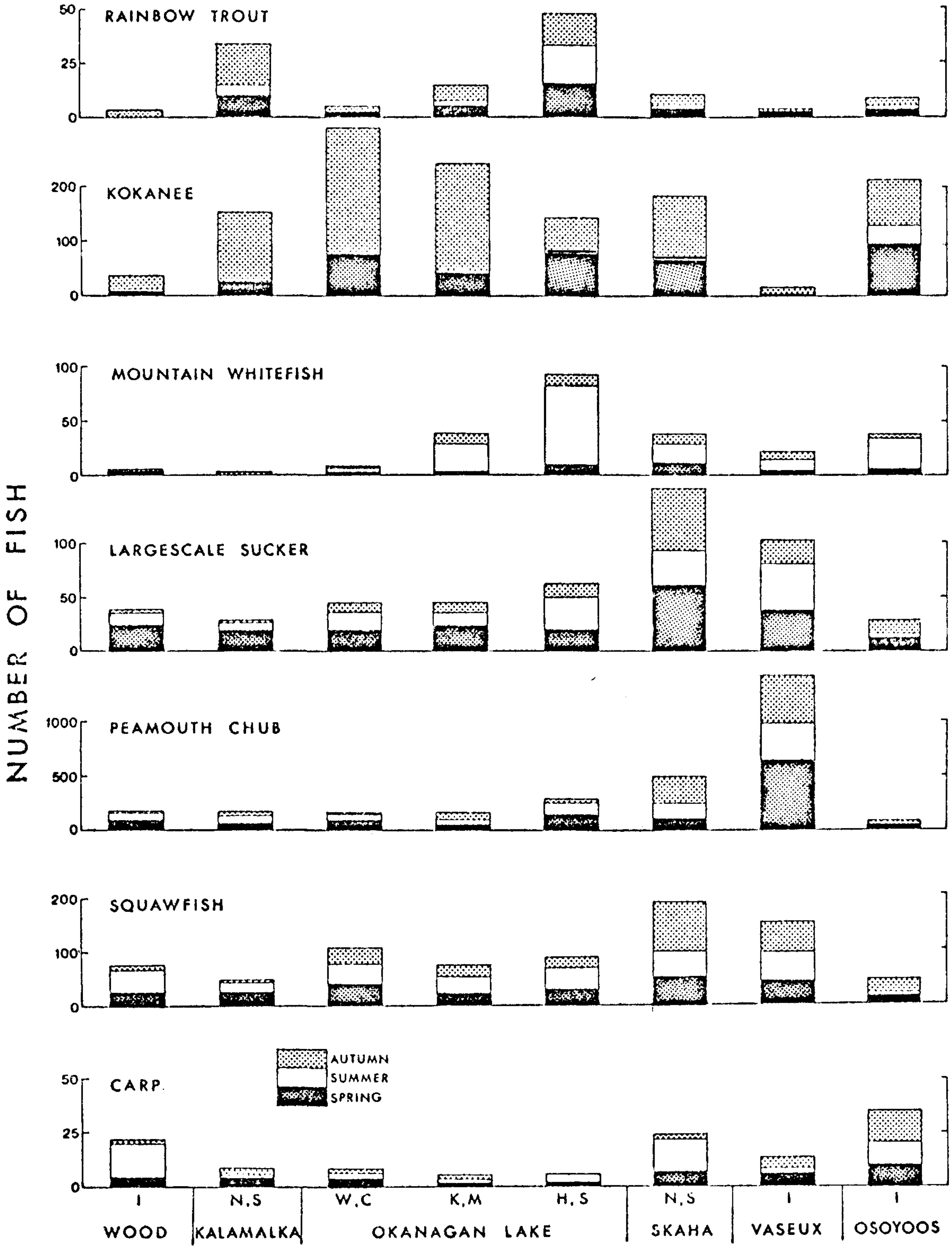
It is of ecological interest to compare the relative abundance of salmonids (rainbow trout, kokanee and mountain whitefish) and coarse fish (castomids and cyprinids) in the Okanagan main valley lakes. The highest and second highest catches of salmonids invariably were taken in either Okanagan or Kalamalka Lake, where the highest catches of coarse fish always came from Vaseux, Skaha and Osoyoos Lake (Figure 7.15). Whitefish were scarce in catches from Wood or Kalamalka Lakes, but in the other takes ranged from between to 8 to 25% of the total catch. This trend of salmonids in Kalamalka and Okanagan Lakes and a greater abundance of coarse fish in the lower lakes, applied also to catches from each of the three seasons, even when considered separately.

It is informative to compare the relative abundance of species found in the present study to that of data collected by Ferguson (1948) from Skaha Lake in the summer of 1948 (Table 7.16). Chi-square analysis showed the difference between years (1948 to 1971) to be highly significant even though data were sparce. Numbers of mountain whitefish appear to be much lower in 1971 than in 1948. Also, no carp were taken in any of the lake net sets in 1948, although several were caught by lake netting in 1971. The combined catch was somewhat lower in 1971 than in 1948 (adjusted catches). Furthermore, the contribution of salmonids to the catch was considerably lower in 1971 compared to 1948 (Table 7.16).



TOTAL CATCH OF FISH IN STANDARD GILL NET SETS AT DESIGNATED STATIONS OF THE OKANAGAN MAIN VALLEY LAKES.

Figure 7.14



NUMBER OF FISH CAUGHT IN STANDARD NET SETS AT DESIGNATED STATIONS OF THE OKANAGAN MAIN VALLEY LAKES.

Figure 7.15

TABLE 7.16

NUMBER OF FISH TAKEN IN STANDARD SUMMER NET SETS NEAR DESIGNATED STATIONS IN SKAHA LAKE, 1948 and 1971.

SPECIES	NORTH		SOUTH		LAKE TOTALS	
	20 July 1948[1]	29 July 1971	22 July 1948[2]	27 July 1971	1948	1971
Rainbow trout		2				2
Mountain whitefish	36	2	24	3	60	5
Lake whitefish		1		7		8
Largescale sucker	72	33	56	29	128	62
Longnose sucker				3		3
Peamouth chub	96	59	80	128	176	187
Squawfish	24	33	16	24	40	57
Carp		12		5		17
Chiselmouth		1				1
TOTAL	228	144	176	199	404	343

[1]Actual catch x 3 (net area adjustment) x 4 (webbing type adjustment).

[2]Actual catch x 2 (net area adjustment) x 4 (webbing type adjustment).

TABLE 7.17

NUMBER OF FISH TAKEN IN STANDARD SUMMER NET SETS NEAR DESIGNATED STATIONS IN WOOD AND OKANAGAN LAKES. 1935 and 1971.

SPECIES	WOOD		OKANAGAN								TOTAL FOR OKANAGAN	
	I		N		K		M		H			
	1935[1]	1971	1935[2]	1971	1935[3]	1971	1935[4]	1971	1935[5]	1971	1935	1971
Rainbow trout						2		2		1		5
Kokanee		2		1	16	1		1		1	16	4
Mountain whitefish	40		12	7	20	17	12	35		44	44	103
Lake whitefish					94	16	36	58	24	29	154	103
Largescale sucker	136	11	12	27	4	21	12	4		12	28	64
Longnose Sucker					18	3		3			18	6
Peamouth chub	1240	27	40	23	112	70	44	8	12	4	208	105
Squawfish	312	28	12	45		32		16			12	93
Carp		12		2				3		1		6
Chiselmouth		4		3								3
Burbot					10	2				6	10	8
Prickly sculpin	20					1						1
TOTAL	1748	84	76	108	274	165	104	130	36	98	490	501

[1]Actual catch x 4.9 (net area adjustment) x 4 (webbing type adjustment)
[2]Actual catch x 3.4 (net area adjustment) x 4 (webbing type adjustment)
[3]Actual catch for [23 July (x 1.9 net area adjustment) + 24 July (X 1.5 net area adjustment) averaged with 20 August (x 1.9 net area adjustment) + 21 August (x 4.5 net area adjustment)] x 4 (webbing type adjustment).
[4]Actual catch for [11 August (x 0.4 net area adjustment) + 24 August (x 3.0 net area adjustment) + 26 August (x 1.9 net area adjustment)] x 4 (webbing type adjustment).
[5]Actual catch x 3.0 (net area adjustment) x 4 (webbing type adjustment).

The data of Clemens *et al* (1939) from Wood and Okanagan Lakes affords another interesting comparison of catch statistics over a 36 year period (Table 7.17). There were marked differences in the relative abundance of fish in Wood Lake between the two years. No carp were netted in the summer of 1935 (although they were in the lake) but 12 were caught in 1971. The contribution of salmonids to the total catch in Wood Lake in each of the years was about the same (Table 7.17).

More reliable comparisons of relative abundance are possible between 1935 and 1971 catches for Okanagan Lake. There appeared to be little difference in total catch (combined stations) between the two years (Table 7.17). No carp were netted in any of the stations in 1935, whereas single summer sets in 1971 took carp at three of the four 1971 stations shown (Table 7.17). Otherwise, relative abundance between each of the stations for 1935 and 1971 were similar. Apparently change in trophic structure has not yet affected the fish populations in Okanagan Lake. This is to some extent borne out by the fact that many of the eutrophication problems of Okanagan Lake are localized, affecting mostly shoreline. areas.

(c) Length Analyses

There were differences in the average length of species captured when comparisons were made among the six main valley lakes. Rainbow trout, of the same age, in Kalamalka Lake were significantly smaller than those from Okanagan Lake, but not significantly smaller than those from Skaha or Osoyoos Lakes. Kokanee from Wood and Kalamalka Lakes were significantly smaller than those from any other lake in this system except Osoyoos Lake. Kokanee from Skaha were the largest in the system. The average length of whitefish from Okanagan Lake increased towards the south. Except for Vaseux Lake, a distinct trend for increasing average length toward the south was evident in lake whitefish from the basin lakes. Those from Skaha Lake were significantly larger than any other, followed by Osoyoos Lake.

It is informative to compare length estimates of several species from Skaha Lake between 1948 and 1971. Although few kokanee were netted in 1948, even the largest of these did not attain the average length of those netted in 1971. Lake whitefish were also much larger in 1971 as were the largescale suckers. It should be kept in mind that the sewage treatment plant at Penticton did not commence operation until 1948, hence an increased rate of eutrophication cannot be considered to be prevalent in this lake at the time of the 1948 sampling. The increase in average size of these species between 1948 and 1971 is likely a real indication of the effects of lake enrichment by sewage.

(d) Length-Weight Analyses

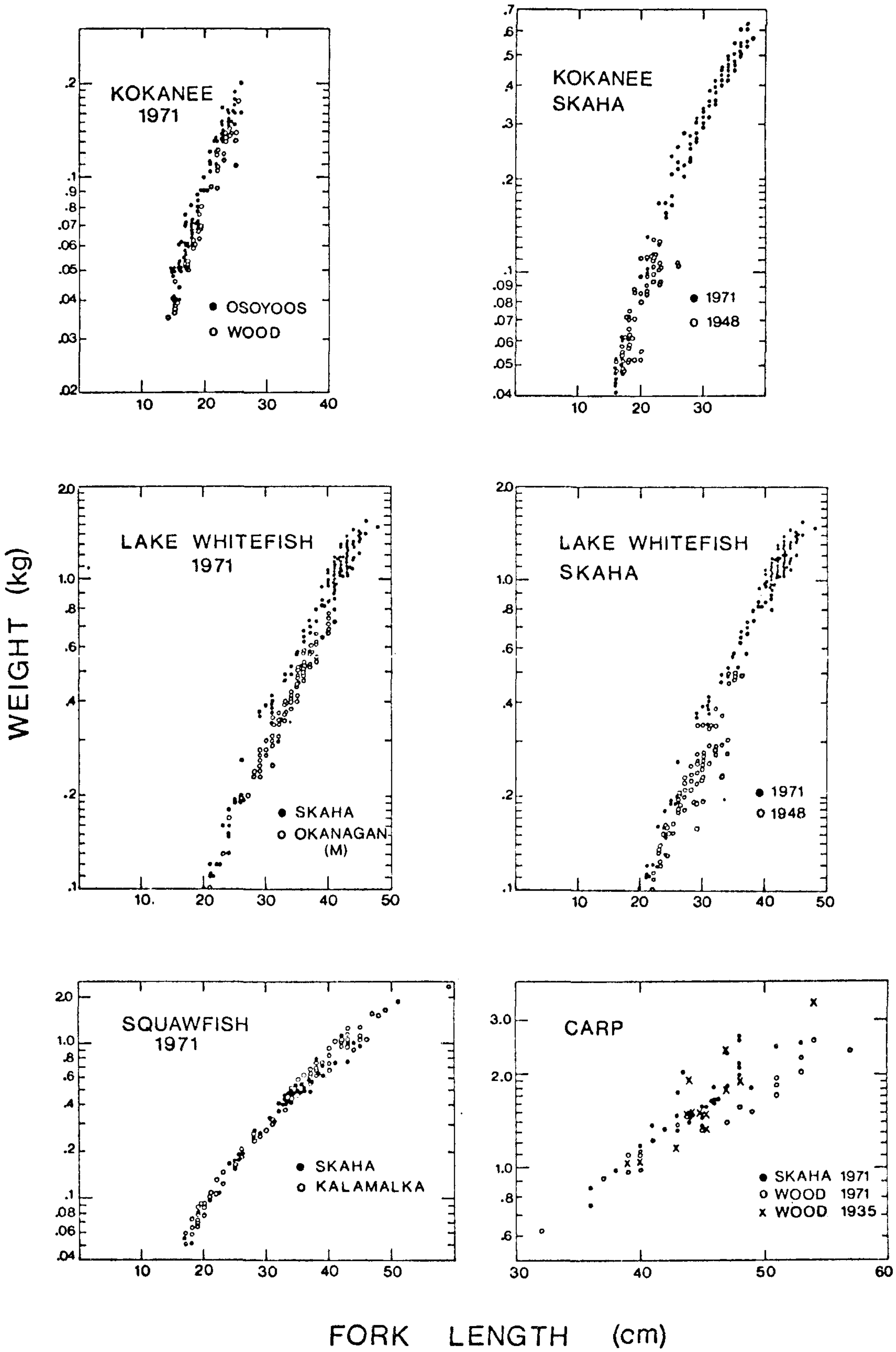
Wood Lake salmonids and coarse fish either had a lower weight-length regression slope or were distinctly lighter in weight over most of the length range considered (negative displacement). In no case did Wood Lake fish show higher regression slopes or positive displacement compared with other lakes (Figure 7.16). Weight-length regressions for Kalamalka Lake fish were either lower than those in other lakes or showed no significant difference (Figure 7.16). Regressions for Okanagan Lake fish were the same or higher than those for all lakes except Skaha. Fish from Skaha Lake generally had the highest weight-length regression slope or positive displacement, lake whitefish showed this most clearly (Figure 7.16). Species in Osoyoos Lake showed the same trend as Okanagan Lake. Vaseux Lake fish tended to fall below those for Okanagan, Skaha and Osoyoos Lakes.

Weight-length regressions for many Skaha Lake fish in 1971 had significantly higher slopes or displacement than those in 1948. There has been little or no change in weight-length regression for Okanagan Lake rainbow trout between 1935 and 1971.

7.6.3 Summary

Based on the above data pertaining to fish population parameters, it was possible to assess the present trophic state of the main valley lakes. Although present data does not indicate a significant shift in species composition, attributable to rapid eutrophication, such a change is predicted if there is not a reversal in the current rate of eutrophication, especially in Wood Lake.

Using a matrix canonical analysis to sort out various population attributes for comparisons among lakes and using other information gathered during the survey, it was possible to rank the lakes on an arbitrary trophic scale. Most fisheries data indicated Skaha to be the most eutrophic lake followed by Osoyoos and Vaseux Lakes. Kalamalka Lake was the least eutrophic, with Okanagan Lake in an intermediate position. Wood Lake - in terms of fish population parameters -ranked low, but evidence suggests that it has reached this position after passing through a more eutrophic stage. In other features discussed in earlier chapters, Wood Lake is considered highly eutrophic.



TYPICAL WEIGHT-LENGTH REGRESSIONS FOR SELECTED SPECIES OF FISH FROM THE OKANAGAN MAIN VALLEY LAKES.

Figure 7.16