Skaha Lake

Skaha Lake, situated to the south of the city of Penticton, receives the main outflow from Okanagan Lake via the Okanagan River. Chief sources of nutrients are from the Penticton S.T.P. and the Alymer Cannery, that discharge their nutrients into the Okanagan River approximately 1 km upstream from the lake. The lake has annually produced heavy blue-green algal blooms over the past 5 years.

In 1970, two NEB experiments were run, one in the spring, the other in the fall. The water sample was obtained just off the mouth of the Okanagan River in the north end (Fig. 2). NO_3(N) additions alone increased growth to about twice that observed in the control, while PO_4(P) additions alone had no stimulatory effect. Addition of a small amount of PO_4(P) and a range of NO_3(N) concentrations from 0.21 -2.1 mg/l yielded an even greater production of algae, proportional to the amount of NO_3(N) added up to a concentration of 2.1 mg/liter (Fig. 10). Conversely, when NO_3(N) additions were held constant but PO_4(P) varied, no increase in growth was noted. When bicarbinate was added with a small amount of NO_3(N) and PO_4(P), results were similar to those obtained in Osoyoos - namely additions of 4.4 and 13.2 mg/l were stimulatory, while greater amounts were inhibiting.

In 1971, two stations were selected for the NEB experiments, one in the north off the mouth of the Okanagan River, the other in the south near the Village of Okanagan Falls (Fig. 2).

Figure 10. NUTRIENT ENRICHMENT BIOASSAY RESULTS.

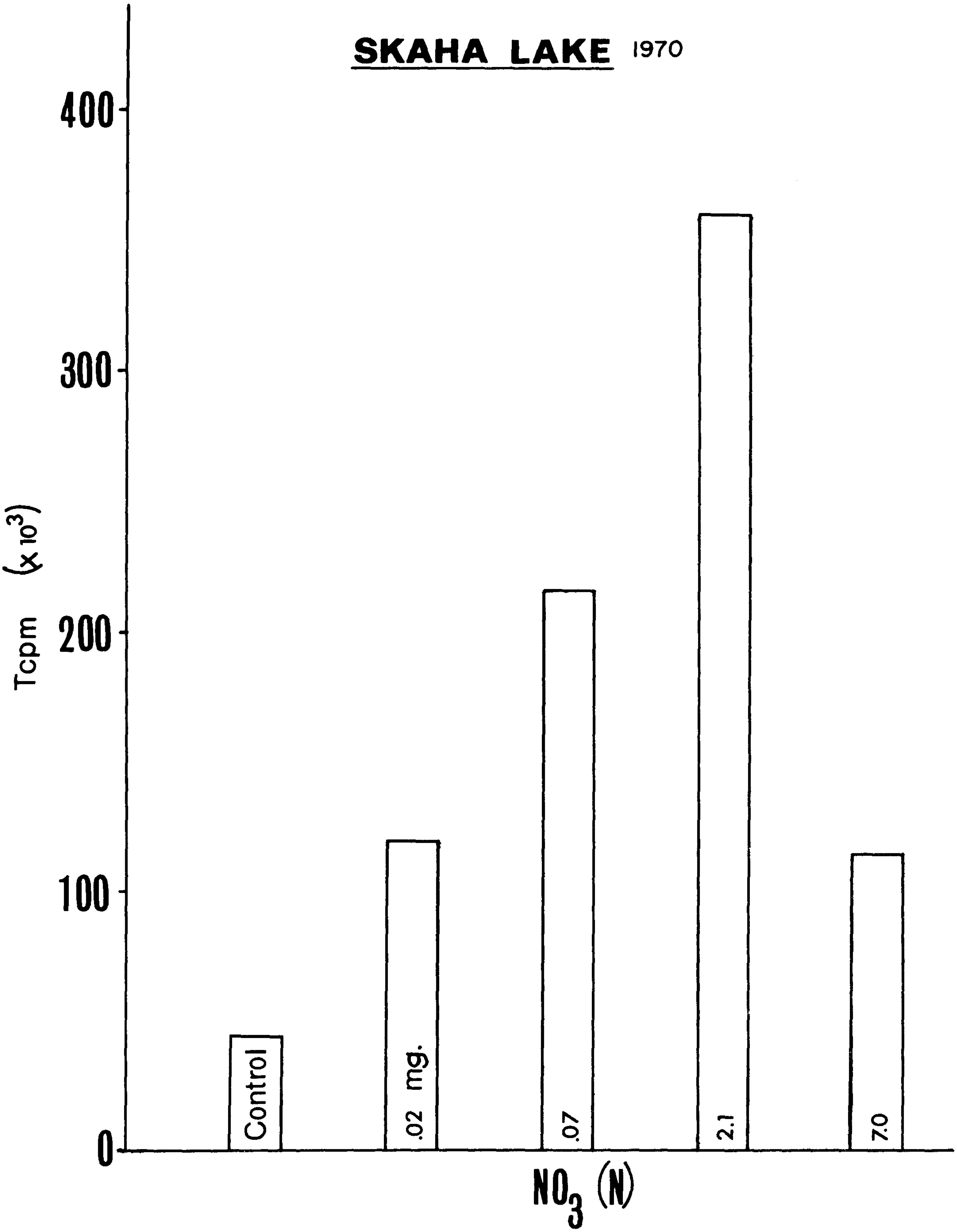
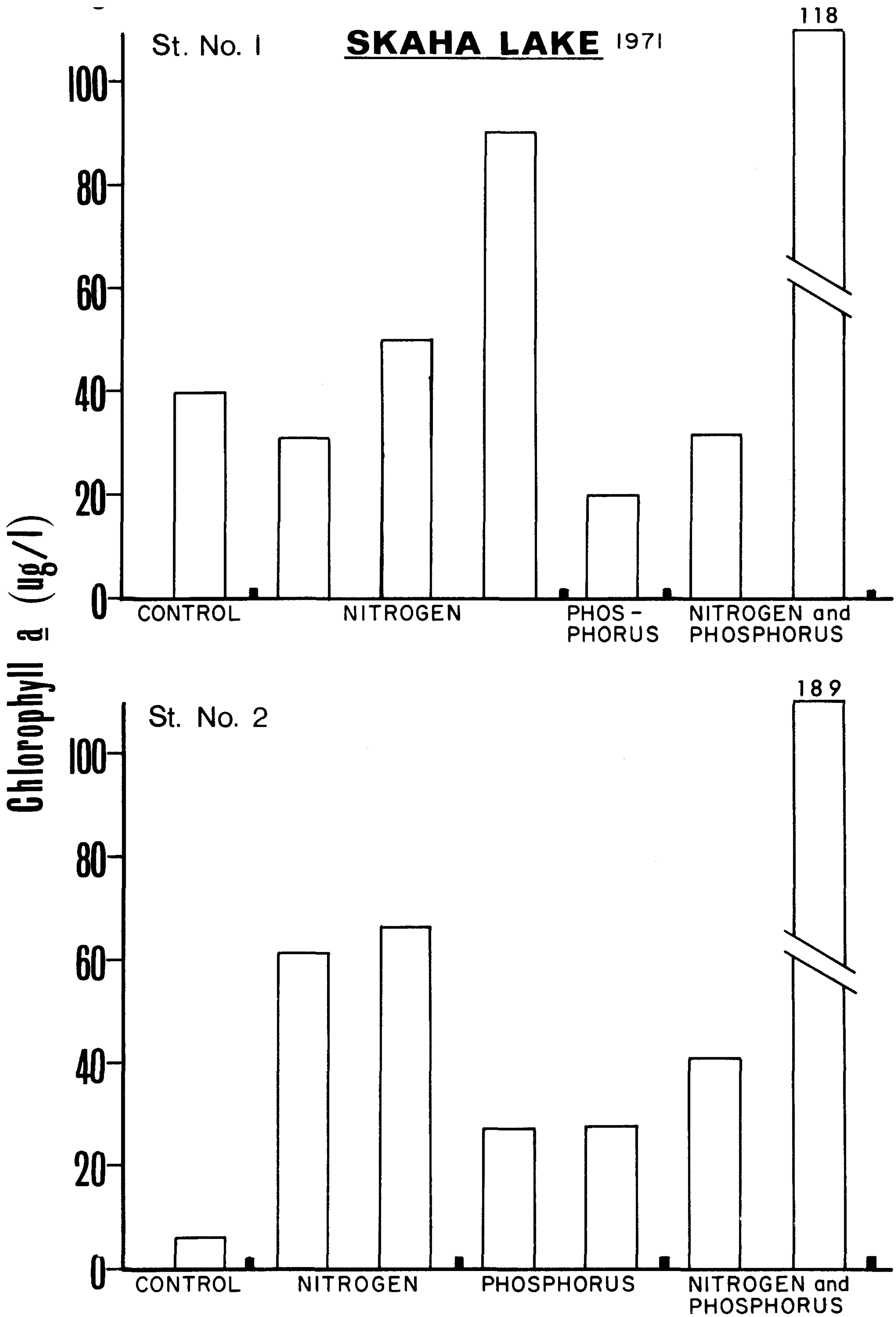


Figure 11. NUTRIENT ENRICHMENT BIOASSAY RESULTS.



Station 3: (mouth of Okanagan River). Additions of NO_3(N) at three concentrations, 0.2, 0.7, 2.1 mg/liter, were stimulatory while a single PO_4(P) addition was not (Fig. 11). 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 greater than the control (Fig. 11).

Station 2: (Okanagan Falls). Addition of NO_3(N) at both concentrations, promoted growth to approximately three or four times that of the controls (Fig. 11). With the addition of PO_4(P) at both concentrations, growth of algae did not surpass that of the control flasks (Fig. 11).

Okanagan Lake

Okanagan Lake is the largest in the basin and receives most of its nutrients from sewage discharge from the cities of Armstrong, Vernon and Kelowna. It is in these locations that most algal problems presently occur. The main body of the lake itself is still in a pristine, Oligotrophic state.

Two nutrient enrichment bioassays were performed in 1970, on water samples taken from one station, mid-lake off the Summerland Trout Hatchery (Fig. 3). 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 the test samples. Flasks, giver constant amounts of PO_4(P) but varying amounts of NO_3(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_3(P) varied, growth remained constant throughout the series. Bicarbonate additions produced results similar to those discussed for Osoyoos Lake with the greatest yield at 44 mg/l CO_2 (Fig. 12).

Six stations were selected for the spring run of the nutrient enrichment bioassay 1971, and only one for the fall run. The spring NEB will be discussed here while results from the fall experiment will be discussed later as part of the trace metal experiments.

Station 1: (Vernon Arm). Additions of NO_3(N) and PO_3(P), alone, at two concentrations had little effect on the growth of algae from Okanagan lake at this station. Nutrient additions of NO_3(N) and PO_3(P), together, in lowest concentrations promoted growth to three times that of the controls, whereas NO_3(N) and PO_3(P) together, at the highest concentrations stimulated growth to approximately fifteen times that of the controls (Fig. 13).

Station 2: (Armstrong Arm). Addition of NO_3(N) in the lowest concentration 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_3(P) together. The growth with NO_3(N) alone was equivalent to ten times that of the controls (Fig. 13). Addition of PO_3(P) alone and NO_3(N) and PO_3(P) together, at both concentrations, stimulated growth to only two times that of the controls (Fig. 13).

Figure 12. NUTRIENT ENRICHMENT BIOASSAY RESULTS.

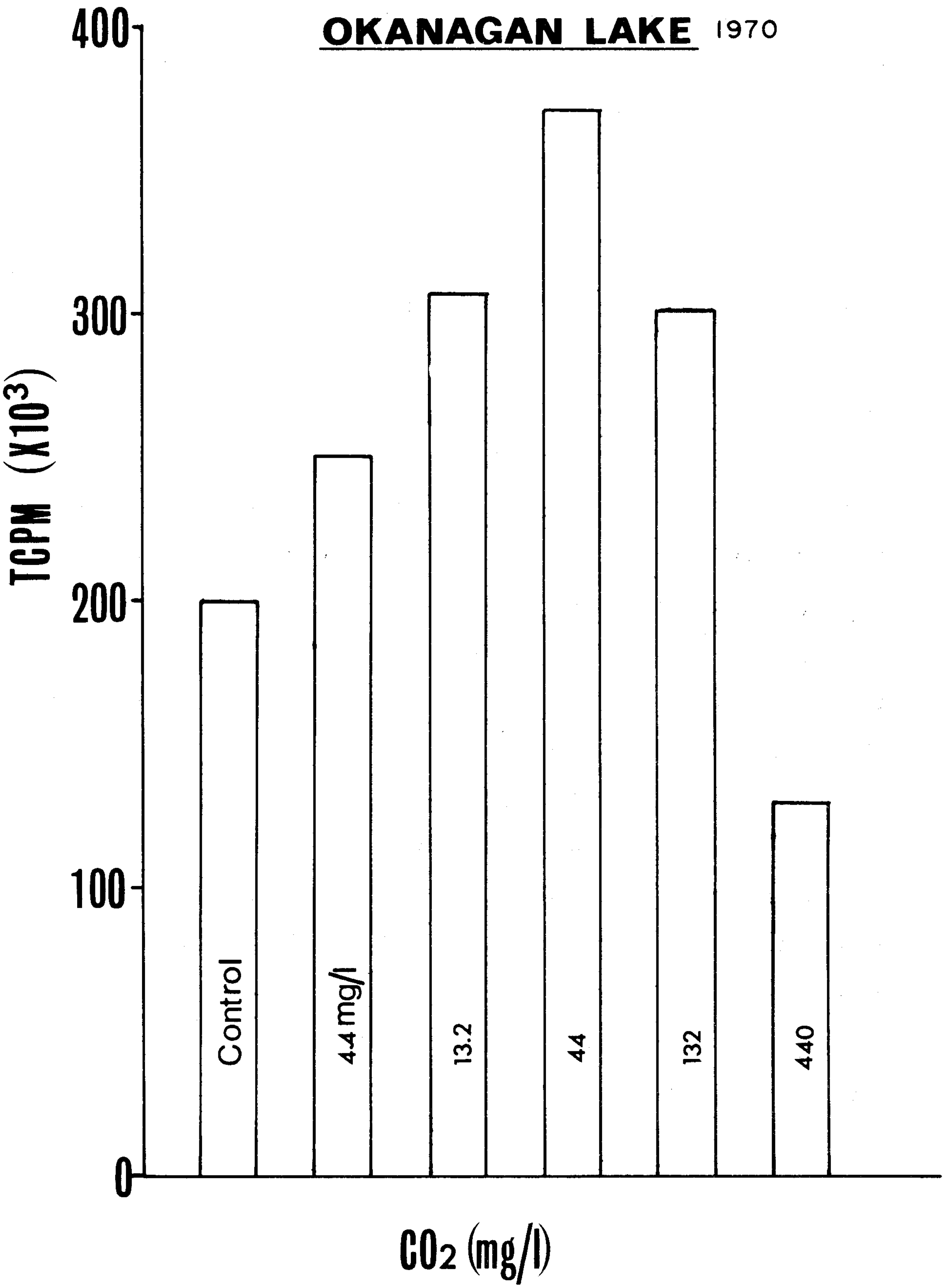
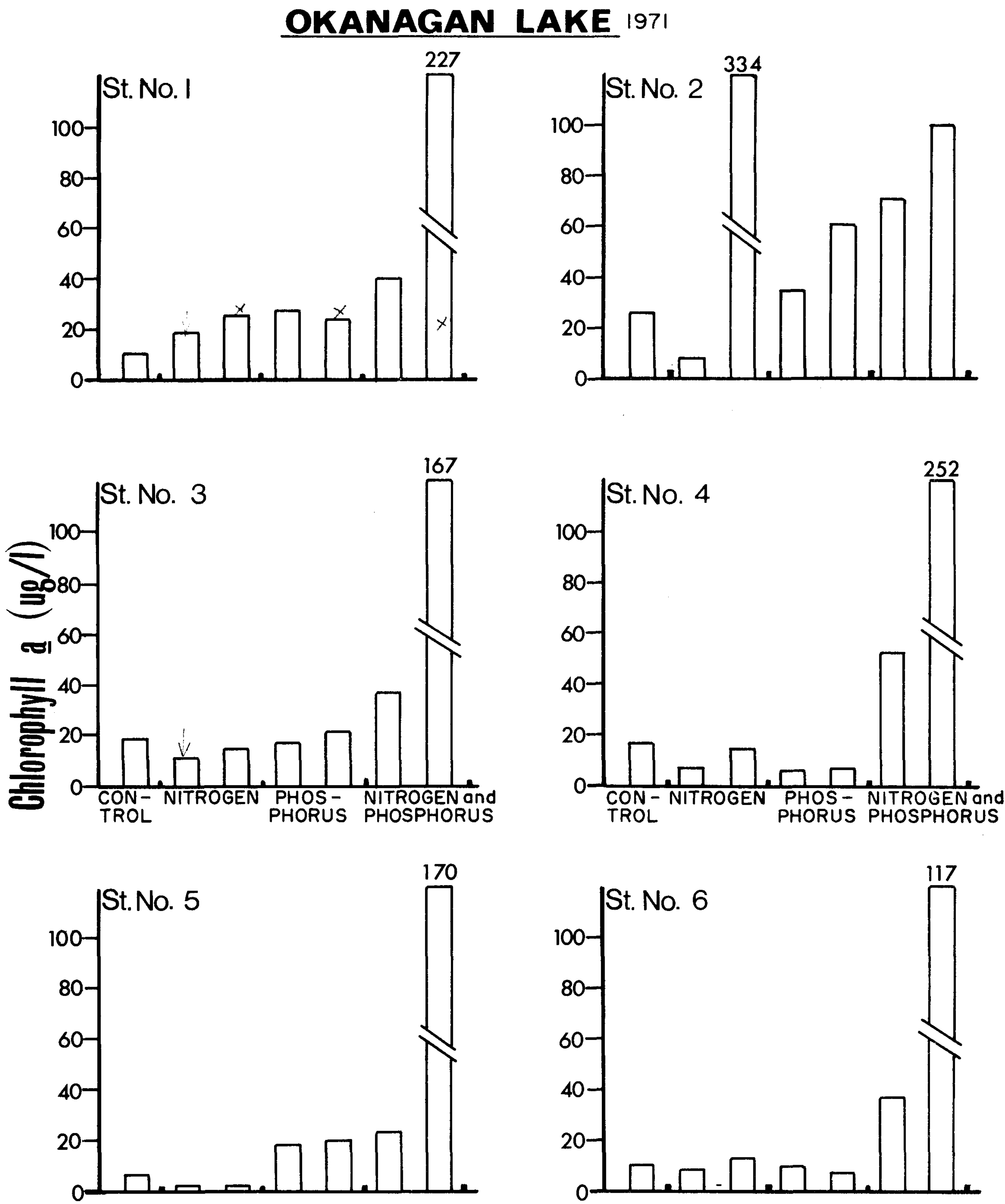


Figure 13. NUTRIENT ENRICHMENT BIOASSAY RESULTS



Station 3: (Off the Kelowna Bridge). With NO_3(N) and PO_3(P) additions by themselves, growth of algae was in most cases below that of the controls. NO_3(N) and PO_3(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 (Fig. 13).

Station 4: (Off Peachland). Flasks with NO_3(N) and PO_3(P) additions alone, at both concentrations, showed less growth than seen in the controls. Flasks with NO_3(N) and PO_3(P) additions together, at both concentrations, stimulated growth to two and from ten to fifteen times that of the control flasks.(Fig. 13).

Station 5: (Off Summerland). Growth inhibition was observed with additions of NO_3(N) at both concentrations whereas stimulation of growth to a little beyond that of the control was evident with PO_3(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 (Fig. 13).

Station 6: (Off Penticton). Only a little growth beyond that observed in the controls was evinced when NO_3(N) and PO_3(P) were added alone. Additions of NO_3(N) and PO_3(P) together, in the lowest and highest concentrations, showed similar trends to the other stations tested; namely stimulation to two and ten times, respectively, the growth of the control flasks (Fig. 13).

Kalamalka Lake

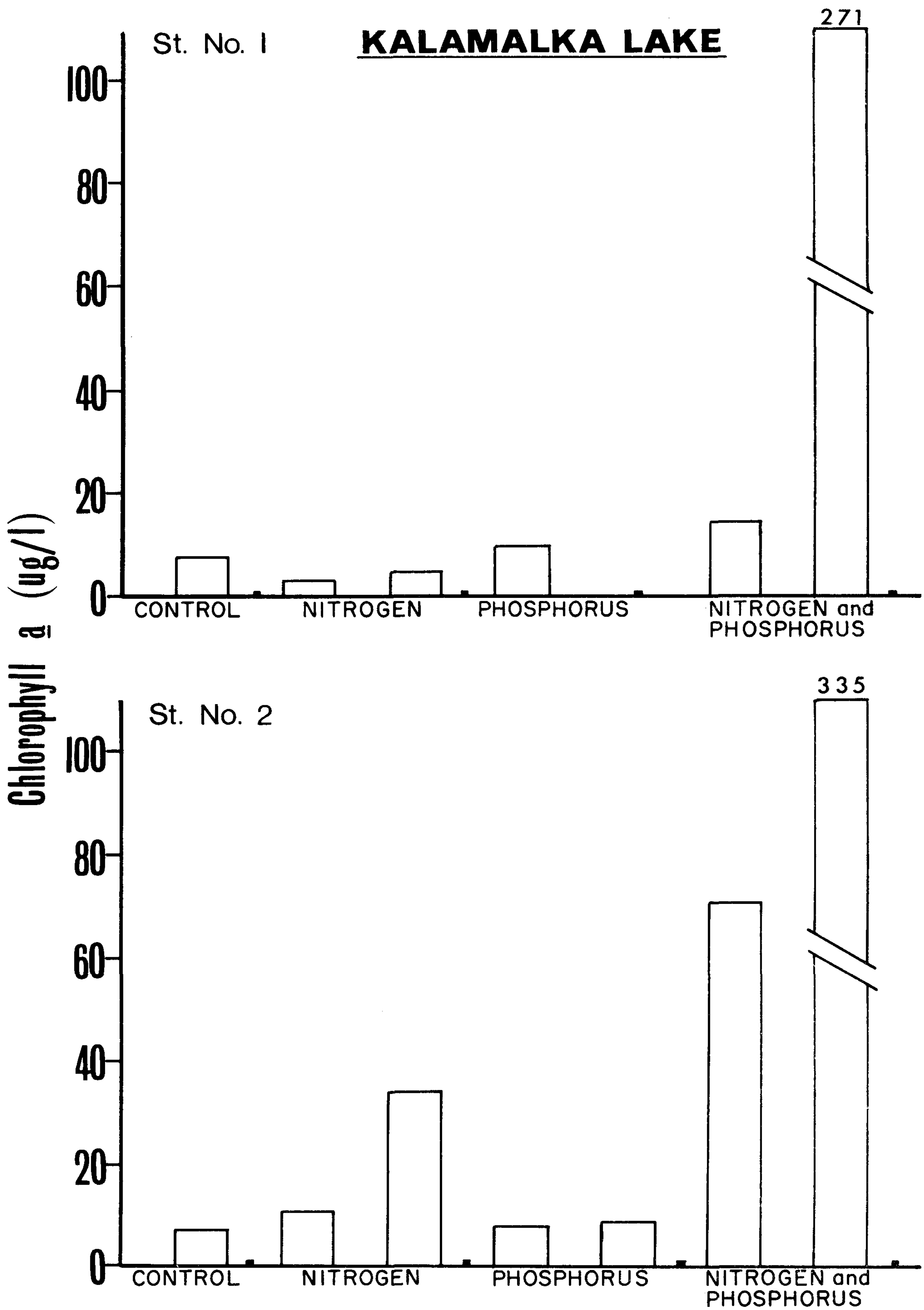
Kalamalka Lake is unquestionably the most Oligotrophic lake in the Okanagan Basin. Some nutrients reach the lake via the channel from Wood Lake, but these appear insignificant.

Two NEB experiments were performed on one mid-lake station, off Crystal Waters Resort, in 1970 (Fig. 4). Both sets of experiments showed similar trends and are treated as one in the 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 control.

Two stations were selected for the NEB in 1971. Station one, located in the southern region, showed inhibition when NO_3(N) was added alone, and only slight growth with PO_4(P) alone (Fig. 14). 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 control (Fig. 14).

The other station, located in the northern region, showed a 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 (Fig. 14). 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 (Fig. 14).

Figure 14. NUTRIENT ENRICHMENT BIOASSAY RESULTS



Wood Lake

Wood Lake, located to the south of Kalamalka Lake, receives nutrients from Vernon Creek that drains into its southern end, and from septic tank sepage and land drainage from around the shoreline. Wood Lake is one of the most eutrophic lakes in the Okanagan Basin.

Results of the NEB in 1970 showed stimulation of algal growth at all concentrations of NO_3(N), whereas PO_4(P) alone promoted no growth. The yield of algae in those flasks receiving NO_3(N) additions was proportional to the concentrations added. NO_3(N) and PO_4(P) added together promoted the greatest growth. The response of the phytoplankton to CO_2 additions was similar to that noted in other lakes (Fig. 12).

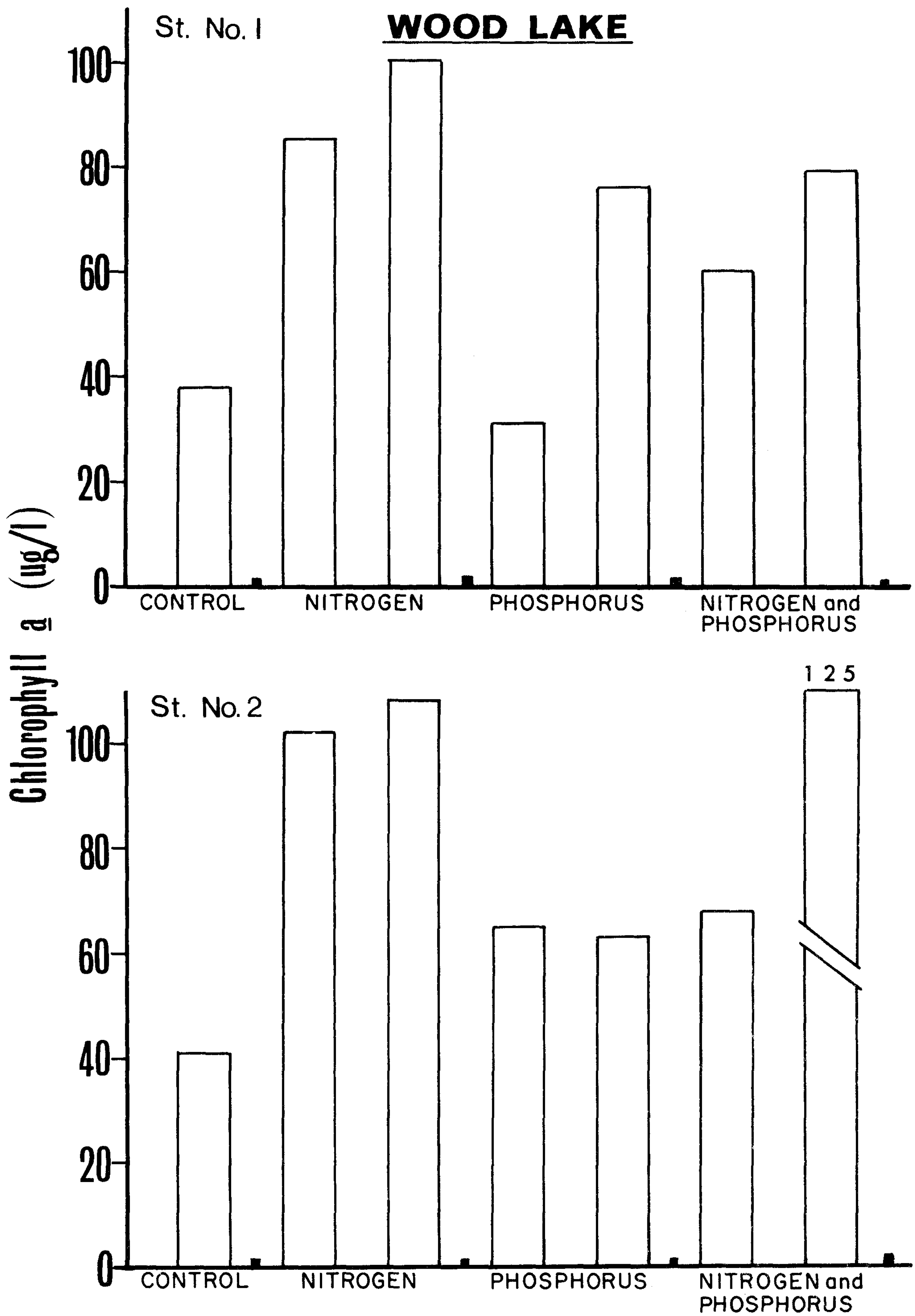
Two stations we're selected in Wood Lake in 1971 (Fig. 5). Station 1, located in the northern region, showed a growth of algae twice that of the controls with NO_3(N) additions (Fig.15). At the lowest concentration of PO_4(P), no growth was observed beyond that of the controls,

whereas growth doubled at the higher concentration of PO_4(P) (Fig. 15).

In both cases, with addition of nitrogen and phosphorus together, growth was only twice the controls, a phenomenon quite different from that observed in the other Okanagan lakes (Fig. 15).

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 (Fig. 15). Addition of NO_3(N) and PO_4(P) together, at the lowest concentration, showed stimulation of growth

Figure 15. NUTRIENT ENRICHMENT BIOASSAY RESULTS



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 (Fig. 15).

SUMMARY AND CONCLUSIONS

NUTRIENT ENRICHMENT BIOASSAY PROGRAM

The greatest growth of algae in most all lakes was observed in those flasks receiving moderate concentrations of NO_3(N) and PO_4(P) together. There were some exceptions, however, where NO_3(N) or PO_4(P) when added alone were more stimulatory. NO_3(N) alone was important in Wood Lake, Skaha Lake, in Armstrong Arm of Okanagan Lake, and to a lesser degree at Station 1 in Osoyoos Lake. The only significant stimulation by PO_4(P) alone occurred in Vaseux Lake and at two stations in Okanagan lake. Low concentrations of NO_3(N) and PO_4(P) together, though stimulatory in all lakes, appeared to be below optimum level to produce maximum growth of algae, whereas NO_3(N) and PO_4(P) together in highest concentrations seemed to be at an optimum level and at an optimum N:P ratio (8.1:1) for the production of algae in all lakes.

Some lakes in the Okanagan Basin, notably Wood and Skaha, currently exhibit characteristics of a nutrient-rich or eutrophic state, Certain areas of other Okanagan lakes also show signs of over-enrichment -e.g. Vernon and Armstrong Arms of Okanagan Lake, short stretches of shoreline near Kelowna and Summerland in Okanagan Lake, and the northern sector of Osoyoos Lake. Results of the NEB to a large extent substantiate these observations, not only in the absolute yield of algae in flasks, but also in which ions were stimulatory. For example $NO_3(N)$ stimulated growth in most all of these lakes and stations, while $PO_4(P)$ additions did not. Preliminary conclusions would be that in these eutrophic situations, $PO_4(P)$ concentrations are sufficient but $NO_3(N)$ levels are sub-optimal and therefore limiting phytoplankton growth.

In lakes that exhibit nutrient poor characteristics, neither $NO_3(N)$ or $PO_4(P)$ alone would promote much growth, whereas additions of both together would illicit a significant growth response. Examples of this type of response were repeated in numerous experiments in Kalamalka Lake, most stations of Okanagan Lake, Vaseux Lake, and to a lesser degree in Osoyoos Lake. The response noted in Vaseux Lake is somewhat unexpected, hut it is no doubt due to the prolific growth of periphyton and rooted aquatic vegetation which trap most available nutrients entering the lake (see Task Report 122). Osoyoos Lake too exhibits some nutrient-rich characteristics, notably in the development of an oxygen deficit in September, but the lake appears to utilize its nutrient load efficiently, thereby preventing the development of nuisance conditions. This may be related to the presence of planktivorous sockeye sockeye salmon smolt during the summer months (Willcocks, personal communication). Results of the 1971 NEB did not indicate $PO_4(P)$ limitation for Osoyoos Lake.

The main water mass of Okanagan Lake and Kalamalka Lake gave similar results from NEB experiments. The yield was low in most all cases and only $NO_3(N)$ and $PO_4(P)$ additions together illicited any significant growth response by the phytoplankton. This may be due to their low density at time of sampling and to the paucity of stored nutrients within their cells. Irregardless, the noted response to nutrient additions was different than that observed in other lakes and were similar to responses seen in other Oligotrophic lakes (Sakamoto 1971), where both ions were in critical supply.

B. PURE CULTURE BIOASSAY (PCB).

Three test organisms were used in the experiment: Selenastrum capricornutum, Anabaena flos-aquae, and Microcystis aeruginosa. These species were recommended 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 (Cyanophyceae). 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-stem lakes.

Intra and interlake lake comparisons are made on the basis of yield or 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.

Osoyoos Lake

Results of a single PCB conducted in 1970 on mid-lake water near the city of Osoyoos (Fig. 1), produced the highest yield of Anabaena of any of the five lakes tested (Table 5). Growth of Microcystis and Selenastrum was relatively low when compared with results from the other

Figure 16. PURE CULTURE BIOASSAY RESULTS.

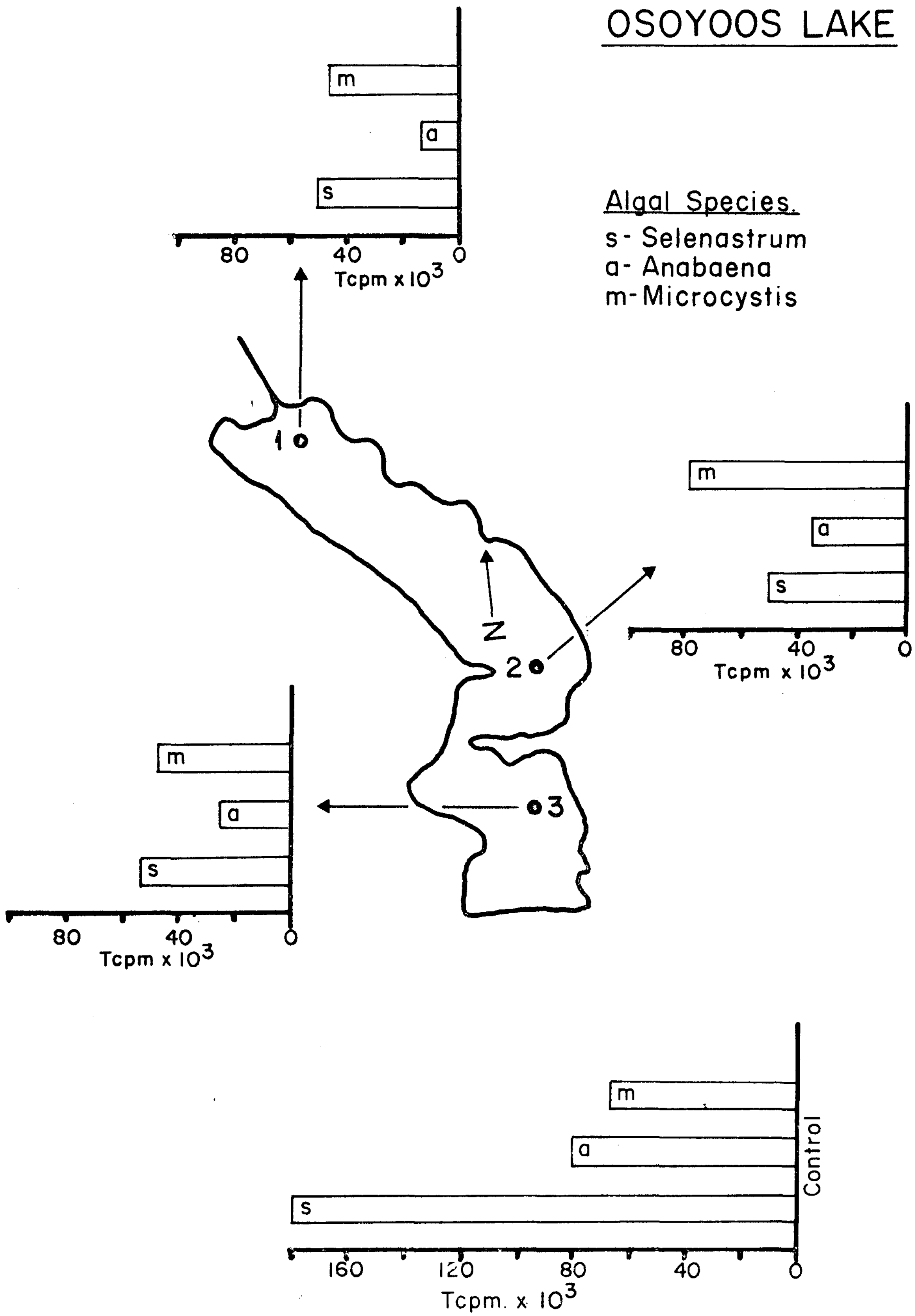
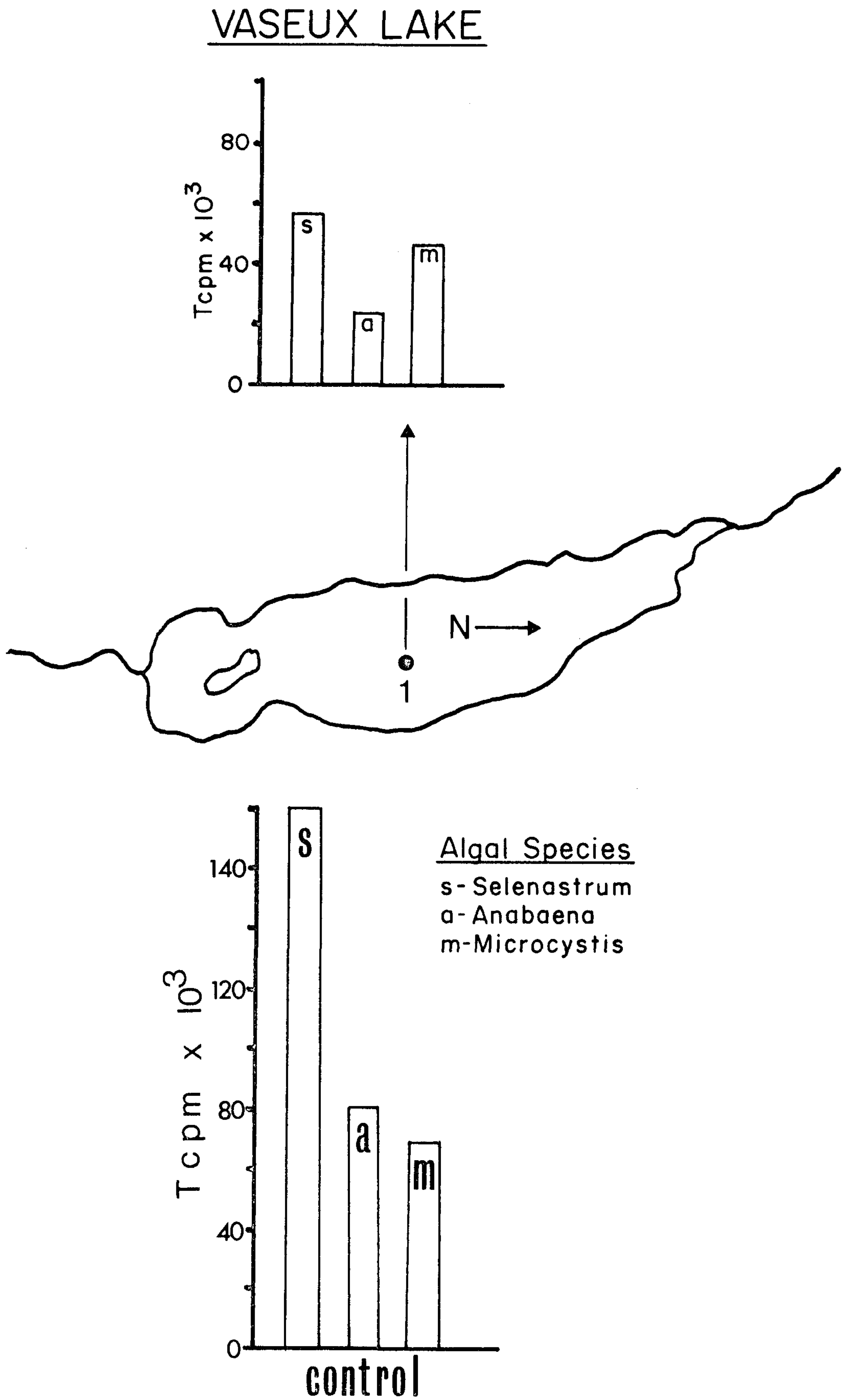


Figure 17. PURE CULTURE BIOASSAY RESULTS



lakes (Table 5). 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 at this time may be related to its ability to fix nitrogen in the presence of an insufficient external supply.

In 1971 the PCB was repeated using three stations (Fig. 16). Growth of Anabaena and Microcystis was high at Station 2, but relatively low at Stations 1 and 3 (Table 6). Selenastrum showed moderate growth at all stations, with little variability in growth among stations. When yields were ranked with results obtained in other lakes, Osoyoos ranked second in the growth of Anabaena and Microcystis and fourth in the growth of Selenastrum. It can be tentatively concluded that some available nutrients were present at the time of sampling and this is partially confirmed by chemical results obtained in the 1971 "Monitor Program" (see Task Report 118).

Vaseux Lake

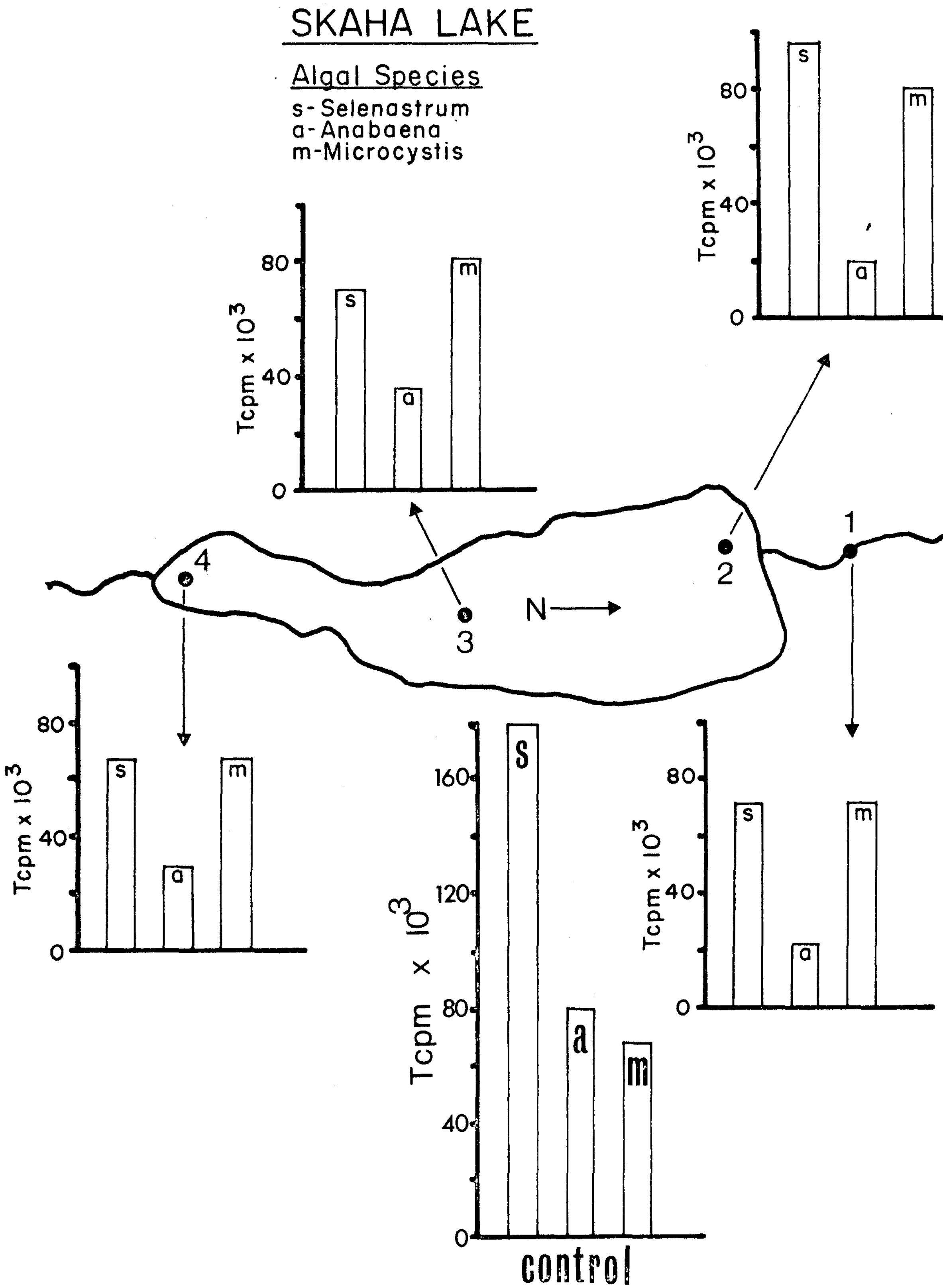
No PCB experiment was run on Vaseux water in 1970. A single experiment was performed in 1971 using surface water obtained from a mid-lake station (Fig. 17). Selenastrum yield was the sixth highest observed among all lake stations tested (Table 6). Growth of Microcystis was negligible. Some available nutrients were present at time of sampling, but to a lesser extent than in Skaha and Osoyoos (see Task Report 118).

Skaha Lake

In 1970, two runs of the PCB were performed at each of two stations (Fig. 2). The greatest yield of Selenastrum was obtained in the first test at the station just off the mouth of the Okanagan River (Table 5). 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, the greatest yield of all three algae was observed at Station 1, just off the mouth of the Okanagan River (Table 5). Growth of the test algae at Station 2, off Okanagan Falls, was good, but nothing exceptional (Table 5). 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/l, respectively. The observed algal yield at each of the stations is in good agreement with the noted nutrient levels.

In the 1971 PCB, water from four stations was tested. On both a lake-to-lake and stations within lake basis, the greatest yield of all three test algae was again observed in Skaha Lake (Table 6). Station 1, 2, and 3 were similar in yield, with Anabaena growing best at Station 3, and Selenastrum at Station 2 (Fig. 18). Station 2 at the mouth of the Okanagan River tended to promote the greatest algal growth,

Figure 18. PURE CULTURE BIOASSAY RESULTS.



further substantiating results obtained in the 1970 PCB, and indicating considerable nutrient availability at this station located in the plume of the Okanagan River.

Okanagan Lake

In 1970 two PCB experiments were conducted on water obtained from three stations; Vernon Arm, Kelowna Bridge, and off Summerland Trout Hatchery (Fig. 3). In the first experiment, water from the Vernon Arm and off Summerland Hatchery promoted good growth of all three test algae (Table 5). Results of chemical analyses of water from these stations showed low nutrient levels at all stations, 0.01 mg/l NO_3(N) and PO_4(P), with the one 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 Hatchery exhibiting higher yields than water off the Kelowna Bridge (Table 5). Nutrients were again at low levels, 0.01 mg/ liter, but Total P values were high in the Vernon Arm, 0.07 mg/liter.

In 1971 one PCB experiment was performed on water samples at 10 stations (Fig. 19). There was little variability in growth among stations and a very low growth of all test algae was noted at all stations (Table 6). Among the six lakes tested in 1971, Okanagan ranked lowest

Figure 19a. PURE CULTURE BIOASSAY RESULTS.

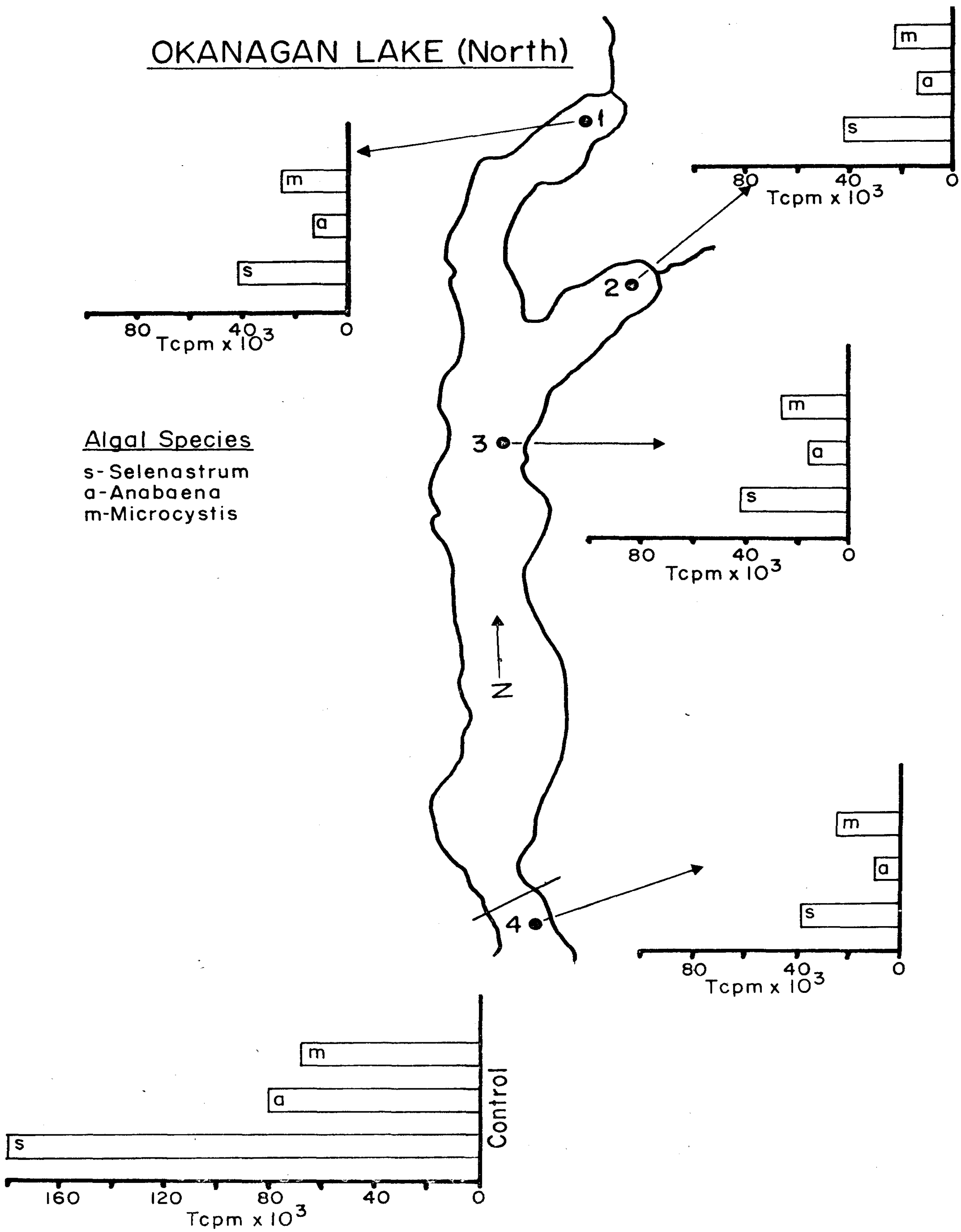
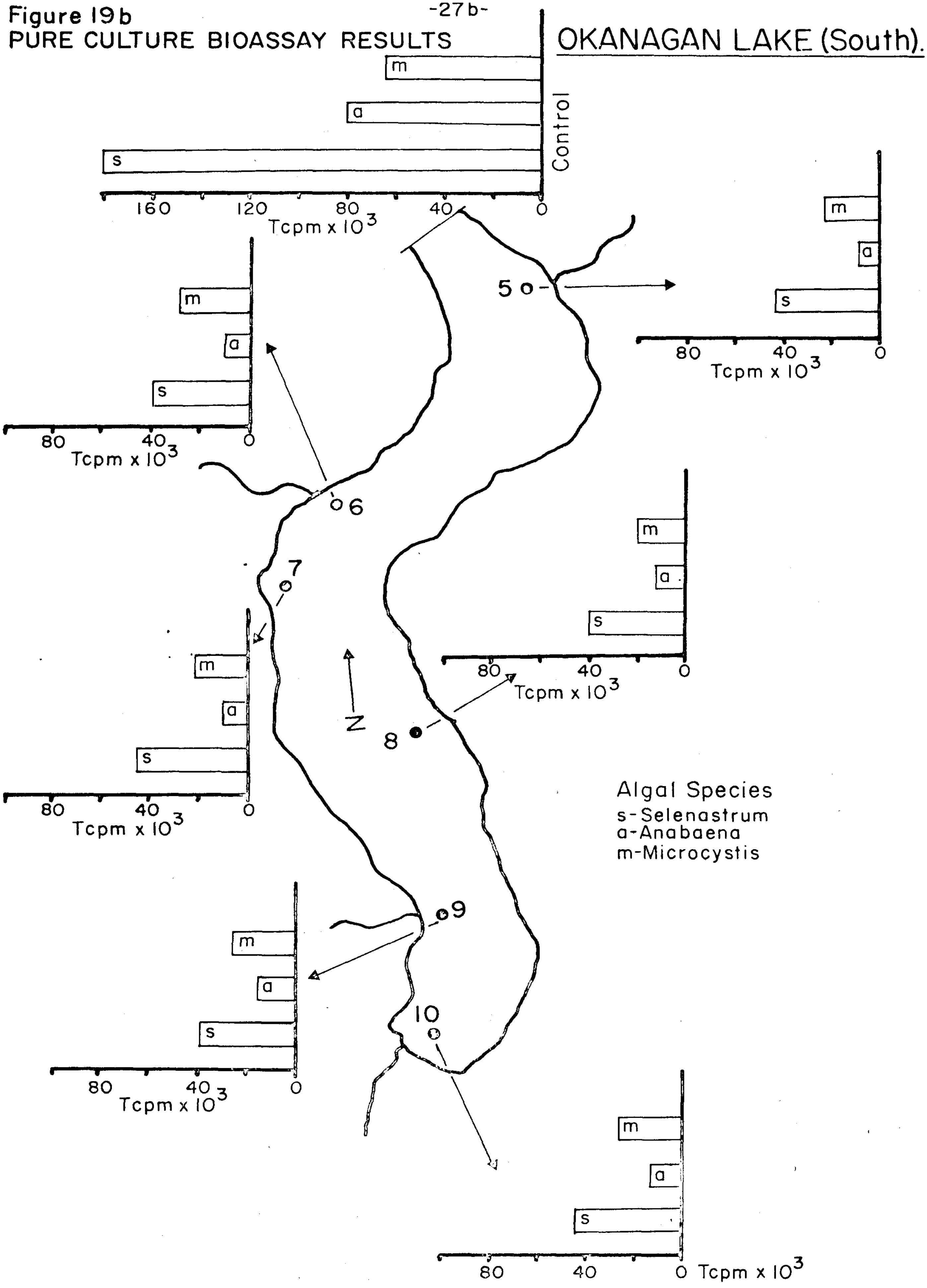


Figure 19b
PURE CULTURE BIOASSAY RESULTS

OKANAGAN LAKE (South).



in yield (Table 6), and it can be concluded that at the time of sampling, Okanagan Lake possessed few available nutrients.

<u>Kalamalka Lake</u>

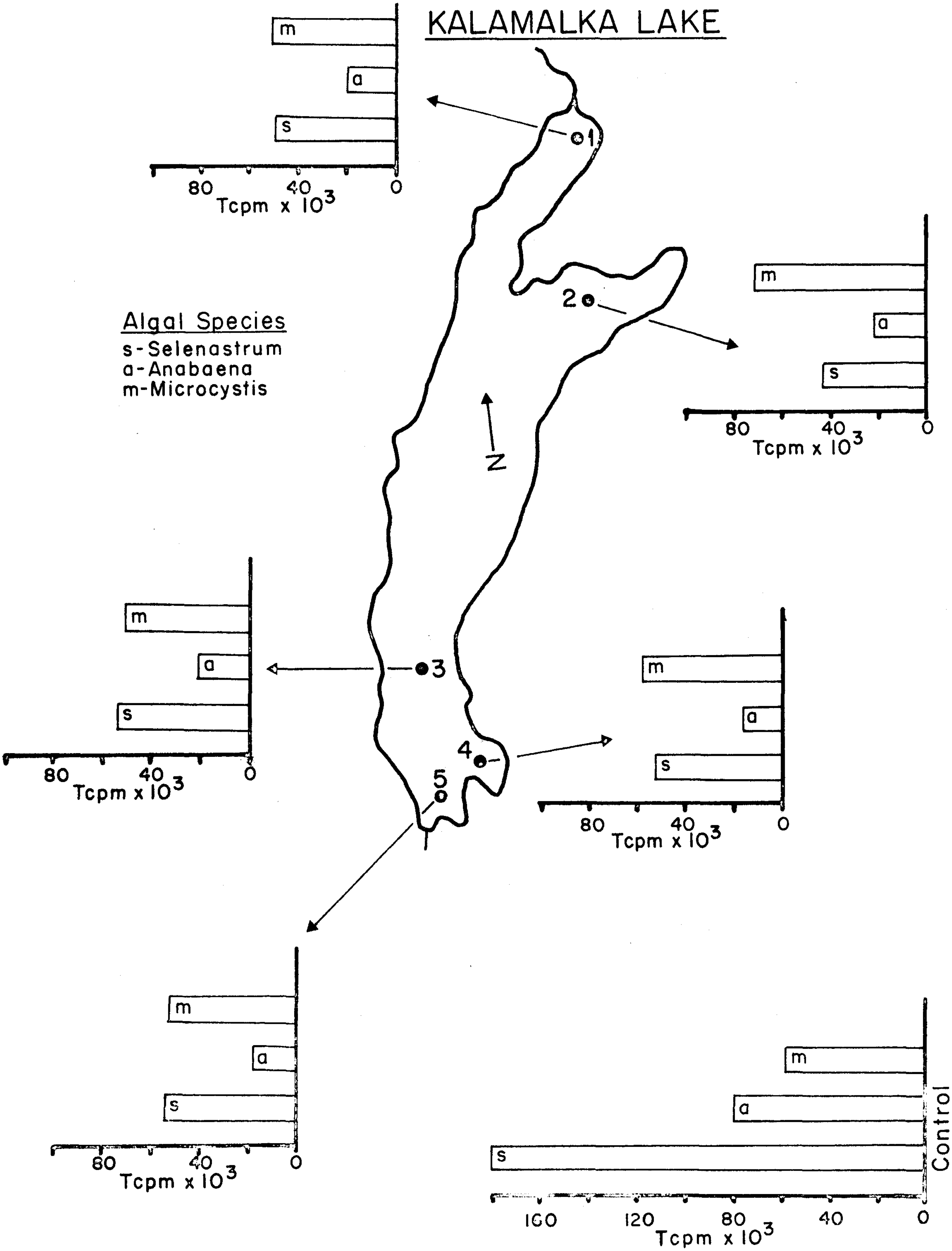
A surface water sample from mid-lake was sampled in each of two PCB experiments conducted in 1970 (Fig. 4). In the first run, *Anabaena* and *Microcystis* exhibited moderate growth, ranking second and third, respectively, while the growth of *Selenastrum* was among the lowest recorded in any lake (Table 5). In the second test, results were similar to those just described (Table 5). Available nutrients were low at both periods, 0.03 mg/liter in NO_3(N) and 0.01 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 (Fig. 20). 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 (Table 6). Growth of *Anabaena* and *Microcystis* was moderate, ranking fourth among six lakes tested in 1971.

<u>Wood Lake</u>

In 1970, only one PCB experiment was performed on a surface sample from mid-lake (Fig. 5). Yield of *Microcystis* was the highest recorded in any of the five lakes tested, and very similar to the algal yield obtained off Summerland hatchery (Table 5). Growth of *Anabaena* was high, ranking second among lakes tested (Table 5). Growth of

Figure 20. PURE CULTURE BIOASSAY RESULTS



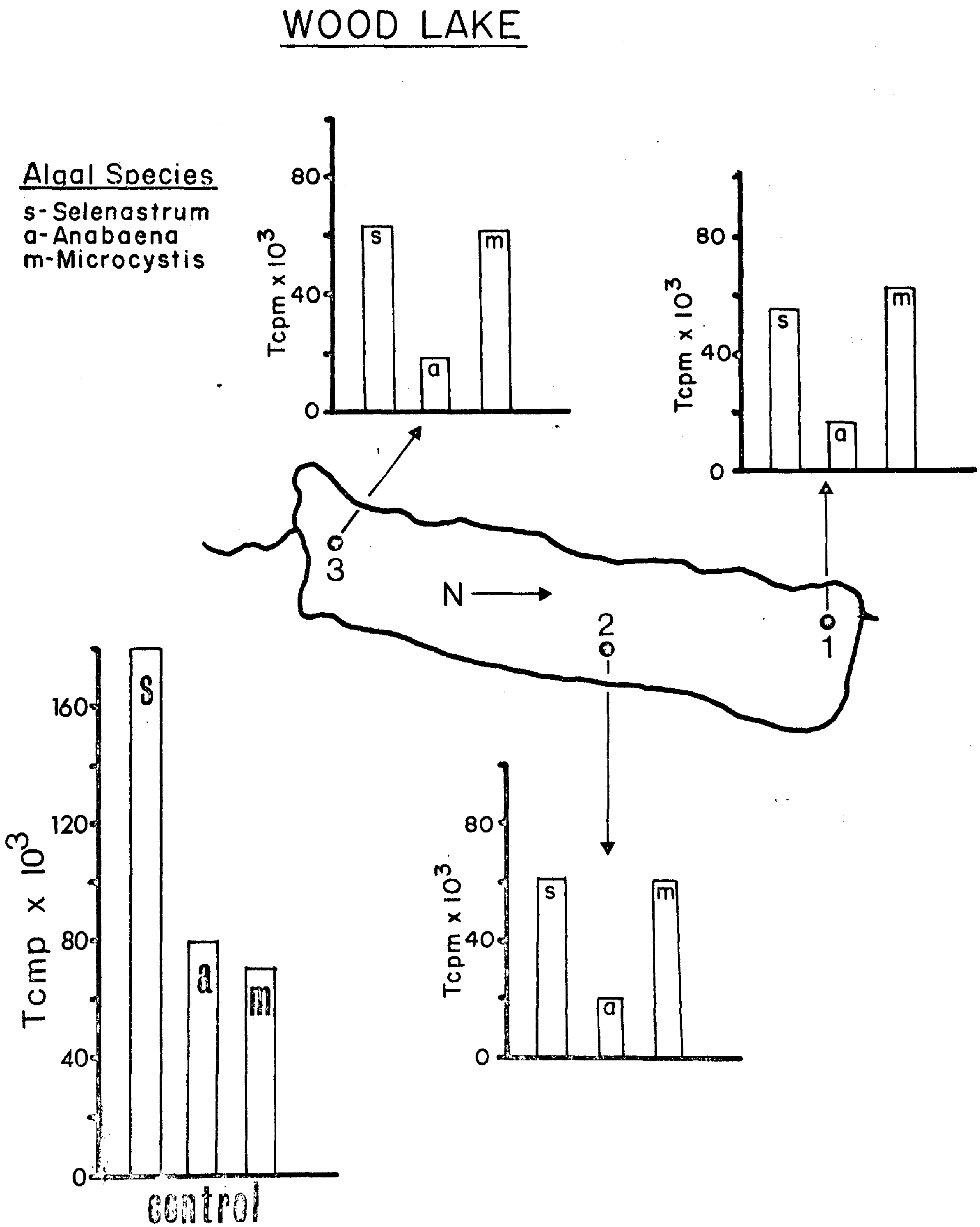
Selenastrum was the lowest observed in any lake. Chemical analysis showed low nutrient availability, 0.01 mg/l for both NO_3(N) and PO_4(P).

In 1971 water from three stations was tested (Fig. 21), and the yield of *Selenastrum* was second only to Skaha (Table 6). Growth of the other species was moderate, but nothing exceptional (Table 6). There was little difference in yield among the three stations tested (Fig. 21). At the time of sampling for the 1971 PCB, Wood Lake was between blooms and available nutrients were low (see Task Report 118).

GENERAL CONCLUSIONS, PCB EXPERIMENTS 1970-71

There were many shortcomings that could not be overcome within the time and budgetary constraints imposed by the study. Despite these limitations some meaningful information about each lake was gathered from the PCB experiments. Based on yield of the three test alga, the six lakes of the Okanagan System could be arbitrarily ranked in decreasing order of fertility: 1. Skaha Lake, 2. Wood Lake, 3. Osoyoos Lake, 4. Vaseux lake, 5. Kalamalka Lake, 6. Okanagan Lake. In most lakes the problems are localized and results from these experiments should not be extrapolated to the lake as a whole. In Wood Lake the eutrophic condition is lake-wide and not restricted to localized areas. On a station-to-station basis, currently the most fertile water mass occurs in the plume of the Okanagan River upon entry into Skaha Lake. Other stations exhibiting high fertility were: plume of Okanagan River in Osoyoos Lake (Station 1); Vernon Arm of Okanagan Lake; Summerland, off

Figure 21. PURE CULTURE BIOASSAY RESULTS



Hatchery in Okanagan Lake; and Wood Lake, all stations. It can be concluded that at these stations at the time of sampling there were sufficient available nutrients to promote the observed high yield of algae. This is not surprising in that each of these stations is located in close proximity to known sources of effluent discharge. The exception is Wood Lake that must receive nutrients via septic tank leaching or by internal loading. The results of these bioassays show quite clearly that Wood Lake currently possesses "excess" nutrients, and can be considered nutrient-rich (eutrophic) throughout much of the growing season. Certain areas of other lakes also exhibit nutrient-rich (eutrophic) characteristics throughout the growing season. Such data as these should be given priority consideration when planning future water quality conditions in these lakes.

C. SEWAGE ENRICHMENT EXPERIMENTS (SEE).

The chief source of nutrients for the Okanagan lakes is municipal sewage. Algal nuisance conditions occur within the immediate vicinity of each municipal effluent discharge and these have led to considerable public concern over the past few years. The sewage enrichment experiments were designed to demonstrate the fertilizing capacity of both raw and treated sewage when added to uncontaminated lake water. It was of further interest to note the short-term growth response of the phytoplankton to the nutrients contained in sewage, and to observe the shift of dominant species in the algal assemblage. The approximate concentrations of PO_4(P) and NO_3(N) added from each type of sewage effluent are presented in Table 3. Results from the five lakes tested in 1971 were similar in respect to growth related to the type and amount of sewage added, but differed in absolute yield and in final species succession. These differences are not surprising since the standing stock of phytoplankton in each lake differed at the time of sampling. Some of the more common observations noted in all lake SEE experiments are listed below.

1. The lowest yield of algae in all lakes occurred in the series of flasks receiving 3' treated sewage. The next lowest was noted in flasks receiving 2' chlorinated effluent.

2. A general pattern of direct proportionality between growth (TCPM) and amount of sewage added was noted in flasks receiving raw, primary, and 2' non-chlorinated effluent. Higher concentrations of mixed

liquor were inhibitory.

3. In most all lakes the addition of 2' non-chlorinated effluent promoted the greatest algal growth (TCPM). The next highest growth occurred in those flasks receiving the lower concentrations of mixed liquor, 5 and 10 ml respectively.

4. All 'control' flasks exhibited the lowest growth (TCPM), and species succession after nine days showed little change in dominant species.

5. The addition of chlorine to 2' and 3' effluent markedly affected algal growth, notably in flasks receiving the two highest concentrations of effluent, 15 and 20 ml, respectively.

6. By increasing the concentration of effluent added to flasks, the observed species succession shifted gradually to a green and blue-green algal dominated assemblage. Diatoms diminished in importance at the higher sewage concentrations.

7. On the basis of the observed growth (TCPM) in each set of experiments in each lake, the lakes could be arbitrarily ranked in order of decreasing response to sewage addition: (l) Okanagan lake; (2) Wood Lake; (3) Skaha Lake; (4) Osoyoos Lake; (5) Kalamalka Lake.

The brief discussion that follows for each lake will note some exceptions to the above observations and introduce in greater detail the observed species succession in each set of experiments.

Osoyoos Lake (Fig. 22)

The control flasks after nine days incubation, contained a mixture of the blue-green alga *Lyngbya* sp. and the diatom *Fragilaria crotonensis.* With the addition of raw sewage, the succession changed to green algal dominance; *Chlorella* spp., with the remainder being several genera of diatoms. With 1' 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 1' treated sewage except the production of algae was much greater. Addition of 2' 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 crotonensis,* and the green alga *Scenedesnus* sp. 3' treated sewage additions gave way to a final succession of almost exclusively, *Scenedesnus* sp.

Skaha Lake (Fig. 23)

The controls after nine days were made up almost exclusively of the diatoms, *Fragilaria crotonensis, Asterionella formosa* and *Tabellaria fenestrata.* and the blue-green, *Anabaena* sp. The flasks receiving raw sewage after nine days contained considerably more *Anabaena* sp., 40 per cent with *Fragilaria crotonensis* and *Synedra* sp. being the dominant diatoms. Additions of 1' treated sewage showed similar results to that of the flasks with raw sewage additions except that *Anabaena* sp. was more abundant, 60 per cent, Mixed liquor additions decreased the

FIGURES 22 - 26

Results of sewage enrichment experiments after nine days growth.

A. Raw sewage

B. Primary sewage effluent

C. Mixed liquor

D. Secondary non-chlorinated effluent

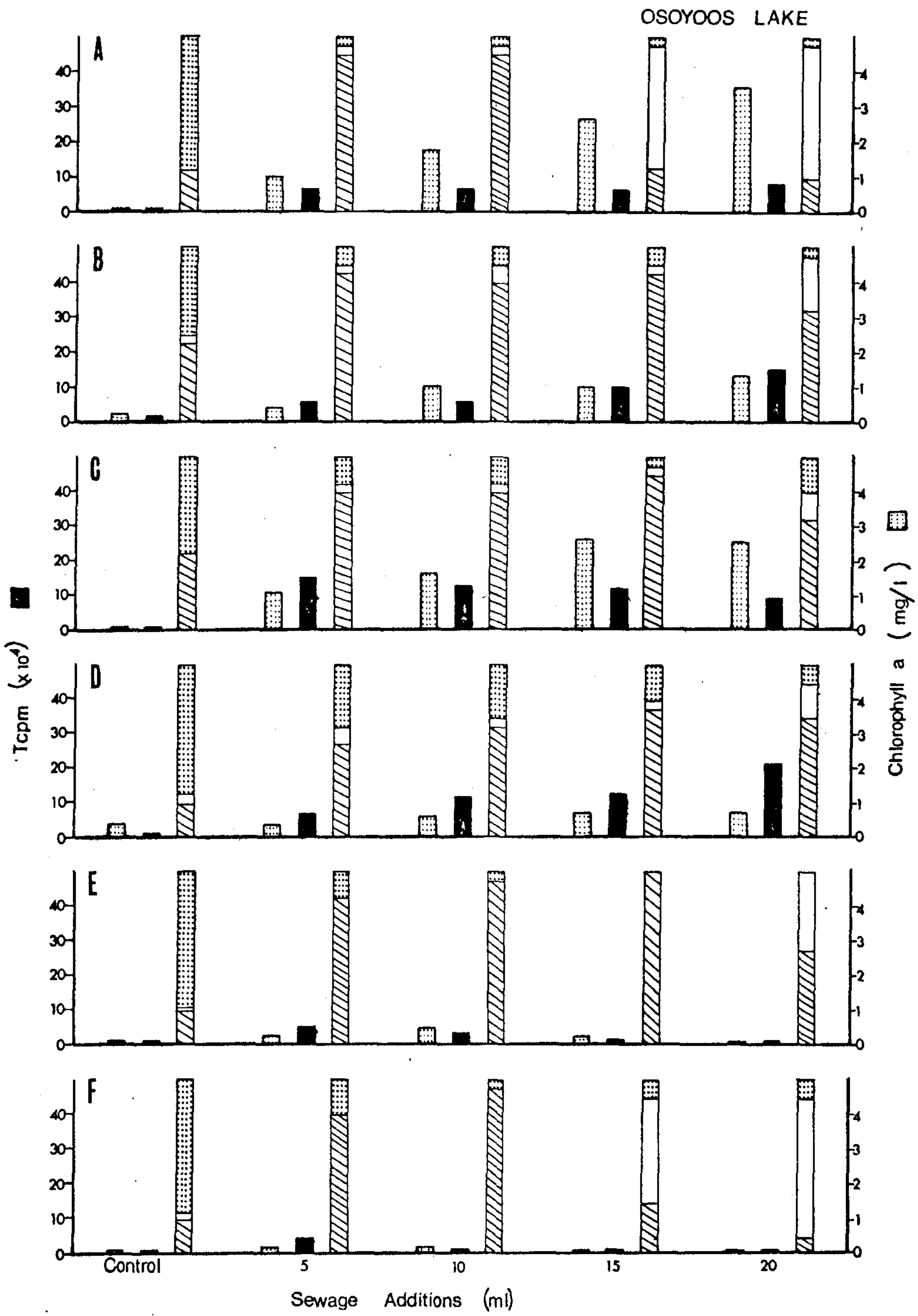
E. Secondary chlorinated effluent

F. Tertiary chlorinated effluent

The third histogram in each series is the percentage composition of the major alga groups: Diatoms ,

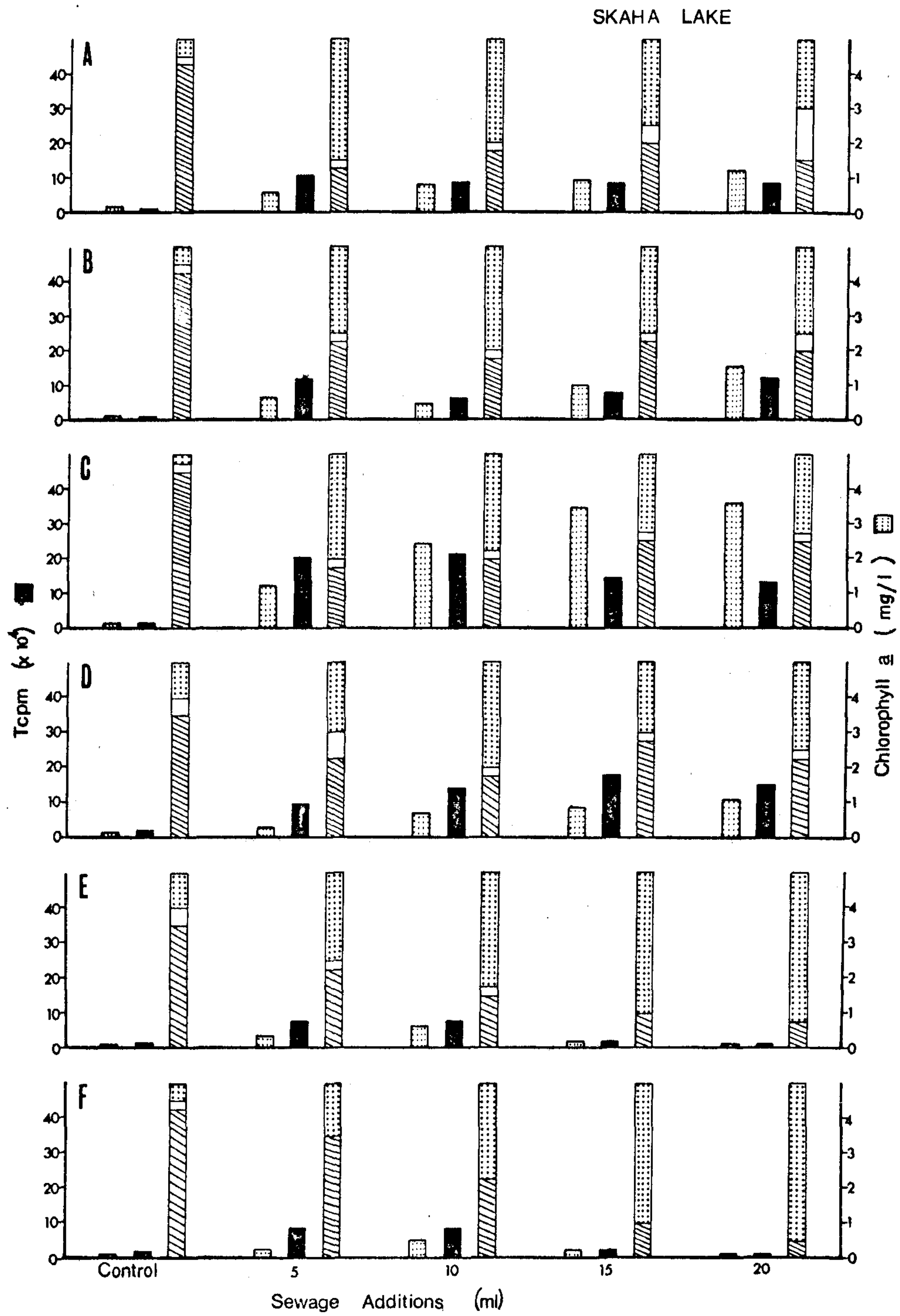
Green alga and Blue-Green alga .

Figure 22



OSOYOOS LAKE
A
B
C
D
E
F
Tcpm (x 10^4)
Chlorophyll a (mg/l)
Control
5
10
15
20
Sewage Additions (ml)

Figure 23



SKAHA LAKE
A
B
C
D
E
F
Tcpm (x 10^4)
Chlorophyll a (mg/l)
Control
5
10
15
20
Sewage Additions (ml)

amount of _Anabaena_ sp., 45% and _Fragilaria crotonensis,_ but stimulated the growth of _Navicula_ sp. 30%. Flasks receiving 2' non-chlorinated and final chlorinated sewage, had an increased growth of _Anabaena_ sp., 50 per cent and 75 per cent, respectively. Flasks with 3' treated sewage additions contained a heavy growth of _Anabaena_ sp. with some _Fragilarja crotonensis_ still present.

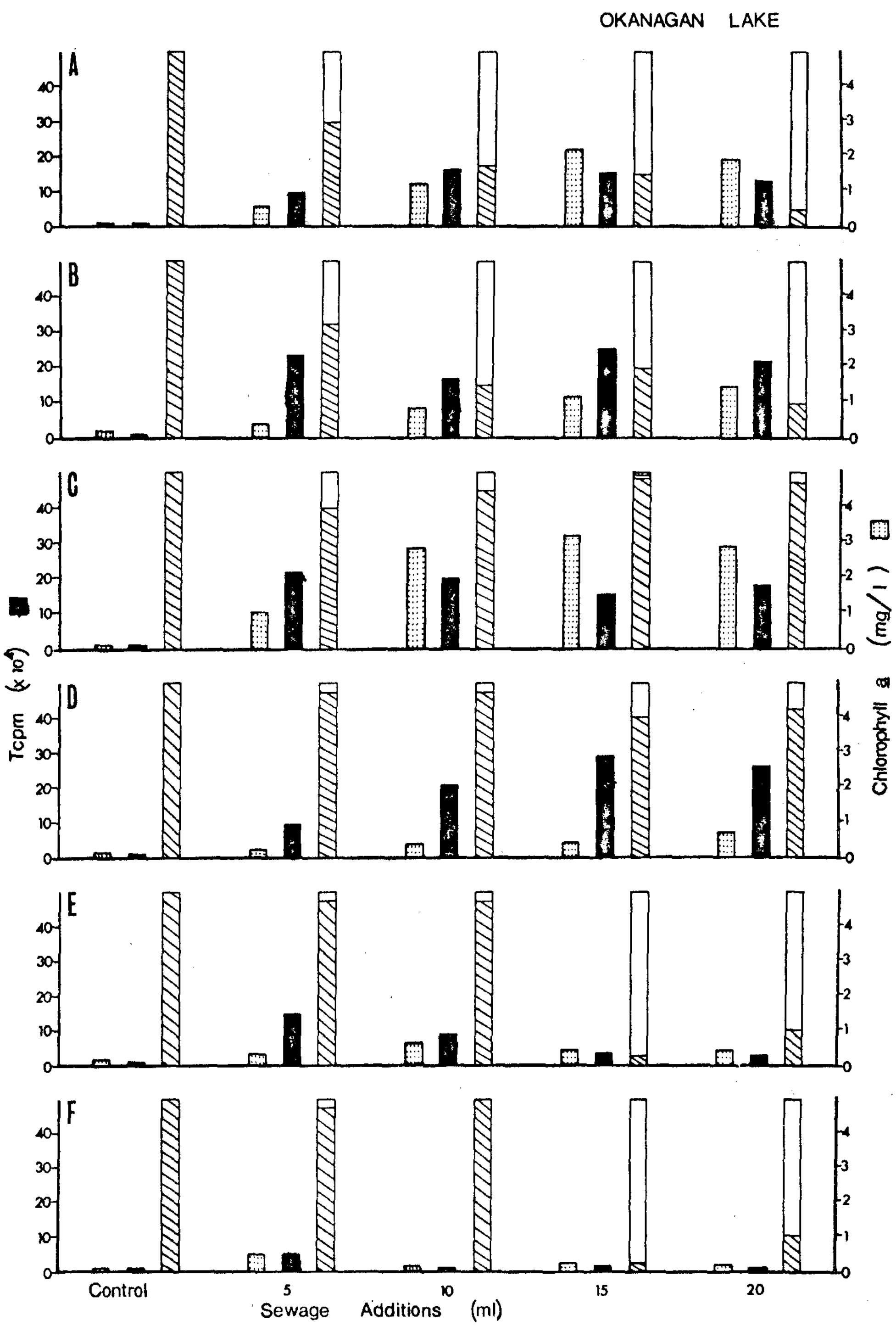
Okanagan Lake (Fig. 24.)

The control flasks after nine days growth, contained mostly diatoms; chiefly _Asterionella formosa_ and _Synedra_ sp. With the addition of raw sewage, species composition changed from diatoms to that of green algal dominance, _Chlorella_ sp. and _Scenedesmus_ sp. With the addition of 1' treated sewage, _Scenedesmus_ sp. became the dominant alga, but with some _Navicula_ sp. present. With the addition of mixed liquor, _Navicula_ sp. became dominant, 90%. 2', 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 2' non-chlorinated sewage additions. Enrichment of flasks with final chlorinated and 3' treated sewage led to a green algal dominance, mainly _Scenedesmus_ sp. and _Chlorella_ sp., with some _Navicula_ sp. present.

Kalamalka Lake (Fig. 25)

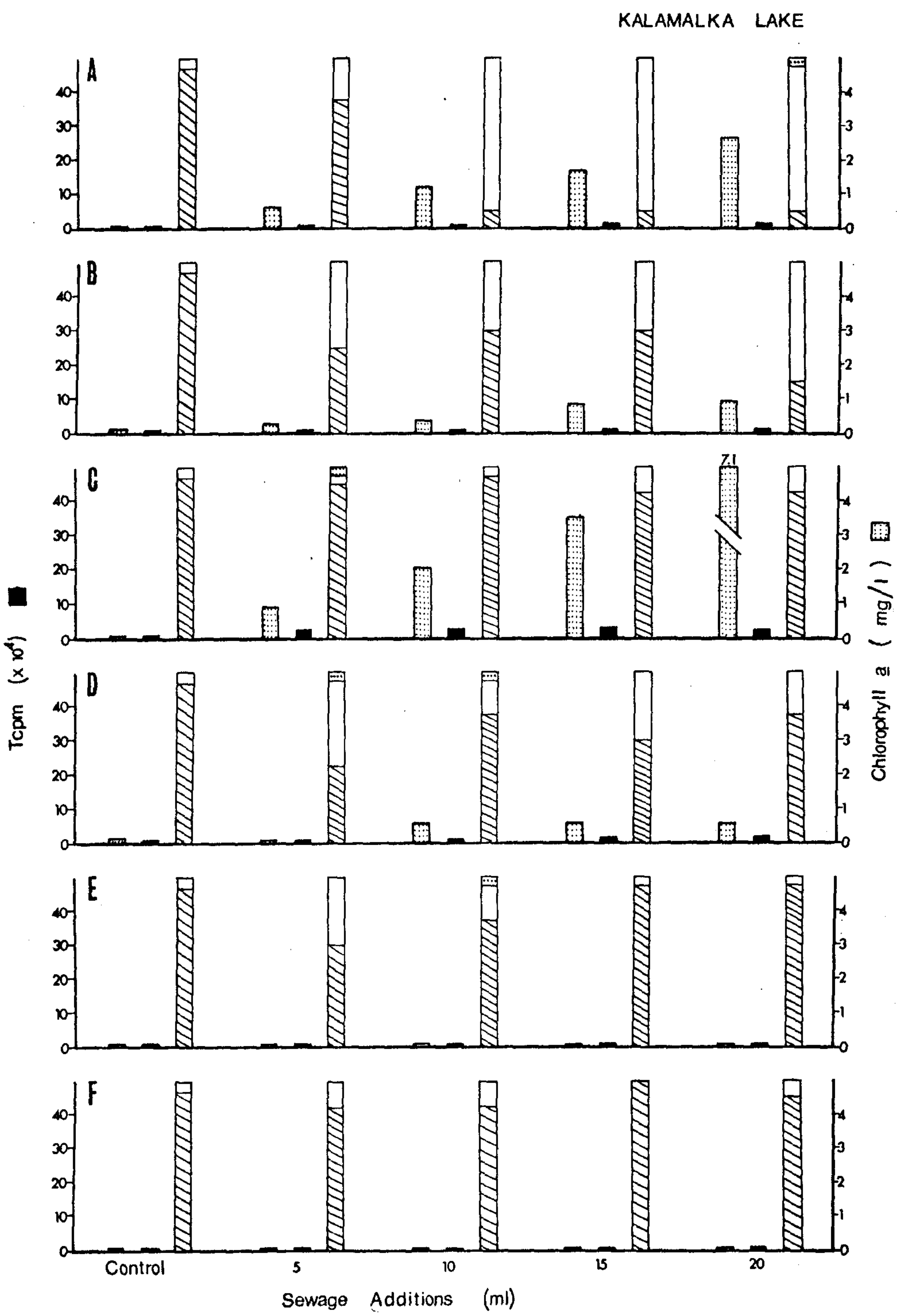
The controls after nine days contained almost exclusively diatoms, chiefly _Synedra_ spp. and _Navicula_ spp. Flasks receiving raw

Figure 24



OKANAGAN LAKE
A
B
C
D
E
F
0
10
20
30
40
0
1
2
3
4
Tcpm (x 10⁴)
Chlorophyll a (mg/l)
Control
5
10
15
20
Sewage Additions (ml)

Figure 25

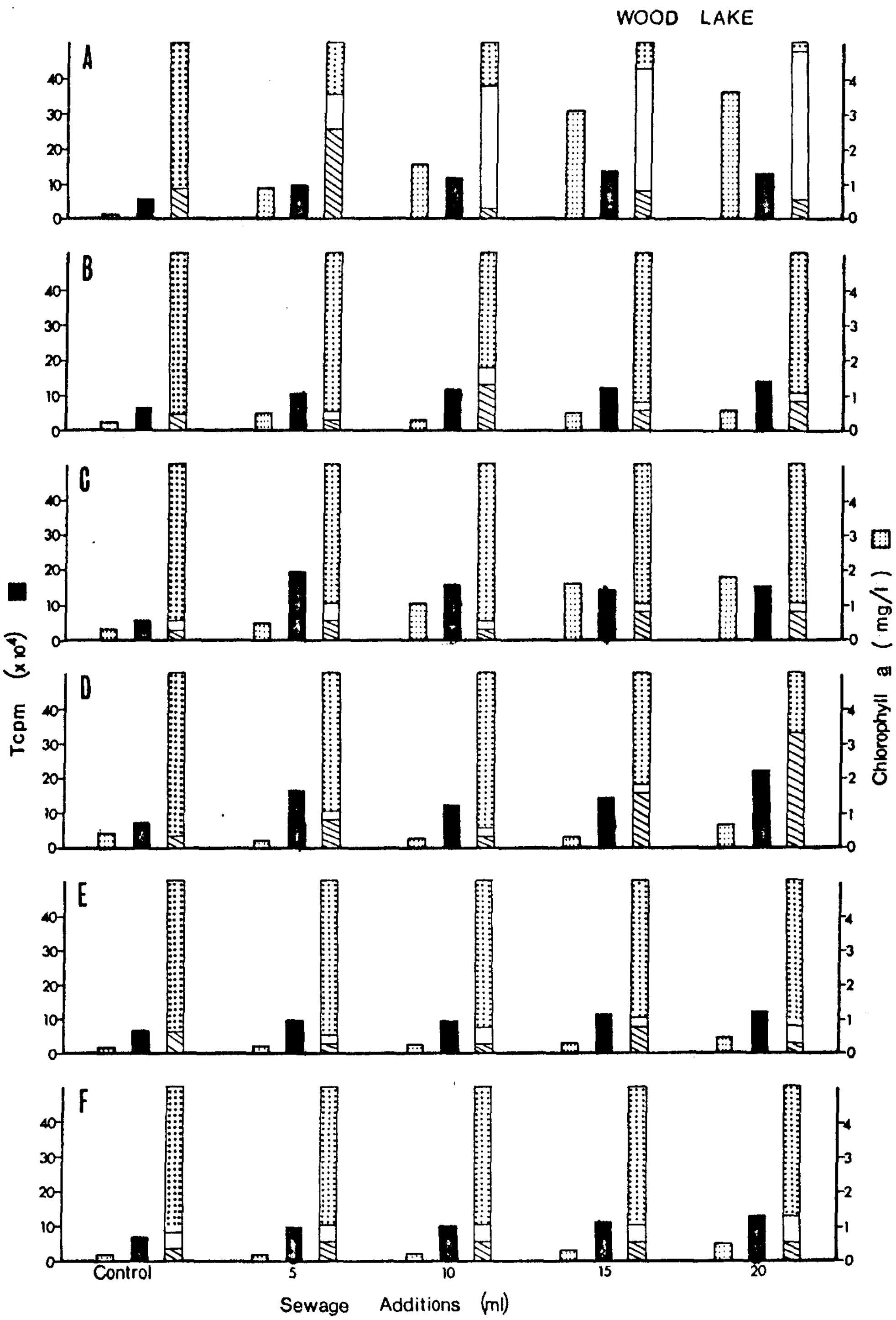

KALAMALKA LAKE
A
B
C
D
E
F
71
Tcpm (x 10⁴)
Chlorophyll a (mg/l)
Control
5
10
15
20
Sewage Additions (ml)

sewage promoted a complete species shift to that of green algal dominance, mainly _Scenedesmus_ sp. and _Chlorella_ sp.]' treated sewage additions gave similar results to that of raw sewage additions, but with less algal growth. With the addition of mixed liquor and 2' non-chlorinated sewage, the diatoms remained dominant, chiefly _Navicula_ spp. but with some _Scenedesmus_ sp. present. Flasks with final chlorinated and 3' 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_ _crotonensis_, in flasks with 3' treated sewage.

Wood Lake (Fig. 26)

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 1' 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 2' non-chlorinated sewage again promoted total dominance of diatoms, mainly _Navicula_ spp., whereas the addition of final chlorinated and 3' treated sewage perpetuated a Cyanophyta dominance, chiefly _Oscillatoria_ spp.

Figure 26


WOOD LAKE
A
B
C
D
E
F
40
30
20
10
0
4
3
2
1
0
Tcpm (x 10⁴)
Chlorophyll a (mg/l)
Control
5
10
15
20
Sewage Additions (ml)

SUMMARY AND CONCLUSIONS
SEWAGE ENRICHMENT EXPERIMENTS

The observed growth and succession of phytoplankton stimulated by sewage additions should be interpreted with caution. This is because 'flask' responses may differ from "in situ" responses, due to differing environmental parameters operative in each lake. Also, the inoculum of algae and hence the final species succession is strongly dependent upon the particular species present when sampled and upon their nutritional state. Nonetheless, some interesting and useful information regarding the behaviour of natural phytoplankton populations in the Okanagan lakes was obtained from these experiments.

Results in all lakes clearly show that 3' treatment as well as 2' chlorinated treatment reduces the reproductive potential of both nuisance and non-nuisance algae. It is difficult to distinguish whether the reduced growth was a response to lower nutrient concentrations or to the presence of chlorine or to both factors. It was interesting to note that the greatest growth (TCPM) was observed in those flasks receiving 2' effluent, despite the greater nutrient concentrations in raw sewage and mixed liquor additions. This is likely due to a greater concentration of "available" nutrients in sewage after it has passed through the various stages of biological treatment. Irregardless, the best treatment is that which removes the most nutrients from the final effluent, namely PO_4(P) and NO_3(N). Present evidence indicates that removal of PO_4(P) will in most all lakes lead to an amelioration of nuisance conditions and hasten the lake's recovery (Edmondson 1970). Nutrient removal can be accomplished by diversion, 3' treatment, or by land irrigation. Since current information indicates domestic waste to be largely responsible for water quality problems in the Valley it would be prudent to upgrade present 2' treatment facilities in the Valley. Also, 3' treatment facilities should be installed where land irrigation methods do not known appear feasible. Since the greatest/source of plant nutrients to most all lakes in the Okanagan system is domestic sewage, every effort should be made to either remove the effluent from the lake or to 'polish' the final effluent before discharge to the lake.

Most algal nuisance conditions in lakes are caused by the overproduction of blue-green algae. Blue-greens produce gas vacuoles which enable them to remain at or near the surface of the water where they can be concentrated by currents or wind, thereby producing nuisance scums or 'blooms'. Sewage is rich, not only in nutrients, but other vital elements essential to algal growth (Vallentyne 1957). It is well documented that in those lakes receiving sewage discharge, blue-green algal blooms are common (Edmondson 1968, Thomas 1957, Mackenthum 1969). In our experiments it was shown that increasing concentrations of sewage led to increased blue-green and green algal dominance, notably *Oscillatoria* sp. and *Anabaena* sp. Therefore it should be clear to those concerned with maintaining good water quality in the Okanagan Valley, that sewage discharge in areas of high population density is inconsistent with good water use planning, especially in the Okanagan Valley where water-orientated recreational activities play such a key role. The key to maintaining better water quality in the Okanagan lies in more stricter control of high nutrient effluent discharge to the Valley lakes.

D. TRACE METAL EXPERIMENTS (TME)

The fall run of the NEB was incorporated into the trace metal experiments. The first seven flasks of each series received nutrient additions equivalent to those in the spring NEB, 1971, The remaining flasks received combinations of nutrients (NO_3(N) PO_4(P)); trace metals; boron, iron and molybdenum, and the chelator, EDTA (Table A). The results obtained from the trace metal experiments will be discussed on the basis of uptake of radioactive carbon as 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.

Osoyoos Lake The fall run of the NEB shoved similar growth trends to that seen in the spring run. NO_3(N) additions of 0.7 mg/l showed growth equal to that of the control, whereas at the higher concentration, 1.2 mg/l growth was observed to be less than that of the control (Table 7). Phosphorus addition at the lowest concentration, 0.03 mg/l, showed growth inhibition whereas at the higher concentration, .09 mg/l, growth was stimulated beyond that of the controls. Addition of NO_3(N) and PO_4(P) together, at both concentrations, showed the greatest growth (Table 7).

Boron. Stimulation of algal growth was evident with boron additions at the lowest concentration, whereas at the higher concentration, growth was inhibited (Table 7). 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, 0.03 mg/l, with boron at both concentrations, 10 and 100 ug/1, 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).

EDTA. 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). 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 lover concentration, along with EDTA at both concentrations, showed growth stimulation, but to a lesser degree than that of NO_3(N) and boron additions. Phosphate additions at the highest concentration along with both concentrations of EDTA proved to be inhibitory to algal growth (Table 7). 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).

EDTA and Iron. 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).

Molybdenum. Growth was again 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).

Skaha Lake

The fall run of the NEB on one mid-lake station in Skaha Lake, showed similar results to that of the spring run, except that the addition of nitrogen at the highest concentration, 2.1 mg/l, showed the greatest production of algae (Table 8).

Boron. 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 8). 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 8).

EDTA. 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 8). 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 8).

EDTA and Iron. The controls and flasks receiving additions of PO_4(P) at the lowest concentration, and EDTA and iron higher concentration, together with flasks inoculated with PO_4(P) highest concentration and EDTA 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 8).

Molybdenum. 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 8).

Okanagan Lake

The fall run of the NEB, 1971 showed stimulation of growth with all nutrient additions. Nitrate additions at the highest concentration showed the greatest production of algae. Flask 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 9). Addition in 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 9).

Boron. Some stimulatory effect on algal growth was evident with boron additions alone, at both concentrations (Table 9). 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 9).

EDTA. Addition of EDTA in most all cases showed greater growth than that of the controls. EDTA additions alone, shoved 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 addition 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 additions of EDTA (Table 9).

EDTA and Iron. 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 9). 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 9).

Molybdenum. In all flasks, except for the addition of molybdenum alone at the lowest concentration, growth was less than that of the controls (Table 9).

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 is the most Oligotrophic lake in the Okanagan Basin.

Wood Lake

The fall run of the NEB, 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 10).

Boron. All additions of boron, alone or in combination with nutrients, showed growth equal to or less than that of the controls (Table 10).

EDTA. 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 lowest concentration and EDTA both concentrations, and 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 10).

EDTA and Iron. Similar growth patterns were observed with the addition of EDTA and iron to that of additions of EDTA, except that 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 10).

Molybdenum. The highest yeild 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 10). The greatest growth response was observed in flasks with additions of NO_3(N) highest concentration, and NO_3(N) and PO_4(P) together at the highest concentration along with both concentrations of molybdenum.

SUMMARY AND CONCLUSIONS
TRACE METAL EXPERIMENTS

The observed trends noted in the TME are from a single set of experiments run on samples obtained from a single mid-lake station in each lake. Extrapolation to other areas within each lake cannot validly be done from this single set of experiments. However, comparison among lakes drawn from algal responses within each lake supplies further information on the relative fertility of the lakes in the Okanagan chain.

In all lakes the greatest stimulatory response was noted with the addition of EDTA and Iron. Increased algal growth was observed more often in flasks with EDTA and iron than with the addition of any other trace metal or chelator. This observation is similar to observations noted by Schelske (1962), Shelske .et al. (1962) and Sakamoto (1971) who noted marked increases in phytoplankton production with the addition of iron and EDTA alone and in combination with other essential nutrients. Among flasks receiving EDTA and iron, the greatest growth occurred with additions of NO_3(N) and PO_4(P).

EDTA additions alone and in combination with nutrients ranked second in stimulating algal growth. Greater stimulation was noted when iron was added with EDTA, especially in Osoyoos Lake, which may indicate an iron deficiency in this lake. Iron plays a key role in the synthesis of chlorophyll and in some enzymatic reactions, and thus if present in insufficient quantities would limit algal growth.

Molybdenum ranked third in stimulating phytoplankton growth in the flasks. One unusual response was noted in that it was either an all or none response, i.e. either all algal growth was stimulated or all was inhibited. It is interesting to note that total stimulatory responses were observed in samples from Osoyoos and Wood Lakes, and total inhibition in Skaha and Okanagan Lakes. This is unusual since Wood, Osoyoos, and Skaha Lakes are highly productive while Okanagan is not, and thus one would expect similar responses in the three productive lakes. A possible explanation may be that the dominant alga in Skaha Lake at the time of sampling was the blue-green <u>Anabaena.</u> a nitrogen fixer, and it is known that molybdenum is required for nitrogen fixation (Hutchinson 1967, Round 1965). It is possible, therefore, that molybdenum concentrations were at optimal levels in Skaha at time of sampling, and further additions were inhibitory. In those lakes with total stimulatory responses, it is likely that concentrations of the metal were sub-optimal.

Boron stimulated little algal growth in any of the lakes, and no distinct patterns could be discerned with the addition of this element. More experiments with this element should be conducted.

In addition to general observations on the effect of each trace metal and chelator on algal growth, these experiments provided further evidence as to which of the lakes are currently productive or unproductive. On the basis of algal response to the fall 1971 NEB, and TME the lakes could be ranked from the most productive to the least; 1. Wood; 2. Skaha 5 3. Osoyoos; 4. Okanagan; and 5. Kalamalka.

APPENDIX I

LIST OF EXPERIMENTS

BIOASSAY PROGRAM

1970, 1971

APPENDIX I

Bioassay Program: Type, station, location and duration of experiments 1970 - 1971.

1970

Experiment	Station	Lake & Location	Duration
		Osoyoos	
NEB	1	midlake	May 26 - June 10
PCB	1	midlake	July 21 - 30
		Skaha	
NEB	1	Okanagan River	May 20 - June 4
	1	"	Aug. 24 - Sept. 8
PCB	1	"	July 21 - 30
	1	"	Aug. 13 - 21
	2	Okanagan Falls	July 21 - 30
	2	"	Aug. 13 - 21
		Okanagan	
NEB	1	midlake off Summerland	May 22 - June 5
	1	trout hatchery	Aug. 24 - Sept. 8
PCB	1	"	July 21 - 30
	1	"	Aug. 13 - 21
	2	Kelowna Bridge	July 21 - 30
	2	Kelowna Bridge	Aug. 13 - 21
	3	Vernon Arm - midlake	July 21 - 30
			Aug. 13 - 21
		Kalamalka	
NEB	1	midlake off Crystal Waters Resort	June 8 - 22
	1	"	Aug. 17 - Sept. 1
PCB	1	"	July 21 - 30
	1	"	Aug. 13 - 21
		Wood	
NEB	1	midlake $\frac{3}{4}$ mile from	June 9 - 23
PCB	1	north shore	June 21 - 30

APPENDIX I (cont'd)

1971

Experiment	Station	Lake & Location	Duration
		Osoyoos	
NEB	1	Northern region	June 7 - 16
	2	Southern region	June 7 - 16
PCB	1	Mouth of Okanagan River	Aug. 10 - 16
	2	midlake	Aug. 10 - 16
	3	Southern region	Aug. 10 - 16
SEE	1	midlake	July 20 - 29
TME	1	midlake	Aug. 19 - 28
		Vaseux	
NEB	1	midlake	June 10 - 19
PCB	1		Aug. 10 - 16
		Skaha	
NEB	1	Okanagan River	May 19 - 28
	2	Okanagan Falls	May 19 - 28
PCB	1	Okanagan River (north of Penticton STP.)	Aug. 10 - 16
	2	Okanagan River - mouth	Aug. 10 - 16
	3	midlake	Aug. 10 - 16
	4	Okanagan Falls	Aug. 10 - 16
SEE	1	midlake	July 7 - 16
TME	1	midlake	Aug. 25 - Sept. 3
		Okanagan	
NEB	1	Vernon Arm	May 22 - 31
	2	Armstrong Arm	May 22 - 31
	3	Kelowna Bridge	June 10 - 19
	4	Peachland (just off)	June 11 - 20
	5	Summerland (just off)	June 23 - July 2
	6	Penticton	June 14 - 23
PCB	1	Armstrong Arm	Aug. 17 - 23
	2	Vernon Arm	" "
	3	Northern region - midlake	" "
	4	Kelowna Bridge	" "
	5	Mill Creek	" "
	6	Trepanier Creek	" "
	7	Peachland	" "
	8	Midlake - between Peachland & Summerland	" "
	9	Trout Creek	" "
	10	Penticton	" "
SEE	1	midlake	July 7 - 16
TME	1	midlake	Aug. 21 - 30

APPENDIX I (cont'd)

<u>1971</u>

Experiment	Station	Lake & Location	Duration
		Kalamalka	
NEB	1	Southern region	May 31 - June 9
	2	Northern region	" "
PCB	1	Western Arm	Aug. 10 - 16
	2	Cosens Bay	" "
	3	midlake	" "
	4	Southern region	" "
	5	Channel	" "
SEE	1	midlake	Aug. 9 - 18
TME	1	midlake	Sept. 14 - 23
		Wood	
NEB	1	Northern region	June 1 - 10
	2	Southern region	" "
PCB	1	Northern region	Aug. 10 - 16
	2	midlake	" "
	3	Southern region	" "
SEE	1	midlake	July 23 - Aug. 1
TME	1	midlake	Sept. 15 - 24

APPENDIX II

TABLES 1 to 10

LABORATORY PROCEDURES AND RESULTS

BIOASSAY PROGRAM

1970, 1971

TABLE 1. Concentration of $NO_3N)$, $PO_4(P)$ and CO_2 added to culture flasks in 1970, NEB. 0 = flask number.

$PO_4(P)$ mg/l \ $NO_3(N)$ mg/l	0	0.2	0.7	2.1	7.0
0	(1)	(2)	(3)	(4)	(5)
.03	(6)	(7)	(8)	(9)	(10)
.09	(11)	(12)	(13)	(14)	(15)
.31	(16)	(17)	(18)	(19)	(20)
.93	(21)	(22)	(23)	(24)	(25)

CO_2 mg/l	4.4	13.2	44	132	440
$NO_3(N)$ 1.4 mg/l + $PO_4(P)$ .09 mg/l	(26)	(27)	(28)	(29)	(30)

<u>TABLE 2.</u> Concentration of NO_3(N) and PO_4(P) added to culture flasks in 1971, NEB. 0 = flask number.

PO_4(P) mg/l \ NO_3(N) mg/l	0	0	0.2	0.2	0.7	0.7	2.1	2.1
0	(1)	(2)			(3)	(4)	(5)	(6)
.03	(7)	(8)	(11)	(12)				
.09	(9)	(10)			(13)	(14)		

TABLE 3. Approximate concentration of PO_4(P) and NO_3(N) added to flasks in the sewage nutrient enrichment experiments.[1]

Flask No.	Stage/Amount Added	PO_4(P) mg/liter	NO_3(N) mg/liter
	Raw	14.00	13.00
1	0 ml	0.00	0.00
2	5 ml	0.07	0.07
3	10 ml	0.14	0.13
4	15 ml	0.21	0.21
5	20 ml	0.28	0.28
	Primary	16.00	10.00
6	0	0.00	0.00
7	5	0.08	0.05
8	10	0.16	0.10
9	15	0.24	0.15
10	20	0.32	0.20
	Mixed liquor	76.00	21.00
11	0	0.00	0.00
12	5	0.38	0.11
13	10	0.76	0.21
14	15	1.14	0.32
15	20	1.52	0.42
C NC	Secondary C NC	9.00	18.00
16 21	0	0.00	0.00
17 22	5	0.04	0.09
18 23	10	0.09	0.18
19 24	15	0.13	0.27
20 25	20	0.18	0.36
	Tertiary[2]	4.00	18.00
26	0	0.00	0.00
27	5	0.02	0.09
28	10	0.04	0.18
29	15	0.06	0.27
30	20	0.08	0.36

1. Values of Raw and Secondary from Penticton S.T.P. laboratory, other from Mr. Archie Pick, Winnipeg Metro Sewage work. All NO_3(N) values from Metro Winnipeg STP.

2. Assumes 45% reduction at Penticton plant which was the case at time of sampling.

TABLE 4. Trace Metal, Chelator and Nutrient Additions, TME 1971. 0 = Flask number.

Ion (mg/l)	Nutrient Addition (mg/l) Control 0	Nitrogen 0.7	Nitrogen 2.1	Phosphorus .03	Phosphorus .09	Nitrogen & Phosphorus 0.7 + .03	Nitrogen & Phosphorus 2.1 + .09
0	1	2	3	4	5	6	7
Boron .01	8	10	12	14	16	18	20
.11	9	11	13	15	17	19	21
EDTA .01	22	24	26	28	30	32	34
.08	23	25	27	29	31	33	35
EDTA + Iron .01 .01	36	38	40	42	44	46	48
.08 .11	37	39	41	43	45	47	49
Molybdenum .01	50	52	54	56	58	60	62
.11	51	53	55	57	59	61	63

TABLE 5. Ranking of Okanagan Lakes on the basis of yield (maximum growth), P.C.B. Experiments, 1970.

PCB No. 1, July 21 - 30, 1970

Rank	*Selenastrum*	*Anabaena*	*Microcystis*
1.	Skaha Lake (mouth of Okanagan R.)	Osoyoos Lake (midlake)	Woods Lake (midlake) Okanagan Lake (off trout hatchery, Summerland)
2.	Okanagan Lake (off trout hatchery, Summerland)	Okanagan Lake (Vernon arm) Woods Lake (midlake) Kalamalka (midlake)	Okanagan Lake (Kelowna Bridge)
3.	Okanagan Lake (Vernon Arm)	Skaha Lake (Okanagan Falls) Okanagan Lake (off trout hatchery, Summerland)	Kalamalka (midlake)
4.	Osoyoos (midlake) Skaha (Okanagan Falls) Okanagan (Kelowna Bridge)	Okanagan Lake (Kelowna Bridge)	Okanagan Lake (Vernon arm)
5.	Kalamalka (midlake)	Skaha Lake (mouth of Okanagan River)	Skaha Lake (off Okanagan River) Skaha Lake (Okanagan Falls) Osoyoos Lake (midlake)
6.	Woods (midlake)		

P.C.B. No. 2[1], August 13 - 21, 1970

Rank	*Selenastrum*	*Anabaena*	*Microcystis*
1.	Skaha Lake (mouth of Okanagan River)	Skaha Lake (mouth of Okanagan River)	Skaha Lake (mouth of Okanagan River)
2.	Skaha Lake (Okanagan Falls) Okanagan Lake (off hatchery, Summerland)	Okanagan Lake (Vernon Arm) Okanagan Lake (off hatchery, Summerland)	Okanagan Lake (off hatchery, Summerland)
3.	Okanagan Lake (Vernon Arm)	Kalamalka (midlake)	Skaha Lake (Okanagan Falls) Kalamalka Lake (midlake)
4.	Kalamalka Lake (midlake)	Skaha Lake (Okanagan Falls) Okanagan Lake (Kelowna Bridge)	Okanagan Lake (Vernon Arm) Okanagan Lake (Kelowna Bridge)
5.	Okanagan Lake (Kelowna Bridge)		

1. Only Okanagan, Skaha and Kalamalka tested.

TABLE 6. Ranking of Okanagan lakes on the basis of yield (maximum growth), P.C.B. Experiments, 1971.

P.C.B. No. 1 August 10 - 23, 1971 Ranking by lake: (station average)

Selenastrum	Anabaena	Microcystis
1. Skaha Lake	1. Skaha Lake	1. Skaha Lake
2. Wood Lake	2. Osoyoos Lake	2. Osoyoos Lake
3. Vaseux Lake	3. Vaseux Lake	3. Wood Lake
4. Osoyoos Lake	4. Kalamalka Lake	4. Kalamalka Lake
5. Kalamalka Lake	5. Wood Lake	5. Vaseux Lake
6. Okanagan Lake	6. Okanagan Lake	6. Okanagan Lake

Ranking by Station

Selenastrum	Anabaena	Microcystis
1. Skaha Lake (St. No. 2)	1. Skaha Lake (St. No. 3)	1. Skaha Lake (St. No. 3)
2. Skaha Lake (St. Nos. 1 & 3)	2. Osoyoos Lake (St. No. 2)	2. Skaha Lake (St. No. 2)
3. Skaha Lake (St. No. 4)	3. Skaha Lake (St. No. 4)	3. Osoyoos Lake (St. No. 2)
4. Wood Lake (St. No. 3)	4. Osoyoos Lake (St. No. 3)	4. Kalamalka Lake (St. No. 2)
5. Wood Lake (St. No. 2)	5. Vaseux Lake (St. No. 1)	5. Skaha Lake (St. No. 1)
6. Vaseux Lake (St. No. 1)	6. Kalamalka Lake (St. No. 2)	6. Skaha Lake (St. No. 4)

TABLE 7. Results of the Trace Metal Experiments, 1971. Osoyoos Lake.
+ (>1.0) growth greater than controls.
-(<1.C) growth less than controls.
e (= 1.0) growth equal to controls.

Trace Metal + Chelator mg/l.	Control 0	Nitrogen 0.7	Nitrogen 2.1	Phosphorus .03	Phosphorus .09	Nitrogen & Phosphorus .07 + .03	Nitrogen & Phosphorus 2.1 + .09
Boron							
.01	+ 1.3	e 1.0	+ 1.5	+ 1.3	- 0.9	- 0.8	- 0.7
.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	+
.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
.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
.11	+ 1.1	+ 1.3	+ 1.7	+ 1.2	e 1.0	e 1.0	+ 1.2

TABLE 8. Results of Truce Metal Experiments, 1971. Skaha lake.

+ (>1.0) growth greater than controls.
- (<1.0) growth less than controls.
e (=1.0) growth equal to controls.

Trace Metal + Chelator mg/l.	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
.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
.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
.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
.11	+ 1.1	+ 1.3	+ 1.7	+ 1.2	e 1.0	e 1.0	+ 1.2

TABLE 9. Trace Metal Experiments, 1971. Okanagan Lake.

+ (>1.0) growth greater than controls.
- (<1.0) growth less than controls.
e (=1.0) growth equal to controls.

	Nutrient Addition (mg/l)						
	Control	Nitrogen		Phosphorus		Nitrogen + Phosphorus	
Trace Metal + Chelator mg/l.	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
.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
.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
.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
.11	e 1.0	- 0.4	- 0.5	- 0.4	- 0.5	- 0.5	- 0.4

TABLE 10. Results of Trace Metal Experiments, 1971. Wood Lake.
+ (>1.0) growth greater than controls.
- (<1.0) growth less than controls.
e (=1.0) growth equal to controls.

	Nutrient Additions						
	Control	Nitrogen		Phosphorus		Nitrogen + Phosphorus	
Trace Metal + Chelator mg/l.	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
.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
.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
.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
.11	+ 1.3	+ 1.2	+ 1.2	+ 1.1	e 1.0	+ 1.3	+ 1.4

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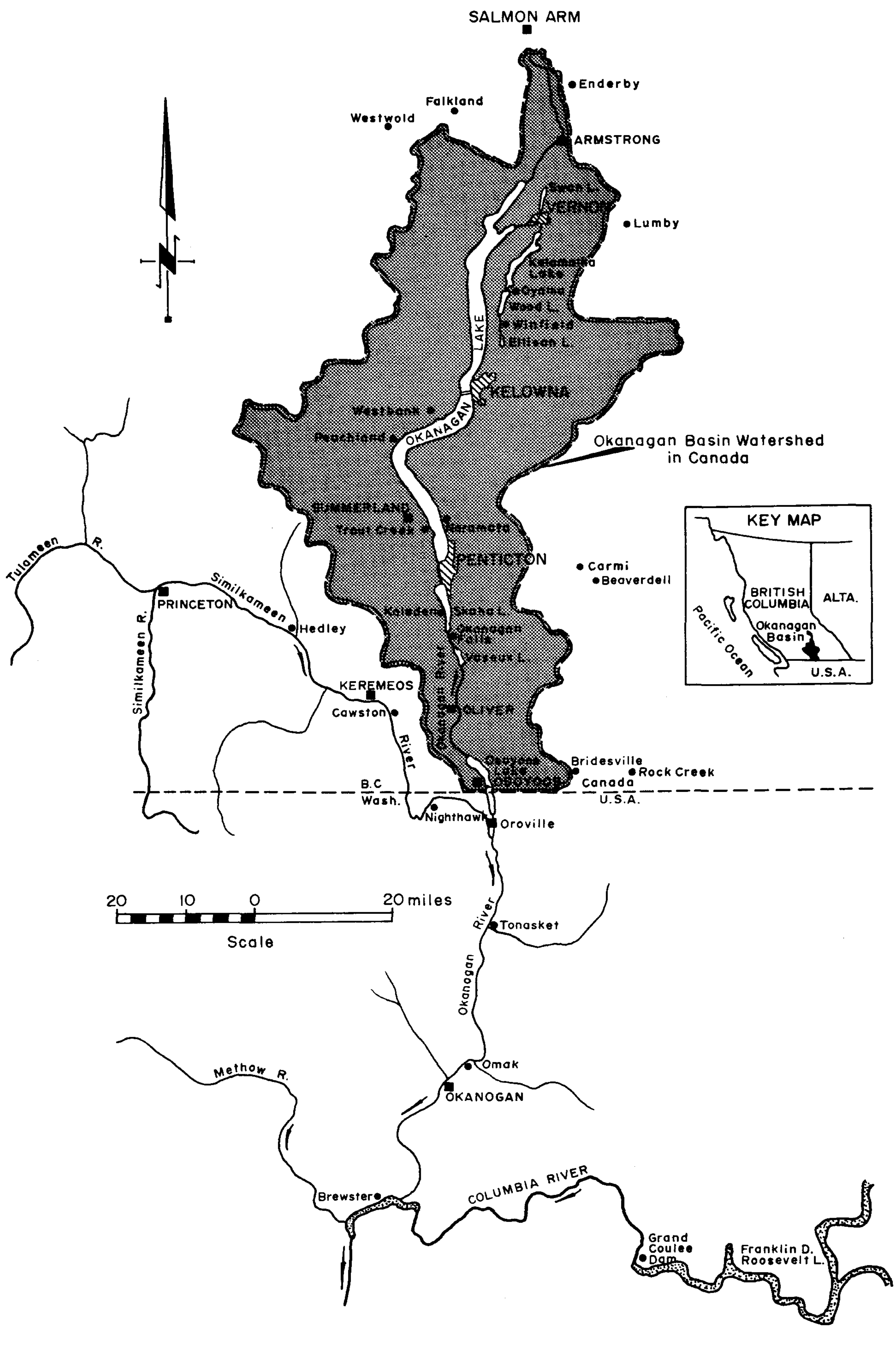

OKANAGAN DRAINAGE BASIN IN CANADA