CHAPTER 3

Methods and Approach

3.1 GEOLOGICAL STUDIES

Information pertaining to basic geologic formation, sediment characteristics of lake bottoms, sedimentation rate arid basin contours was required for numerous portions of the study as basic background data. Much information, particularly basic geology, is available from other investigators. This was used where applicable. Where documentation was lacking, studies were carried out - particularly with regard to contour mapping, sediment core sampling, element analysis and paleolimnological examination.

Field work was carried out during the summer and fall of 1971. An acoustic sounding program took place on the main valley lakes. In addition, a transit sounder survey of the near-shore areas of Skaha and Southern Okanagan Lakes was performed. Over 150 surface samples (0-3 cm.) were collected with a Skipek grab sampler (Figure 3.1). About 50 one meter cores were taken with a benthos corer. All sediment samples were freeze dried in the field after observations of color, texture and general characteristics were noted. Water depth and position of each sample was recorded. Measurements of hydrogen ion concentration (pH), oxidation-reduction potential (Eh), and water content of cores were made in August of 1971.

Samples collected were subjected to a variety of laboratory procedures, and methods employed are detailed below.

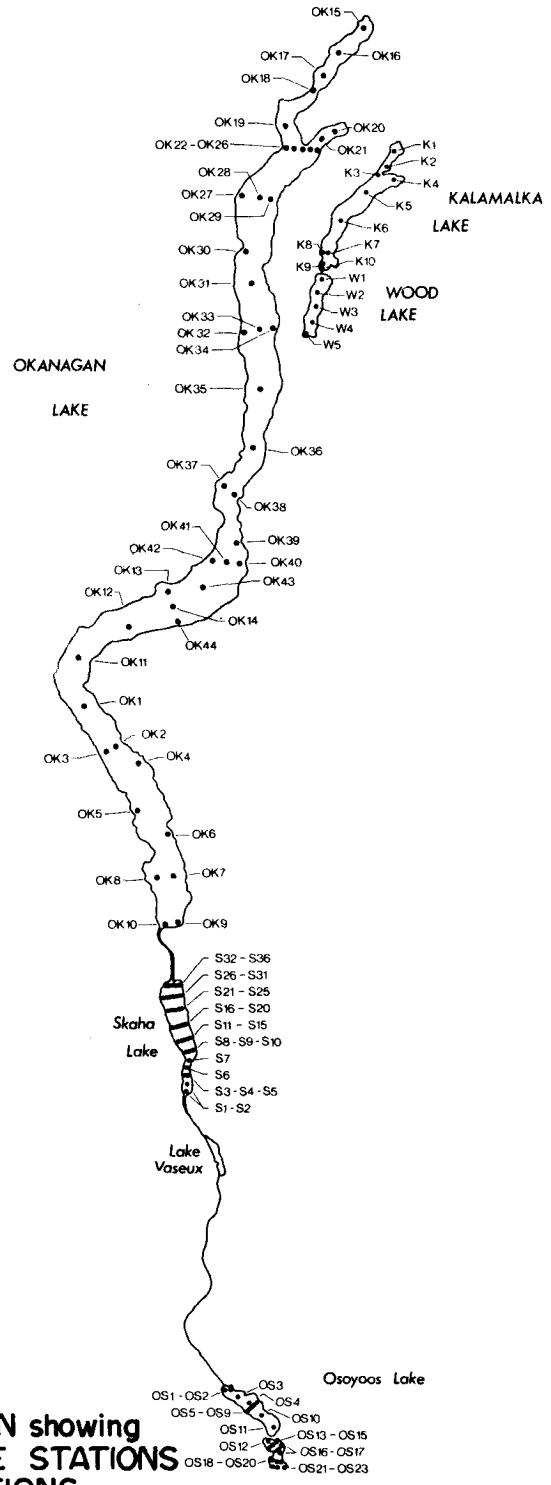
Total major element analysis of samples was done by X-ray fluorescence using a Phillips PW1220C semi-automatic X-ray fluorescence spectrometer on pelletized samples. Ca, Na, Fe, Mg, P, Mn, Si, K, S, Al and Ti were determined with this system. HCl, extractable Pb, Fe, Mn, Cu, Zn, Ni, Co, Cr, Cd, Be, V, K, Mg and Ca, were measured by a Techtron AA-5 Atomic Absorption Spectrophotometer. The freeze dried sediment samples were subjected to attack by hot concentrated HCl for 30 minutes and the leachate was analysed.

Additional trace element results were obtained under contract to the Commercial Products laboratory of the Atomic Energy Commission, Ottawa. This laboratory analysed perchloric acid leaches from the sediments of Cu, Mn, As, Sc, Eu and Sm using instrumental neutron activation analysis.

Mercury analyses of the sediment were made by Barringer Research of Toronto, using their patented mercury spectrometer. Differential thermal mercury analysis of selected samples were done by Barringer Research to assist in characterizing the forms of mercury in the sediments.

core locations

STATION NUMBER	CORE NUMBER
W3	WC-1
K6	KC-1
K9	KC-2
OK1	OKC-1
OK12	OKC-2
OK31	OKC-3
S4	SC-1
S18	SC-2
OS8	OSC-1
OS14	OSC-2
OS22	OSC-3



OKANAGAN BASIN showing BOTTOM SAMPLE STATIONS and CORE LOCATIONS.

Figure 3.1

B.E. St John 1971 Task 121

Organic carbon and carbonate carbon contents of the sediment were measured using a Leco induction furnace according to the method described by Kemp, 1971.

Acid extractable phosphorus was determined by a modification of the method of Shah *et al*, 1968. The modification consisted of the use of HCl in place of H_2S0_4.

The grain size fractionation of the sediments was measured by standard long pipette analysis. X-ray diffraction studies were undertaken on the mineralogical composition of each size fraction, and this work was assisted by microscopic investigation.

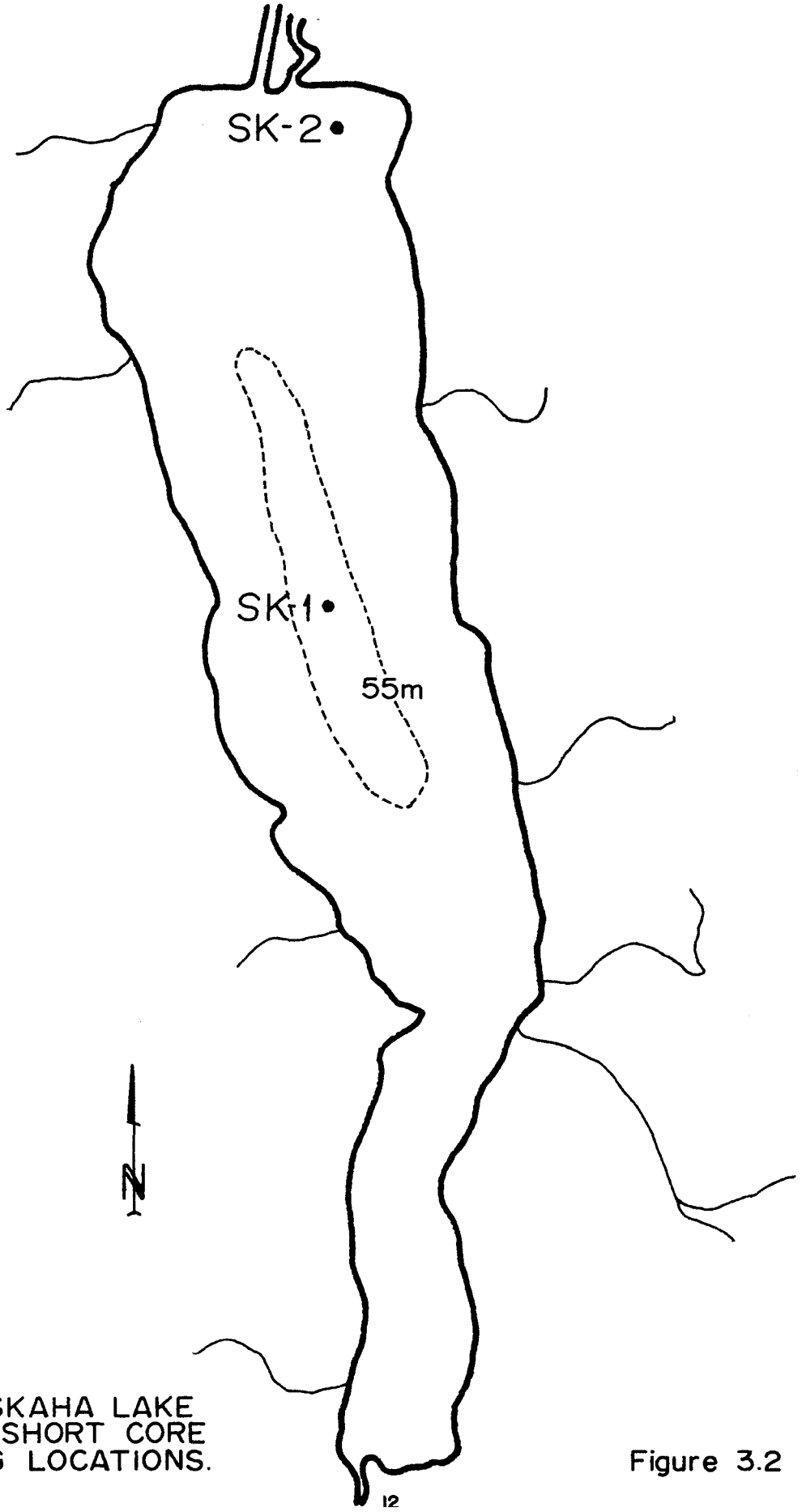
Two short cores were obtained from Skaha Lake for diatom paleolimnological analysis (Figure 3.2). Core SK2 was obtained with a Mackereth corer (Mackereth 1969) in 1970, at a water depth of 6 meters, and Core SK1 was obtained with a gravity corer in 1971 at the area of maximum water depth - 60 meters. Both cores were sectioned within a week of obtaining them. Core SK2 was 45 cm. long and was sectioned at 0.5 cm. intervals to 10 cm., and at 1.0 cm. intervals for the remainder. Core SK1 was 105 cm. long and was sectioned at 1.0 cm. intervals to a depth of 20 cm. and at 5.0 cm. intervals for the remainder. Samples were obtained from the non-smeared inner portion of each section. Loss of weight on ignition (L.O.I.) values were determined for Core SK1 by burning oven-dried samples in a muffle furnace at 500°C for two hours.

Approximately 1 gram of fresh sediment from each core was macerated in concentrated, diluted nitric acid. Samples were boiled until they reached half the original volume, then $K_2Cr_2O_7$ was added for final oxidation. The samples were repeatedly decanted, rinsed, and allowed to resettle until no trace of acid remained. Permanent slides were made. Approximately 300 to 400 diatom frustules per slide were examined microscopically. The monographs of Hustedt 1930, Cleve-Euler 1951 and Patrick and Reimer 1966 were used for identification, the more common diatoms being identified to species, other to genera.

Data were processed on an IBM 360 computer at the University of Manitoba Computer Center. Output gave percentage composition of the total diatom populations for all species, the Order Centrales, and the four Pennate tribes represented. Computer output data for the relative abundance of each species, genus, and group enumerated from the sediment cores were plotted by a Calcomp digital plotter as a function of sediment depth.

3.2 PHYSICAL STUDIES

Data pertaining to temperature, heat content and light transmittance of lake waters are essential to adequately determine the trophic state of lakes. By comparison with established criteria, the dynamics of eutrophication rate



MAP OF SKAHA LAKE
SHOWING SHORT CORE
SAMPLING LOCATIONS.

Figure 3.2

can be assessed. Physical studies involved data collection from the main valley lakes with regard to temperature, heat content and light transmittance and a study of the dispersion of the Okanagan River plume into Skaha Lake. Lake temperatures and light penetration was monitored in 1971, based on sampling stations established by study personnel. Numbers of stations, shown in Maps 3 to 10* in the Map Section at the back of this report, varied with lake size and complexity. (i.e. - 4 stations in Wood Lake, 19 in Okanagan Lake).

Temperature data were obtained with bathythermographs which were accurate to within ± 0.5°C for temperature and ± 1% of the scale used for depth. Monitor cruise data were supplemented with information from Ryan 15-day continuously recording thermographs in each lake (Maps 3 to 10). Ryan accuracies were ± 1°C and ± 1 to 3 hours in 15 days, depending upon the individual instrument.

Light transmittance data were collected on all lakes in September 1970 and May 1971 with submarine photometers. In 1970, a Model C-10 Irradiance and Depth Meter, manufactured by Marine Advisors, Inc., was used. A set of three Kodak Wratten filters (Red #29, Green #58 and Blue #47) were used with maximum transmission as suggested by Vollenweider (1969). In May 1971, a Kahl Scientific Instrument submarine photometer, Model 368 WA310 was used.

To calculate heat content and synthesize bathythermograph data, a Fortran IV program was used to calculate:

1) the average value of temperatures in the hypolimnion, mesolimnion and epilimnion
2) volumes of thermal layers, and
3) heat content of the layers.

The three heat contents were summed to give lake totals.

The input data consisted of:

1) cards punched in the format presently prescribed for digitized bathythermograph data at C.C.I.W., and
2) digitized mean depths of a system of grid squares superimposed on each lake.

The table below compares digitized lake volumes with volumes determined from a hyposometric curve.

Okanagan Lake data were synthesized manually because the long shoreline development would have required a subdivision of the lake into segments, thereby sacrificing efficiency gained by using the Fortran IV program.

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* Maps 1 and 2 are called up later in text.

LAKE	GRID SIZE (Km^2)	VOLUMES		NUMBER OF STATIONS USED
		DIGITIZED (Km^3)	ACTUAL (Km^3)	
Wood	0.250	0.19	0.20	4
Kalamalka	0.109	1.53	1.52	6
Skaha	0.176	0.540	0.558	7
Osoyoos (N)	0.088	0.190	.204	4
Okanagan	-	-	26.20	19

To calculate light transmission values, the percent attenuation of light versus depth were plotted on semi-log paper, placing depth on the linear scale (Vollenweider, 1969). The extinction coefficient, (m^{-1}) was then converted to transmission of light, T (%/m) by the formula:

$$T = 100\ e^{-\bullet}$$

where: $\bullet$ is the slope of the line connecting the percent attenuation versus depth points.

During September, 1970, when Red, Green and Blue filters were used, T was calculated according to the formula:

$$T = 1/3\ (T_{630} + T_{530} + T_{450})$$

where: T_{530}, T_{530}, T_{450} are the transmission values in %/m for the Red, Green and Blue filters respectively.

The effluent from the Penticton sewage treatment plant is discharged into the Okanagan River above Skaha Lake. It was thus considered of value to determine the fate of this river plume as it enters the lake, since nutrient dispersal may follow a similar pattern. Water soluble Rhodamine B dye was used to tag the river water. After determining the natural degradation rate of the dye in Okanagan River water, solutions were adjusted to specific gravity 1.00 and released into the midstream, 400 feet upstream from the river mouth.

Dye diffusion was monitored in the lake vertically and horizontally. Fluorometers were used to measure dye concentrations. Tracking drogues at a variety of depths measured currents. Wind data were obtained from the Penticton Airport, adjacent to the study site.

3.3 CHEMICAL STUDIES

Knowledge of the chemical characteristics of lake waters are required to determine the trophic state and potential productivity of a water body. Okanagan main valley lakes were chemically examined from 45 stations during 1971, (Maps 3 - 10). Temperature, Secchi disc measurements and lake water samples for chemical and biological analyses were collected at 23 "chemical stations" while

temperature and Secchi disc measurements only were made at the remaining 22. Sampling dates were approximately bi-monthly, with two extra samplings in May and July, (Table 3.1). Sampling dates included spring and fall overturns and full summer stratification.

Water samples were collected during isothermy with a 3 liter Van Dorn sampler at 5, 10, 25, 50, 100 meter depths, and at two meters from the lake bottom. If stratification was noted, samples were taken at two depths in the epilimnion, two or three depths in the mesolimnion (depending on steepness of gradient) and three depths in the hypolimnion. Samples for chlorophyll-*a* analysis were taken one meter below the surface and one meter above and below the mesolimnion if stratification prevailed. During isothermy only the one meter below surface sample was collected.

Upon retrieval; dissolved oxygen content, conductivity and pH were determined. One liter samples in plastic bottles were then forwarded in ice to the Mater Quality Division Laboratory in Calgary where chemical analysis took place within 24 hours of sampling. These samples were analyzed for: nutrients, NO_3(N), Total Kjeldahl -N, Ortho-PO_4, Total P (reported as PO_4), SiO_2 major ions; Ca, Mg, K, Na, CO_3, HCO_3, $S0_4$, Cl, F; total dissolved Iron and heavy metals Cu, Zn, Pb, Mn; total organic carbon; total inorganic carbon; pH, alkalinity, total hardness, conductivity, turbidity, and color. The water Quality Division's field laboratory in Kelowna analyzed another liter sample for pH, conductivity, alkalinity, BOD -5, suspended solids and turbidity . All the above analyses were done using methods outlined in APHA Standard Methods (1965).

Chlorophyll-*a* analysis was carried out in the laboratory in the Basin Study office in Penticton. Samples were filtered, dried in a dessicator and analysed fluorimetrically after tissue grinding and acetone extraction(Yentsch and Menzel, 1963).

3.4 BIOLOGICAL STUDIES

Because the quantitative and qualitative aspects of lake biology represent the results of physical, chemical, meteorological and geological factors and interactions, the biological aspects of the main valley lakes were examined in some detail. Nutrient bioassay, macrophytes, periphyton studies, bottom fauna, zooplankton and fish studies were all undertaken. The purpose and methodology for each biological facet examined are outlined below.

3.4.1 Nutrient Bioassay

Photosynthetic production, while providing a "food base" for other Okanagan main valley lakes biota, can become a nuisance factor to man and accelerate eutrophication if not maintained in check. An adequate understanding of the role

TABLE 3.1

SAMPLING DATES, OKANAGAN BASIN LAKES CHEMISTRY PROGRAM

LAKE		CRUISE NO.	DATE
OSOYOOS		OS-01	22/4/71
		OS-02	20/5/71
		OS-03	15/6/71
		OS-04	19/7/71
		OS-05	23/8/71
		OS-06	13/10/71
VASEUX		VA-01	21/6/71
		VA-02	11/10/71
SKAHA		SK-01	29/4/71
		SK-02	25/5/71
		SK-03	17/6/71
		SK-04	21/7/71
		SK-05	24/8/71
		SK-06	7/10/71
WOOD		WO-01	24/4/71
		WO-02	28/5/71
		WO-03	20/6/71
		WO-04	28/7/71
		WO-05	25/8/71
		WO-06	6/10/71
KALAMALKA		KA-01	25/4/71
		KA-02	27/5/71
		KA-03	20/6/71
		KA-04	25/8/71
		KA-05	6/10/71
OKANAGAN	(North)	OK-01	3/5/71
		OK-02	4/6/71
		OK-03	23/6/71
		OK-04	27/7/71
		OK-05	1/9/71
		OK-06	5/10/71
	(South)	OK-01	26/4/71
		OK-02	4/6/71
		OK-03	22/6/71
		OK-04	23/7/71
		OK-05	30/8/71
		OK-06	4/10/71

of various nutrients in regulating algal growth in the lakes was therefore considered essential to the limnology program and studies were designed to test the effects of PO_4(P), NO_3,(N) and CO_2 on stimulating algal growth in the Okanagan main valley lake waters.

(a) Nutrient Enrichment

Nutrient enrichment experiments were carried out using Okanagan main valley lakes water and natural phytoplankton populations during spring and fall of 1970 and 1971. Surface water samples were collected from mid-lake stations in Skaha, Osoyoos, Okanagan, Wood and Kalamalka Lakes in 1970, (Maps 3 - 10). Vaseux Lake was added to the series in 1971. An additional 500 ml. sample was collected and preserved (Lugol's solution) for phytoplankton identification. In 1970 a further sample was taken and analysed for alkalinity, conductivity, nutrients, pH, T.O.C., and turbidity, as this was prior to the inception of the chemical limnology program.

Upon returning to the laboratory a 6 liter water sample was filtered through an 87 micro-mesh net to remove zooplankton. The sample was then divided into 100 ml. aliquots, each of which was placed in a 250 ml. Erlenmeyer flask. Nutrient additions were then made with sterile micropipettes in concentrations outlined in Table 3.2. One micro-curie of $Na^{14}CO_3$ was added to each flask to monitor relative photosynthetic carbon uptake. The cultures were illuminated by a light bank (1750 foot candles, 18,830 lux) from below for 15 days. During the spring of 1970 temperature was not kept constant, varying between 25° and 33° C.

Starting on August 12, 1970, incubation took place under more closely controlled conditions. Temperature was a constant 24° +°C. Flasks #2, 6, 7, 8, 9, 10, 12, 17 and 22 (Table 3.2) were eliminated and only Okanagan, Skaha and Kalamalka Lakes were sampled. All samples were accommodated over one light bank of 400 foot candles (4,304 lux) intensity.

The cultures were gently swirled twice daily and a 10 ml. sub-sample taken every 5 days. The sub-sample was filtered through a 45 micro-millipore filter and washed with distilled water. The filters were placed in scintillation vials containing 20 ml. of scintillation fluid (Schindler and Holmgren, 1971).

Photosynthetic carbon uptake for each culture was recorded as counts per minute (cpm) by means of the Packard Tricarb Scintillation counter at FRB Laboratories, Vancouver, B.C. The relative growth rates monitored in this way provided a measure of activity for comparison among cultures in each experiment.

After 15 days' growth the experiments were terminated and the remaining portion of the cultures were sampled as follows: 10 ml. for measurements of carbon uptake as cpm; 20 ml. filtered through a glass filter for chlorophyll-*a*.

TABLE 3.2

CONCENTRATIONS OF $NO_3(N)$ and $PO_4(P)$ and CO_2 USED IN NUTRIENT ENRICHMENT BIOASSAY

1970

(○) = flask number

$PO_4(P)$ mg/l. \ $NO_3(N)$ mg/l	0	0.9	3.1	9.3	30.5
0	(1)	(2)	(3)	(4)	(5)
.09	(6)	(7)	(8)	(9)	(10)
.28	(11)	(12)	(13)	(14)	(15)
.98	(16)	(17)	(18)	(19)	(20)
2.86	(21)	(22)	(23)	(24)	(25)

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

1971

$PO_4(P)$ mg/l. \ $NO_3(N)$ mg/l	0	0	0.9	0.9	3.1	3.1	9.3	9.3
0	(1)	(2)			(3)	(4)	(5)	(6)
.09	(7)	(8)	(11)	(12)				
.28	(9)	(10)			(13)	(14)		

analysis; 20 ml. placed in a vial with Lugol's solution for algal

identification; and the remaining 30 ml. filtered through a 0.45 Millipore filter and dried between Parafilm sheets. These filters were later photographed for a pictorial representation of the relative effects of the various nutrient additions on algal growth.

Results of C^{14} measurements were calculated using the following formula:

$$T.C.P.M. = cpm \times (10-x) + cumulative\ cpm.$$

As the sub-sample was 10 ml. the cpm was multiplied by 10 to give the total cpm of the culture (TCPM). However, after the first subsample (10-x) was used, x being the total number of 10 ml. samples removed. The cumulative cpm was the total of all radioactivity removed from the culture in earlier samples.

During 1971, further procedural modifications were made. The six liter sample was subdivided into 150 ml. aliquots and duplicate series were run. Nutrient concentrations differed in some respects (Table 3.2). Slightly more (1.5 micro-curie) C^{14} was added to compensate for increased volume of water. The experimental period was shortened to 9 days since 1970 studies showed growth reached optimal levels after 7-9 days. Subsamples were withdrawn at 2-day intervals containing 15 ml. of Aquasol scintillation fluid. On the ninth day, the experiments were terminated as follows: 90 ml. for chlorophyll-*a.* determination, 20 ml. for algal determination and 70 ml. filtered for photographic interpretation.

(b) Pure Culture Bioassay

By removing all phytoplankton from take waters and introducing a known species at a known concentration to lake water under controlled conditions, it is possible to determine, at least on a comparative basis, the latent productive capacity of the waters examined. It was assumed this experiment would yield some insight into what specific regions or water masses within lakes contained residual nutrients stimulatory to test algae.

The following organisms were used to inoculate lake waters:

1. *Selenas capricornutum* (Chlorophyta).
2. *Anabaena flos-aquae* (nitrogen fixing Cyanophyta).
3. *Microcystis aeruginosa* (non-nitrogen fixing Cyanophyta).

The inocula were produced and maintained by transferring them every seven days to defined algal nutrient media (Paap, 1969). These cultures were kept at constant temperature (24 ±l°C, 1970; 21±°C, 1971) on a light bank (400 foot candles, 1971) and swirled at least four times daily.

In preparation for the experiments, water samples were collected from five main valley lakes in 1979 (Vaseux excluded) and from all main valley lakes in

1971. One liter samples were collected from stations indicated in Maps 3 to 10.

Upon return to the laboratory, water samples were filtered through 0.45 micro-millipore filters to remove all plankton. Six 100 ml, sub-samples of filtered water were placed in six 250 ml. sterilized Erlenmeyer flasks. Two ml. of synchronous 7 day old *Selenastrum* inocula plus 1.0 micro-curie of $Na^{14}CO_3$, was added to each of two flasks. Additives of Microcystis plus $Na^{14}CO_3$ and *Anabaena* plus $Na^{14}CO_3$ in the same amounts were added to two other pairs of flasks. Thus, a monoculture growth series was established in duplicate. Similar flasks for each test organism were prepared, but instead of lake water a defined algal nutrient medium was used. These flasks, containing 50 ml. of nutrient medium, 1.0 ml. of culture inocula and 1.0 micro-curie of $Na^{14}CO_3$ were used as controls.

The cultures were placed on a light bank (400 foot candles) and either swirled 4 times daily or shaken continuously at 80 oscillations per minute. In 1970, the experiments were of 9 days' duration, while in 1971 a seven day experimental period was used. Every second day, light absorbance and transmittance at 600 m*u* was measured. Photosynthetic carbon uptake was monitored every second day in 1971. In 1971, sub-sampling included chlorophyll-a analysis.

(c) Sewage Effluent Experiments

In 1971 a sewage effluent experiment was conducted in an attempt to gain insight into effects sewage enrichment might have on natural phytoplankton populations of five (Vaseux Lake excluded) Okanagan main valley lakes. It was also designed to test the effectiveness of tertiary treatment facilities currently in operation at the Penticton sewage treatment plant.

Surface water from each lake was obtained from an area free of the direct effluent influence (Maps 3 to 10). Sewage was collected from the Penticton sewage treatment plant in the following states:

1. raw sewage
2. after primary treatment
3. mixed liquor
4. non-chlorinated post secondary
5. chlorinated post secondary
6. chlorinated post tertiary

Removal of PO_4(P) at the time of sampling was estimated to be between 40% and 50%.

Laboratory procedure was identical to that of the 1971 nutrient enrichment experiment, except that varying amounts of sewage were added to each flask instead of defined nutrients (Table 3.3).

TABLE 3.3

CONCENTRATIONS OF $PO_4(P)$ AND $NO_3(N)$ USED IN SEWAGE ENRICHMENT EXPERIMENTS

FLASK NUMBER	STAGE/AMOUNT ADDED (ml)	$PO_4(P)$ mg/liter	$NO_3(N)$ mg/liter
	Raw	14.00	13.00
1	0	0.00	0.00
2	5	0.07	0.07
3	10	0.14	0.13
4	15	0.21	0.21
5	20	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 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 Sewage Treatment Plant laboratory, other from Mr. Archie Pick, Winnipeg Metro Sewage works. All $NO_3(N)$ values from Metro Winnipeg STP.

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

(d) Trace Metal Experiments

These experiments were designed to test the effects of the nutrients NO_3(N) and PO_4(P) in combination with some trace metals and the chelator EDTS on the growth of natural phytoplankton populations in five of the Okanagan Basin Lakes.

Samples were obtained from the surface waters of the five major lakes, Vaseux Lake excluded (Maps 3-10). These samples formed the basis for sixty-three flasks, which included seven for the fall run of the nutrient bioassay. The procedure was identical to that of the 1971 spring nutrient enrichment experiment except that nutrients and trace metals were added in different concentrations and combinations (Table 3.4).

3.4.2 Periphyton and Rooted Aquatic Vegetation

The trophic state of the lake often manifests itself in the density and variety of rooted aquatic vegetation that grows in the littoral area and the algae that in turn uses the macrobenthos and other littoral substrate for attachment. In lakes which are abundantly supplied with nutrients and a suitable substrate, these plant forms may reach nuisance densities and restrict water use in a number of ways. The extent of this growth in the Okanagan main valley lakes was examined in 1972, as was the determination of biomass and relative growth rate of periphyton. Four glass slides were suspended on a plexiglass tray (Figure 3.3) at 1.5 meter depth in selected stations in each lake. (Maps 3 to 10). Slides were removed from the trays at biweekly intervals, placed in glass jars with distilled water and transported to the laboratory. Two slides were scraped onto a preweighed Sartorius membrane filter (o.45 microns) and dried in a desiccator overnight. A third slide was scraped, filtered onto a Whatman GFC glass fiber filter, and macerated in a tissue grinder with 10 ml. of acetone. The extract was measured for chlorophyll-a. content using fluorometic methods (Nicholson, 1970). The last slide was scraped, filtered onto a Whatman filter, dried overnight and frozen. Total phosphorus was determined at the FRB-FI, Winnipeg laboratory using methods described by Stockner and Armstrong (1971). A few stations were chosen for a complete chemical tissue analysis -including total carbon and total nitrogen, as well as total phosphorus.

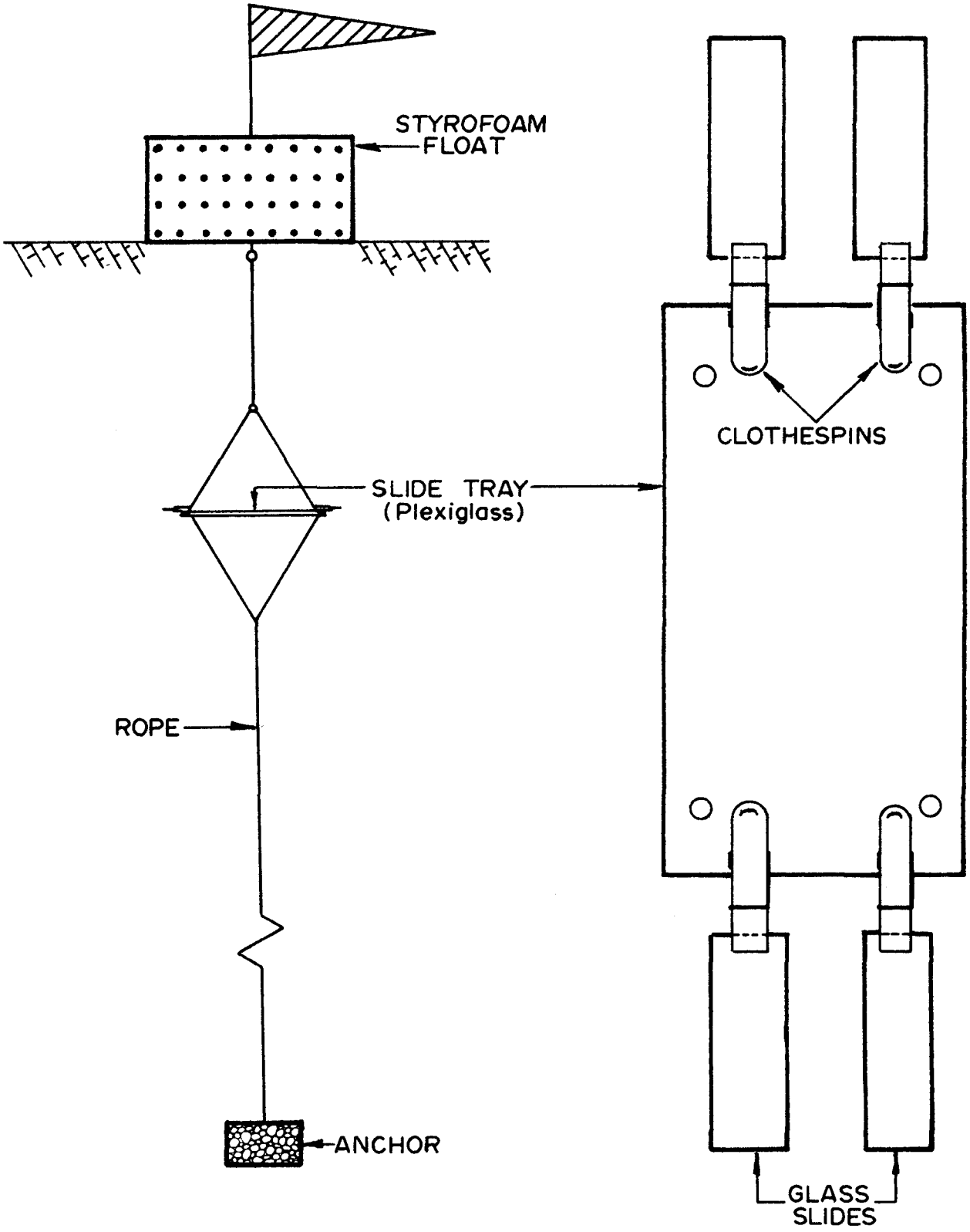
A strip of periphyton was removed from the plexiglass tray at each sampling period and analyzed for species composition. The same strip was repeatedly sampled, thereby reducing the likelihood of sampling more advanced stages of succession. At the laboratory, Lugol's solution was added and the samples were stored in small glass vials to await microscopic analysis. Upon examination, up to four glass slide mounts were made of each sample. If little variation was observed on two successive slides, no further examination was carried out. However, if considerable variation was encountered on the first two slides, an additional two were examined. The percentage composition of the major algal phyla, together with a list of dominant species was prepared. Absolute counts were not performed. Since species composition and growth on glass slides may be different than on

TABLE 3.4

TRACE METAL, CHELATOR AND NUTRIENT ADDITIONS, 1971

(n) = Flask number

Iron (mg/l) \ Nutrient Addition (mg/l)	Control	Nitrogen		Phosphorus		Nitrogen & Phosphorus	
	0	0.7	2.1	.03	.09	0.7 + 0.3	2.1 + .09
0	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Boron .01	(8)	(10)	(12)	(14)	(16)	(18)	(20)
Boron .11	(9)	(11)	(13)	(15)	(17)	(19)	(21)
EDTA .01	(22)	(24)	(26)	(28)	(30)	(32)	(34)
EDTA .08	(23)	(25)	(27)	(29)	(31)	(33)	(35)
EDTA + Iron .01 .01	(36)	(38)	(40)	(42)	(44)	(46)	(48)
EDTA + Iron .08 .11	(37)	(39)	(41)	(43)	(45)	(47)	(49)
Molybdenum .01	(50)	(52)	(54)	(56)	(58)	(60)	(62)
Molybdenum .11	(51)	(53)	(55)	(57)	(59)	(61)	(63)



APPARATUS USED TO COLLECT PERIPHYTON IN THE OKANAGAN MAIN VALLEY LAKES Figure 3.3

plexiglass (Sladeckova, 1963), later in the summer a fifth slide was attached to the tray to allow this comparison to be made. The extent of the littoral zone was estimated using Secchi disc measurements and direct underwater photometer light readings. Air color photos of each lake were also used to better define the littoral zone. The substrata were identified by observation from a boat or with an Ekman grab. Macrophytic vegetation was collected by hand, placed in jars with 10% formalin, and later tentatively identified. By midsummer it was apparent that extensive collections from each lake could not be completed in the time allotted and the major aquatic vegetation was therefore lumped into three groups for mapping: Floating leafed, submergent vegetation, and emergent vegetation. The size of weed beds was estimated first with a range-finder, followed by several transects through the beds by boat. Small patches of vegetation were noted by visual observation as the boat followed the shoreline of each lake at a very slow speed. All observations were recorded on a rough base-map and later transferred to a field notebook. Some vegetation was sampled by diving.

Base maps with major substrates were drawn to scale at the Study Office. Separate maps designating the dominant vegetation were drawn to the same scale as the base maps to serve as overlays.

3.4.3 Bottom Fauna

Bottom fauna (bottom living invertebrate animals) serve as valuable indicators of trophic conditions in lakes. For several decades limnologists have studied the relation between density and species composition of invertebrates living in the bottom sediments of lakes exhibiting a wide variety of trophic as well as morphological characteristics. Because bottom fauna tend to be sedimentry organisms, they often integrate temporal, environmental change thus serving as sensitive barometers of lake change.

Benthos samples were collected September 9 to 11, 1969 and May 10 to 12 in 1971 from the main valley lakes (Maps 3 to 10). In Skaha Lake the sampling sites were essentially the same as those taken during the 1969 survey (Saether, 1970), with the addition of one sampling site in the south basin. In Kalamalka and Wood Lakes, the sample sites were chosen near inlets and outlets with additional samples taken from the deep parts.

A new improved Ekman sampler (Burton and Flannagan, 1973) was used. The samples were sieved through an 0.2 mm. mesh size whenever possible, and in selected samples, through a 0.6 mm. mesh size sieve. In most cases the sediments filled up the samplers to about 2.5 inches from the top, the preferred level mentioned by Flannagan (1970). Some littoral samples contained only a couple of inches of sediment, mostly of sand and/or vegetation. All samples were preserved with 4% formalin and examined in the laboratory where animals were identified and densities calculated.

3.4.4 Zooplankton

Zooplankton populations, while highly variable seasonally, are nonetheless dependent on lake trophic character for their expression. Zooplankton species and densities can be used to typify the trophic status of lakes and also monitor changes in productive capacity. Zooplankton analyses in the Okanagan main valley lakes was carried out with a view to providing basic data and providing a comparison with the data collected by earlier workers.

Okanagan Lake was sampled on September 9 and 10, 1969 and August 26 and 27 of 1971 at three points on each of 10 transects, (Map 2). In Skaha lake, three stations were sampled on both September 11, 1969 and August 24, 1971. representing the northern, central and southern parts of the lake. On the same days, one station was sampled in the middle of each of the north and central basins of Osoyoos Lake. Kalamalka and Wood Lakes were sampled only once on August 25, 1971 at five and two stations, respectively. A Wisconsin type plankton net (mesh opening 77 microns) with a 25 cm. diameter mouth was used at each station to obtain vertical hauls from a depth of 50 meters to the surface, or from just above the bottom to the surface at stations shallower than 50 meters. In addition, 0-5 meter hauls were made on August 25-26, 1971 on Okanagan Lake to study the differences between inshore and offshore plankton. At each of the inshore stations, four 0-5 meter vertical hauls were made perpendicularly to the shoreline spaced at 50 meter intervals beginning from the point with a water depth of 5 meters. One 0-5 meter haul was made at each offshore station located in the middle of the west-east lake transect. Samples were collected at 5 meter intervals within 4 separate layers: 0-25, 25-50, 50-75 and 75-100 meters, using a transparent 5 liter van Dorn bottle. The samples within each layer were combined and filtered through a No. 20 plankton net, preserved in a 2% formaldehyde solution and analysed using a subsampling technique with at least 200 specimens per subsample being counted. Zooplankton abundance was expressed as the number of 2 specimens per 1 cm^2 of lake area, assuming the filtration efficiency of the net to be 100%. The counts of rotifers do not include all forms due to a loss of smaller specimens through the 77 micron mesh size netting. The plankton volume collected at each station was measured by settling in Imhoff sedimentation cones prior to specimen enumeration. In addition, at all stations temperature profiles were recorded and dissolved oxygen, TDS, Ca, Mg, Na, K, Cl and water transparency were measured.

3.4.5 Fishes

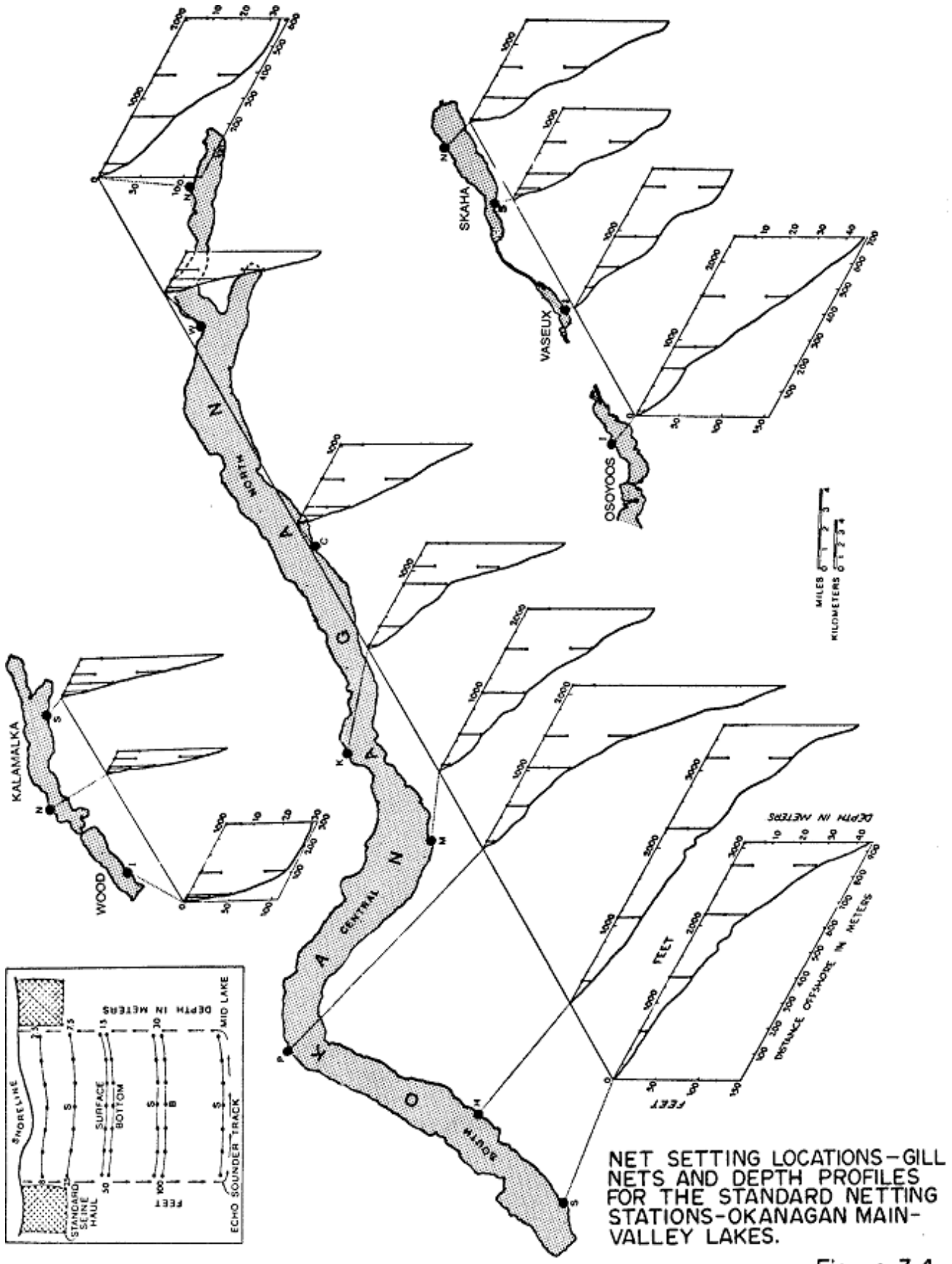
Fishes are often the top of the aquatic food web in fresh water lakes and as such can serve as convenient indicators of trophic lake state. While variability is high, due to the vast number of factors acting upon higher level consumers, data derived from a standard approach can elucidate valuable trends and trophic status. It was with this in mind that the main valley lakes fishing sampling project was undertaken.

Standard netting stations were established on the study lakes (Figure 3.4), early in April, 1971. For the smaller lakes one or two stations were located near the deeper basins but for Okanagan Lake they were spread out to cover the northwest arm (1 station), and the northern area (2 stations), the central area (3 stations) and the southern area (2 stations). Despite attempts to place stations over only moderately sloping bottom, there was wide variation in bottom profiles between stations (Figure 3.4). Often other considerations (marinas, swimming beaches, shipping, and boating lanes, etc), dictated station location.

At each station standard series of gill net sets were made (Figure 3,4). All gangs were set approximately parallel to shore, following the designated depth contours. At the 2.5 and 7.5 meters (8 and 25 feet) contours, nets of those respective depths were set; at the 15 meter contour (ca 50 feet), surface and bottom gangs each 7.5 meters deep fished the whole depth zone. At the 30 meter contour (ca 100 feet), floating and bottom gangs each 7.5 meters deep, left a 15 meter midwater stratum unfished. Further offshore at 7.5 meters deep, gang was set at the surface to fish the upper layer only. Each gang consisted of 6 mesh sizes - 38, 51, 63, 76, 102 and 127 mm. stretched mesh (1.5, 2, 2.5, 3.4 and 5 inch) with 15 meter (50 feet) of each mesh size. The webbing was made of 0.20 mm. diameter monofilament nylon (Grylon fiber). The nets were set in the evening and lifted in the morning, fishing for about a 12 hour overnight period. A spring (May 2-23), summer (July 19-August 10) and autumn (October 2-November 3) series was run, each station received the complete standard net set once during the seasonal period indicated. Other sets were made periodically over the year to obtain additional samples.

An echo sounder tracing was usually made around the whole netting area (Figure 3.4) in the evening after the nets were set, and again in the morning before they were lifted. A 50 Kc/second Furuno F701 sounder was used. In conjunction with each standard netting station (spring and autumn only), one or two beach hauls were made in late evening with a 32 mm. seine. The seine had a central panel of 6 mm. stretched mesh 6 meters in length and depth joined at each end by a 2.4 meter length (6 meter deep) of 12 mm. stretched mesh and a 10 meter "wing" section of 25 mm. mesh which tapered to 0.9 meters in depth at the bridle end. All webbing was knotless green nylon.

Fish were left gilled in the nets when lifted and were removed onshore later in the morning, the catch from each gang (but not each mesh size) being recorded separately. Usually the total net catch of each species was measured (fork length in mm.), and many were weighed to the nearest gram. Sex was recorded routinely where it was obvious from the state of maturation and occasionally by internal examination. Scales were taken for aging from most species as described by McHugh (Ms 1936) and Clemens *et al* (1939). Otoliths were taken from burbot as well as from a few other species (lake trout, kokanee).



NET SETTING LOCATIONS – GILL NETS AND DEPTH PROFILES FOR THE STANDARD NETTING STATIONS – OKANAGAN MAIN-VALLEY LAKES.

Figure 3.4

Fish captured by seining were usually preserved in a 10% formalin solution, although large individuals often were sampled similarly to netted fish. Small fish (•150 mm.) made up the bulk of the seine catch and these were measured, weighed and scale samples (where feasible) obtained in the laboratory. No adjustments in length or weight were made for changes, which might have occurred during the preservation period (<9 months at the most).

The survey was conducted entirely in 1971, starting in April and ending in December. Information from recent years was available from files of the British Columbia Fish and Wildlife Branch. Earlier data were obtained from a summer study on Skaha Lake (Ferguson, MS 1949), and from the work of Clemens and others on the basin in 1935 (Clemens *et al* 1939; McHugh, MS 1936).

All data were transferred from original field sheets or earlier reports to Fortran coding forms and then single computer cards were punched for each individual fish to maximize flexibility of analysis. A total of 23,288 fish were analyzed; 1,257 from 1935; 2,406 from 1948; 755 from 1949 to 1970 and 18,870 from 1971.