10. PHYSICAL-CHEMICAL CONDITIONS

10.1 Field observations.

Observations were conducted at the deep-water stations in each lake (Fig. 2-12). The results are summarized in Table 6.

10.1.1 Temperature.

Detailed temperature profiles from each visit are shown in Fig. 13. All the lakes undergo characteristic summer thermal stratification. In most cases this becomes quite intense; a product of active heating, generally small size of the lakes, and protection from wind action. Stratification lasts longest in the deepest lakes, particularly at lowest altitudes. These conditions retard the cooling process. The epilimnion was from 3 to 6 m thick at midsummer in all lakes except Agur, where the entire water mass warmed and circulated after early stratification broke down. Surface temperatures at midsummer ranged from 15.5 to 24.5°C, and were generally lower in higher lakes.

Mean observed temperatures of the epilimnion at midsummer are given in Table 6. This is a useful derivation since it is the approximate temperature of the main productive zone at the height of the growing season. Mean epilimnion temperatures are low in the deepest lakes

TABLE 6. Summary of temperature, dissolved oxygen, pH, and transparency conditions in eleven headwater lakes in the Okanagan Basin, 1971.

	AGUR	MUNRO	HEAD WATERS#1	JACK PINE	LAMBLY	PINAUS	OYAMA	ALEX	SWALWELL	FISH HAWK	HYDRAULIC
Midsummer thermal features											
Surface temperature, C	21.8	21.5	21.0	23.3	24.5	17.5	18.3	24.5	22.5	15.5	21.5
Bottom temperature, C	20.2	6.0	11.8	12.8	7.5	6.2	6.5	4.8	6.0	8.0	14.1
Epilimnion depth, m.	>7	3	2	2	2	6	4	4	3	3	2
Mean epilimnion temp.,C	20.6	19.7	20.4	22.2	22.7	17.4	16.5	16.1	21.2	14.9	21.2
Midsummer dissolved oxygen											
Surface, ppm	7.5	7.3	8.8	7.8	7.2	7.3	8.2	7.1	7.6	7.8	7.4
Bottom, ppm	6.0	0.6	0.6	0.4	1.1	0.5	0.8	1.5	3.8	1.0	0.7
Bottom, % saturation	76	6	6	3	10	4	8	13	36	10	6
Midesummer pH											
Surface	8.5[+]	8.0	8.0	7.5	7.3	8.5	7.3	7.1	7.6	7.0	7.1
Bottom	8.5	6.8	6.9	6.7	6.6	7.0	6.5	6.0	6.6	6.1	6.3
Secchi disc, m.											
Spring	6.1	3.0	2.0	3.0	1.2	4.2	2.9	2.2	-	-	2.4
Midsummer	4.5	5.0	2.4	2.3	2.6	5.0	2.8	1.4	2.0	3.1	2.0
Autumn	6.6	3.2	1.7	2.0	1.1	5.3	2.0	1.5	3.2	3.0	1.0
Turbidity, Jackson Units	1.2	1.4	2.8	1.1	5.6	2.4	-	2.7	-	-	-
Color	0	20	30	50	65	5	30	60	30	25	65

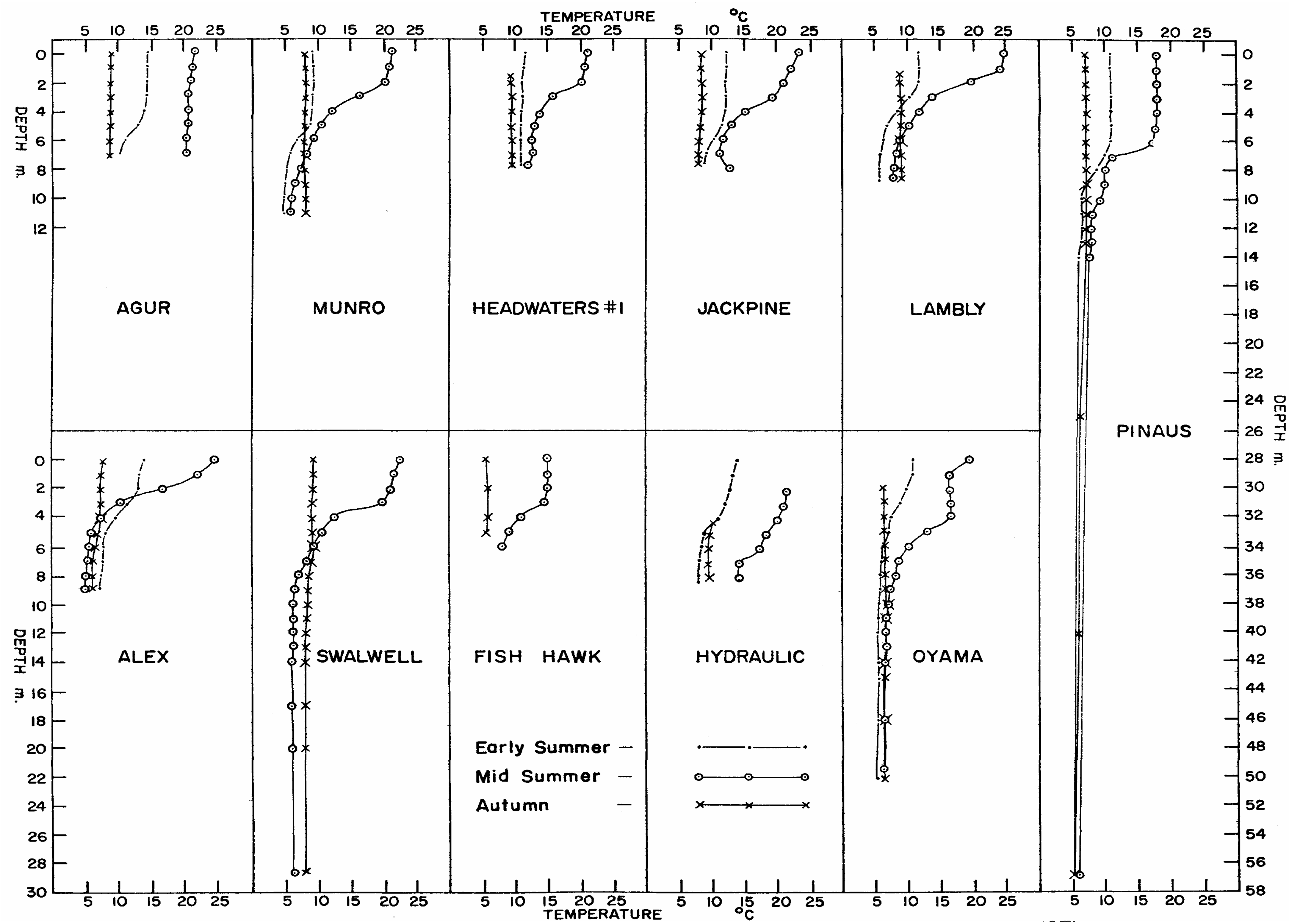

Fig. 13. Temperature profiles for eleven headwater lakes in the Okanagan Basin, 1971.

(Pinaus and Oyama), but Fish Hawk at highest altitude is colder still. Rawson (1942) showed that plankton quantity in several western Canadian lakes correlated more closely with epilimnion temperature than with the temperature of the whole lake. Northcote and Larkin (1956) found a tendency in B.C. lakes for greater plankton volumes to occur in lakes with higher epilimnion temperatures.

10.1.2 Oxygen.

Dissolved oxygen was determined simultaneously with thermal observations. Detailed oxygen profiles from each visit are shown in Fig. 14. Surface concentrations ranged from 7.1 ppm (Alex Lake) to 9.8 ppm (Agur Lake), occupying the narrow range from 84 to 114% saturation during the midsummer sampling series. This range also encompasses surface values observed in spring and autumn.

Of special significance in stratified temperature lakes such as these is the amount of midsummer oxygen depletion in bottom waters. All the lakes, except Agur, exhibit nearly anaerobic bottom conditions during the stratified period. For some lakes (e.g. Swalwell) bottom depletion was much more intense during the autumn series (i.e. before complete turnover), than during midsummer. Only in Hydraulic Lake, however, was a significant fraction of the water mass seriously depleted (less than 3 ppm oxygen below 3 m in August). Bottom oxygen increased at turnover even

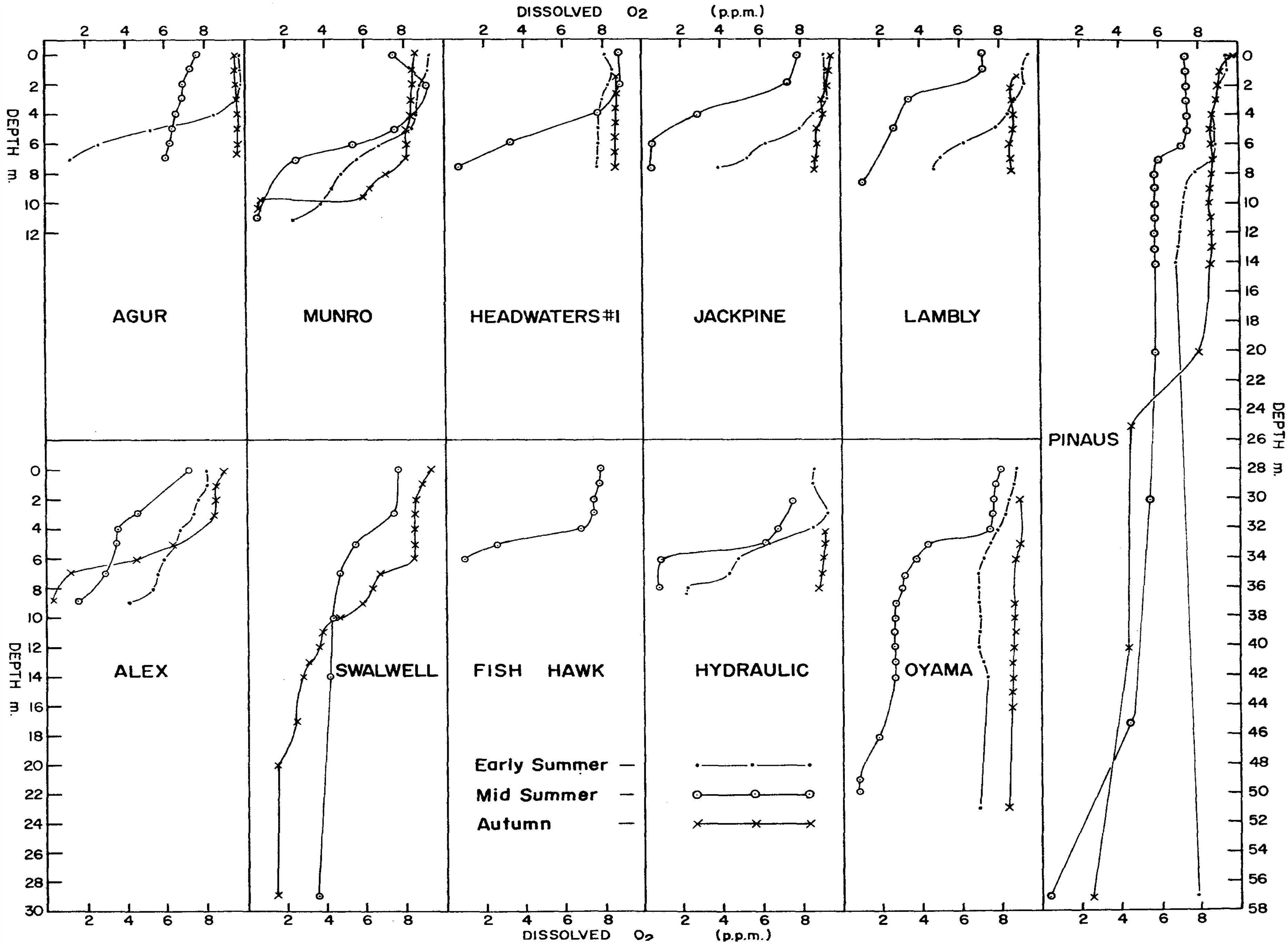

Fig. 14. Dissolved oxygen profiles for eleven headwater lakes in the Okanagan Basin, 1971.

in the deepest of these headwater lakes.

10.1.3 pH.

Of the lakes examined, only Agur was consistently basic at all depths throughout the sampling period (pH8.5^{+}). Munro, Pinaus, and Headwaters Lake No. 1 were slightly alkaline at the surface during midsummer stratification. All the lakes were more acidic at the bottom, in agreement with their stratified condition and active productivity. Surface and bottom values, however, never differed by more than 1.5 pH units. These lakes have generally slightly higher pH, at least at the surface, than do Canadian Shield lakes of similar dimensions (Koshinsky MS 1968; Armstrong and Schindler 1971).

10.1.4 Transparency.

The lakes were found to be relatively un-transparent. The highest Secchi disc readings (average 6.6 m^{+}) were obtained in Agur Lake. Pinaus and Munro Lakes are of intermediate transparency. Secchi disc readings in excess of -6 m are commonly associated with oligotrophy (Rawson 1960); such values indicate lack of significant interference with light penetration by plankton. However, the high transparency of Agur Lake in particular, and lakes on the west side of the basin generally, is thought to derive from peculiarities of chemistry and drainage, rather than specifically from paucity of plankton production. Presumably the high pH and the abundance of calcium and magnesium ions favors precipitation of light absorbing organic colloids and related materials. A similar relationship was observed among Shield lakes in Saskatchewan (Koshinsky MS 1968).

10.1.5 Turbidity.

Turbidity is a measure of the concentration of suspended particles. It was maximal in Lambly Lake where it undoubtedly contributed to the low transparency. Lambly Lake has a recent history of a very substantial increase in area through impoundment, along with dredging operations (Section 8).

10.1.6 Water Color.

Color is an indication of the influence of shoreline and bottom features on the contained water, and also of drainage characteristics. Lambly Lake, with its recently submerged trees and other debris, and its new and unstable shores, produced the highest color readings along with Hydraulic Lake. The latter is choked with forest debris and undergoes marked water fluctuations. Similar features dictate high color values for Jackpine, Headwaters, and Swalwell Lakes. High coloration in Oyama Lake, and more particularly in Alex Lake, is undoubtedly related to the predominance of low, marshy areas in their watersheds. Pinaus Lake is practically colorless, a reflection of the considerable volume and depth of the lake relative to its shoreline. Agur Lake is completely colorless, a product of its unique and isolated chemistry.

10.2 Ionic composition and nutrient values

The complete results of chemical analyses of waters from the 11 lakes are recorded in Appendix Table C. The more pertinent features are summarized in Table 7. Rawson (1960), Northcote and Larkin (1956), and others indicate that TDS is a useful index to general edaphic and other physiographic conditions. The Okanagan headwater lakes examined are generally low in dissolved solids, although not as low as extremely dilute lakes such as those on the Canadian Shield (Koshinsky MS 1968; Armstrong and Schindler 1971). Of 100 British Columbia lakes examined by Northcote and Larkin (1956) the median TDS was 125 ppm. Lakes with TDS lower than this tended to have below-average biological production. The only member of the present series with a higher TDS was Agur Lake (232 ppm). Lambly and Pinaus Lakes, with 103 and 122 ppm respectively, approach B.C. mid-range values. TDS in the other lakes ranged from 48 to 90 ppm. The over-riding factor determining total dissolved solids content among the Okanagan headwater lakes would appear to be precipitation (Fig. 15). Precipitation in turn is largely a function of altitude, so that altitude emerges as a key predictor for dissolved ion concentrations (Appendix Table A,).

No phenolphthalein alkalinity was observed in any of the lakes, indicating absence of hydroxide and carbonate

TABLE 7 . Concentrations of nutrients and major ions in 11 selected headwater lakes in the Okanagan Basin, 1971. Values are parts per million.

	AGUR	MUNRO	HEAD WATERS #1	JACK-PINE	LAMBLY	PINAUS	OYAMA	ALEX	SWAL-WELL	FISH HAWK	HYDRAULIC
Total dissolved solids	232	82	88	90	103	122	54	53	63	48	71
Specific conductance,mho	485	86	89	61	75	123	51	41	44	21	31
Total Kjeldahl nitrogen(N)											
Spring, surface	1.67	0.48	0.52	1.11	1.67	0.75	0.13	0.69	-	-	0.41
Midsummer, surface	1.41	1.02	<0.01	0.64	0.28	1.07	0.49	1.26	1.15	1.16	0.82
bottom	1.62	1.23	<0.01	0.97	0.61	0.43	0.56	1.23	0.90	0.10	0.43
Autumn, surface	0.95	0.39	0.33	0.39	0.59	0.20	0.15	0.26	0.36	0.03	0.26
Nitrate nitrogen(N)											
Spring, surface	0.01	<0.01	0.01	<0.01	<0.01	0.01	<0.01	0.01	-	-	0.01
Midsummer, surface	0.30	0.17	0.01	0.01	0.02	0.12	<0.01	0.04	0.03	0.03	0.01
bottom	0.05	0.01	0.05	0.01	<0.01	0.28	0.16	0.06	0.32	0.02	0.04
Autumn, surface	<0.01	0.01	<0.01	0.05	0.04	0.14	<0.01	0.01	0.04	<0.01	<0.01
Total phosphorus (PO_4)											
Spring, surface	0.03	0.04	0.04	0.05	0.11	0.18	0.06	0.04	-	-	0.06
Midsummer, surface	0.03	0.03	0.05	0.05	0.05	0.06	0.05	0.03	0.03	0.17	0.07
bottom	0.05	0.31	0.06	0.68	0.41	0.62	0.44	0.14	0.07	0.06	0.12
Autumn, surface	0.04	0.03	0.04	0.08	0.25	0.24	0.09	0.05	0.05	0.04	0.10
Ortho-phosphate (PO_4)											
Spring, surface	0.01	0.01	0.01	0.01	0.02	0.14	0.01	0.01	-	-	0.01
Midsummer, surface	<0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	<0.01	<0.01	0.02
bottom	<0.01	0.11	0.01	0.42	0.15	0.45	0.17	0.04	0.02	0.01	0.03
Autumn, surface	<0.01	<0.01	<0.01	0.02	0.12	0.17	0.03	<0.01	0.01	<0.01	<0.01
Silica (SiO_2) (col)											
Midsummer, surface	6.4	8.5	12.3	7.2	17.0	20.0	5.2	7.3	4.2	3.2	7.9
bottom	6.5	12.4	12.7	9.1	18.5	22.0	5.9	12.0	7.7	3.9	7.8
Calcium	21.6	13.3	14.2	7.1	8.9	16.2	4.2	3.7	6.8	1.6	3.6
Magnesium	18.7	1.6	1.4	1.3	1.5	6.6	1.4	1.3	-	-	0.7
Sodium	29.2	1.9	1.8	1.5	1.9	8.5	1.7	1.3	2.0	1.0	1.1
Sulphate	2.8	7.2	5.2	17.4	13.0	4.4	2.6	2.6	3.5	1.7	1.8

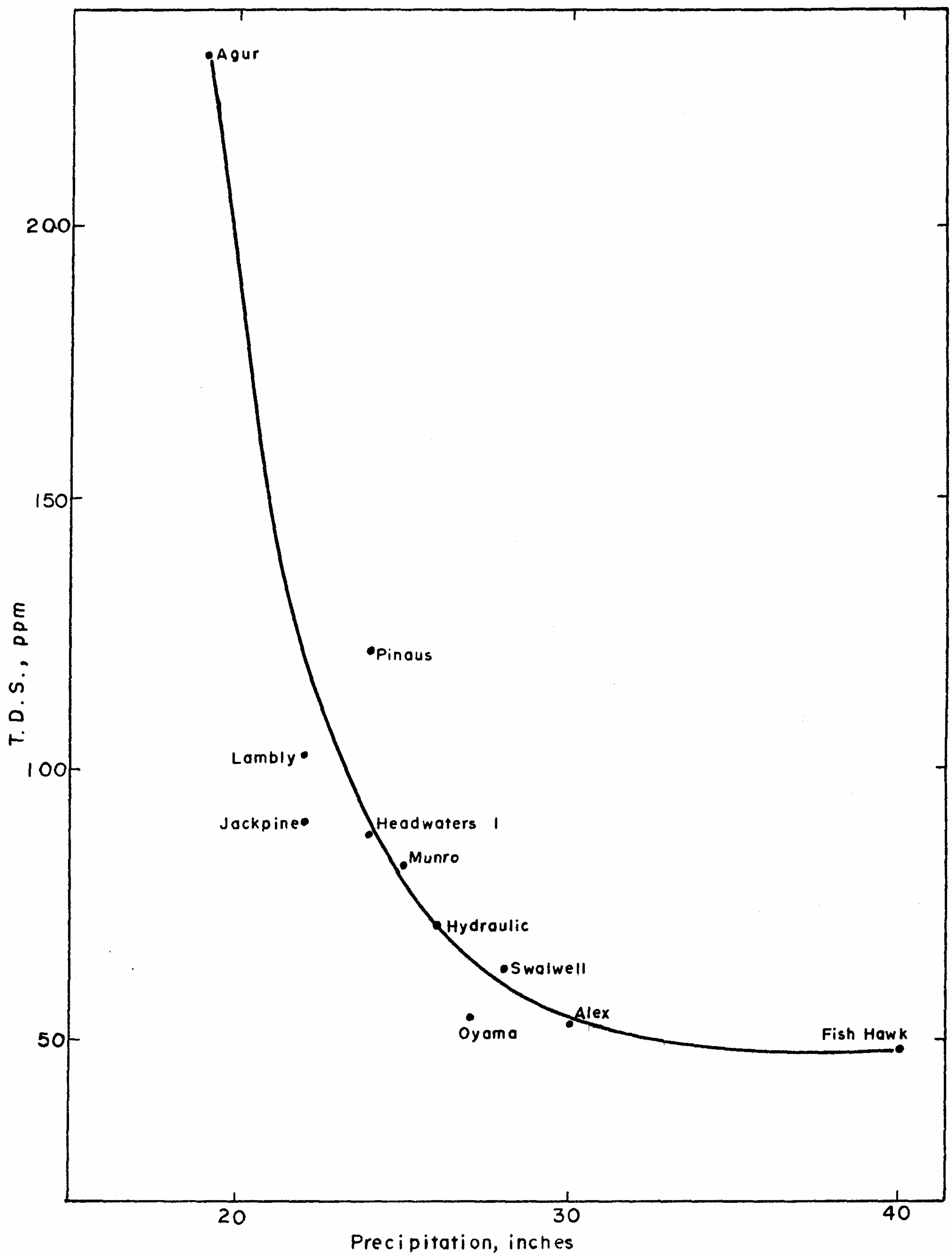

FIG. 15. Relation between total dissolved solids and annual precipitation among II selected headwater lakes in the Okanagan Basin, 1971.

ions. Methylorange alkalinity ranged from a very low 4.3 ppm in Fish Hawk Lake through a moderate 84 ppm in Pinaus Lake to a high of 201 ppm in Agur Lake. Calcium concentrations were notably higher in Agur, Pinaus, Headwaters No. 1, and Munro Lakes. Magnesium and sodium levels were uniformly low in all lakes except Agur and Pinaus where the higher values parallel relatively high conductance. Conductance, in turn, shows a clear parallel to TDS. Highest sulphate concentrations were observed in Jackpine and Lambly Lakes, perhaps reflecting their geographical contiguity.

Phosphorus levels occupy a broad range among these lakes. Surface phosphorus values were highest in Lambly and Pinaus Lakes, a feature which was particularly notable during the autumn sampling series. In the case of Lambly Lake, high phosphate availability may be the result of recent impoundment, excavation, and clearing activities. Rodhe (1964) noted an increase in phosphate in Ranseren Lake, Sweden, following impoundment and burning of brush on the shores. Significant midsummer elevation of bottom phosphorus values was noted in five of the lakes: Munro, Jackpine, Lambly, Pinaus and Oyama. These occurrences coincided with severe bottom oxygen depletion (Fig. 14). The very low phosphorus values in Agur Lake are at first surprising in view of the high levels of other dissolved materials. Presumably this phenomenon is linked to precipitation of phosphate in conjunction with the high oxygen values here encountered. The oxygen situation in Agur Lake is linked at least in part to the high transparency and accompanying photosynthetic activity throughout the water column.

Total Kjeldahl nitrogen concentrations are highly variable among these lakes and do not appear diagnostic. Available nitrate nitrogen was uniformly low in all lakes in spring, suggesting rapid uptake by phytoplankton under peak light conditions. Silica, which is required by diatom algae for formation of frustules, was invariably adequate to meet this requirement, at least for the planktonic species (Hutchinson 1957). By far the highest silica concentrations were encountered in three west-side lakes: Pinaus, Lambly and Headwaters. Lowest values (3.2 ppm) were recorded from Fish Hawk Lake. Manganese concentrations, not given in Appendix Table C, were less than detectable (0.008 ppm) in all lakes except Swalwell and Fish Hawk where 0.010 ppm was recorded. Absolute manganese requirements are poorly understood, although the element is known to be necessary for phytoplankton development.

11. PLANKTON

11.1. General

The microscopic organisms inhabiting the water column constitute the plankton. Phytoplankton (minute plants) and Zooplankton (tiny animals) are the basic components of this important biotic group. The phytoplankton is the main component of the first trophic level in most lakes. It shares the ability of all green plants to synthesize organic matter from its constituents using radiant energy. It in turn is consumed by Zooplankton, and both provide food for bottom fauna, and ultimately for fish. The plankton is thus a valuable index to productivity and to the capacity of a lake to produce fish.

Settled volumes of net plankton from total vertical hauls from the 11 representative headwater lakes in autumn are shown in Fig. 16. Results from this single sampling series are not very helpful in characterizing the productive capacities of the lakes. Ten of the values fall within the overall range (0.2 to 14.0 cc) found by Northcote and Larkin (1956) in their investigation of 100 lakes throughout British Columbia. The exception is Oyama Lake (31.0 cc) where sampling coincided with a heavy bloom of diatoms, particularly Tabellaria.

To at least some extent, plankton samples derived in this manner will reflect the depth of the lake, i.e. the thickness of the water column through which the net was drawn.

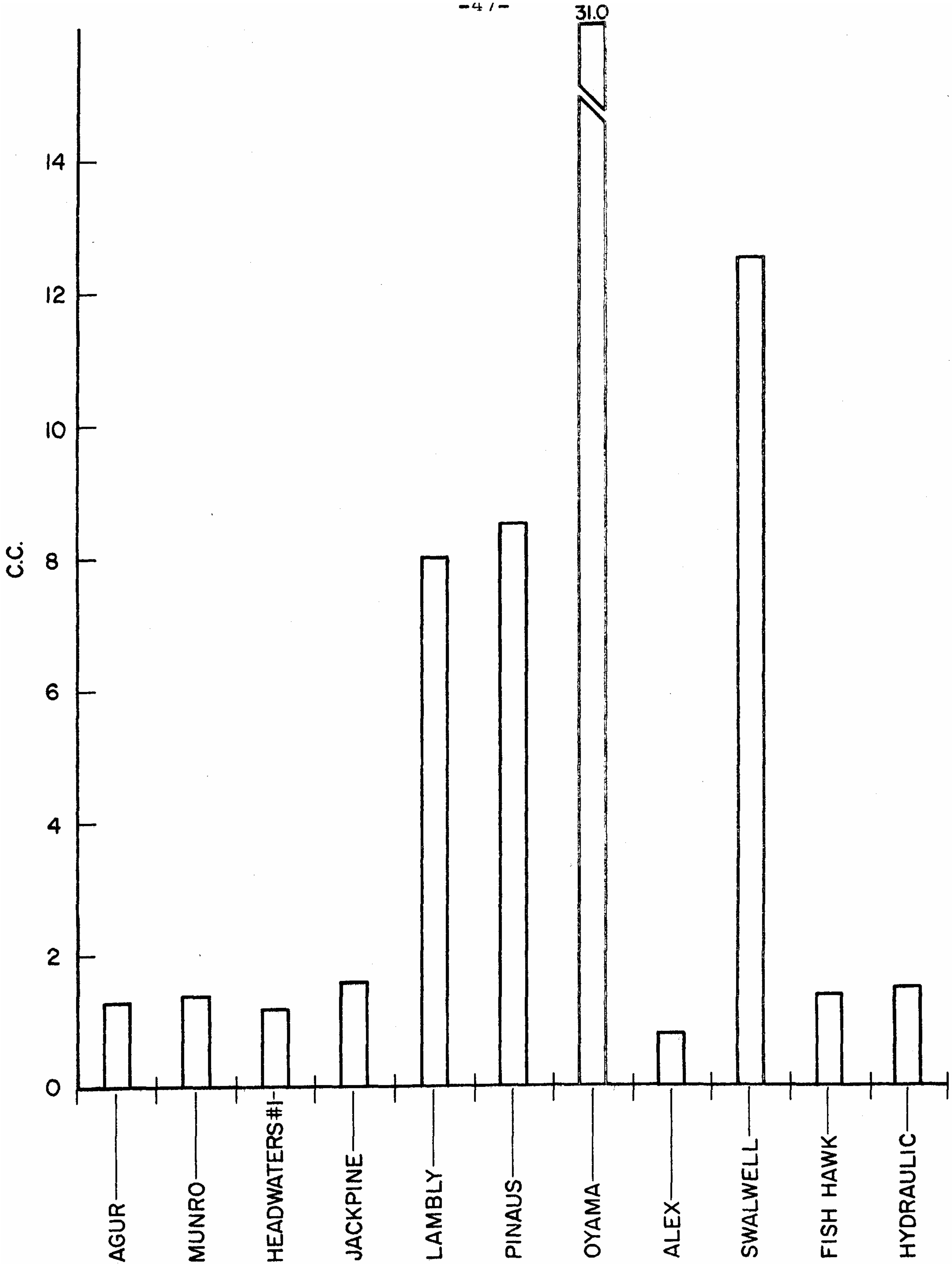

Fig.16. Settled volume of net plankton from II selected headwater lakes in the Okanagan Basin, autumn 1971.

It is thus not surprising that the three deepest lakes (Pinaus, Oyama and Swalwell) have the greatest plankton volumes per unit area. Among the eight shallow lakes, only Lambly exhibits an unusual autumn net plankton volume. Lambly also exhibits high values of other biotic indices, and is clearly of high productivity.

11.2. Phytoplankton

The occurrence and relative abundance of phytoplankton species (from settled samples) in the 11 headwater lakes is recorded in Appendix Table D. Results of the midsummer and autumn series are shown separately, although the sampling was clearly too infrequent for a meaningful analysis of seasonal species successions. Qualitative relationships are summarized in terms of broad algal groupings in Table 8. The most consistent seasonal trend is the generally greater abundance of diatoms (Bacillariophyceae) in autumn than in midsummer. This trend fails in two of the lakes (Lambly and Alex); these lakes have particularly high color and low transparency values (Table 6). These two lakes are quite different, however, in nutrient content (Table 7), and the implication is that available light limits production of this important algal group at least in the more discolored Okanagan headwater lakes. *Melosira* spp. and *Synedra* spp. are probably the consistently most important diatom genera in these headwater lakes. Both make markedly higher contributions to the phytoplankton in

TABLE 8 . Percent abundance of phytoplankton groups, and concentration of chlorophyll a, in eleven selected headwater lakes in the Okanagan Basin, 1971.

	AGUR		MUNRO		HEAD-WATERS		JACK-PINE		LAMBLY		PINAUS		OYAMA		ALEX		SWAL-WELL		FISH-HAWK	HY-DRAULIC	
	Aug 19	Oct 20	Jul 31	Sep 26	Jul 19	Oct 7	Aug 12	Oct 3	Jul 23	Oct 4	Aug 24	Oct 26	Aug 26	Oct 19	Aug 4	Oct 12	Aug 4	Oct 12	Sep 29	Aug 10	Sep 25
CYANOPHYTA	25	5	5	10	5	4	10	15	0	55	5	5	25	2	0	60	2	5	5	0	5
CHLOROPHYTA	15	30	10	10	60	3	30	15	0	15	25	1	15	3	10	5	2	5	3	60	35
CHRYSOPHYTA																					
Bacillariophyceae	5	60	10	75	20	90	5	70	25	30	5	89	50	92	80	25	70	85	90	35	60
Chrysophyceae	5	5	35	5	3	3	5	0	0	0	0	5	10	3	5	0	23	5	2	5	0
XANTHOPHYTA	0	0	20	0	0	0	0	0	5	0	60	0	0	0	0	10	0	0	0	0	0
PYRROPHYTA																					
Cryptophyceae	45	0	10	0	5	0	0	0	35	0	0	0	0	0	5	0	3	0	0	0	0
Peridineae	5	0	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EUGLENOPHYTA	0	0	5	0	2	0	50	0	35	0	5	0	0	0	0	0	0	0	0	0	0
Chlorophyll a (μg/l) from integrated vertical column																					
Midsummer series[a]	13.11		20.06		21.82		12.58		4.25		1.78		12.23		17.42		24.99		10.47[c]	62.04	
Autumn series[b]	3.55		2.85		13.42		7.61		19.01		2.58		15.18		7.17		13.42		3.48	11.35	

[a]From 0-7 m stratum, July-August.

[b]From stratum corresponding to twice the Secchi disc visibility, September-October.

[c]August 17.

autumn than in summer. To some extent, at least, this is probably a physical phenomenon. _Melosira_ is known to depend on active water circulation (such as occurs at turnover) to maintain a planktonic state. During stratification it goes into a resting stage at the bottom (Hutchinson 1967).

Cyanophyta, (blue-green algae) were found in all the lakes, but no blooms were observed. Greatest relative concentrations were noted in autumn, particularly in Lambly and Alex Lakes. Abundance of blue-greens in Lambly Lake is probably a reflection of high nutrient availability (Table 7), whereas in Alex Lake it is more probably a reflection of a generally poor suitability of the lake for other phytoplankton groups. Koshinsky (MS 1968) found that blue-green algae, while responding positively to high nutrient levels in Saskatchewan lakes, also tended (perhaps by virtue of their nitrogen-fixing abilities) to gain competitive advantage over other phytoplankton groups in nutrient-deprived media.

The green algae (Chlorophyta) show a weak tendency toward greater prominence in midsummer than in autumn; this is consistent with the known general preference of this group for high temperatures (M. Pomeroy, pers. comm.). The same adaptation is exemplified by the greater chlorophyte abundance in lakes with higher epilimnion temperatures. Pyrrophyta, although rare overall, displayed an even stronger tendency to peak in summer; none were found in the autumn samples. Chrysophyceans showed the same trend, but less strongly. Cyanophyta (blue-green algae) displayed no uniform seasonal trend, befitting their diverse nutritional adaptations (Koshinsky MS 1968).

Perhaps the single most notable feature of algal composition is posed by the group Chrysophyceae. These algae are noted for their rigorous requirement of undisturbed waters with low nutrient levels; they comprise the largest algal group in small unproductive undisturbed lakes on the Precambrian Shield in northwestern Ontario (Schindler and Holmgren 1971). In waters of similar productive capacity in Sweden, even moderate disturbance by human activities has shifted the species composition from Chrysophyceae to other groups (Schindler and Holmgren 1971). One of the most cosmopolitan Chrysophyte genera, Dinobryon, is generally acknowledged to be inhibited by $P.PO_4$ concentrations in excess of ± 5/ug per liter (Hutchinson 1967). By way of local illustration, Dinobryon is one of the few algal dominants in the sparse spring algal flora of Kalamalka Lake (Stein and Coulthard MS 1971). Kalamalka is, by concensus of available indices, the most Oligotrophic of the Okanagan mainstem lakes (Dr. J. Stockner, pers. comm.). Among the Okanagan headwater lakes, Chrysophyceae never completely dominated the phytoplankton, but were nevertheless represented in all members of the present series except Lambly (Table 8). The implication, consistent with other indices, is that Lambly Lake, at present, is the richest lake of the series.

Chlorophyll values from integrated vertical samples from midsummer and autumn sampling series are included in Table

8. A rather consistent feature is the tendency for higher chlorophyll concentrations in the most severely manipulated lakes. This may be a reflection of continuing nutrient inputs from disturbed shores and bottom in these instances. Low integrated chlorophyll concentrations are characteristic of lakes which are very transparent (Agur), deep and cold (Pinaus), and at high altitude (Fish Hawk). The autumn series of determinations shows better internal consistency in these regards. These autumn chlorophyll values show a weak but positive overall relation to midsummer epilimnion temperatures (Fig. 17). This is indicative of a negative influence of altitude on algal production in these lakes.

The depth-distribution of chlorophyll was investigated during the midsummer sampling period; the results are shown in Fig. 18. Examination of these distributions provides important additional clues to the mechanisms controlling phytoplankton production in these particular waters. Six of the lakes (Munro, Headwaters, Alex, Swalwell, Hydraulic and possibly Oyama) display distinct chlorophyll maxima in the epilimnion (but not at the very surface), followed by a rapid decline deeper in the water column. This parallels the typical production-depth curve encountered by Schindler and Holmgren (1971) among Ontario Shield lakes in which light penetration (rather than nutrients or temperature) was the key determining factor. Thus in Alex Lake, which is highly discolored, maximum phytoplankton growth occurs much nearer the surface than in Munro Lake, which is highly transparent.

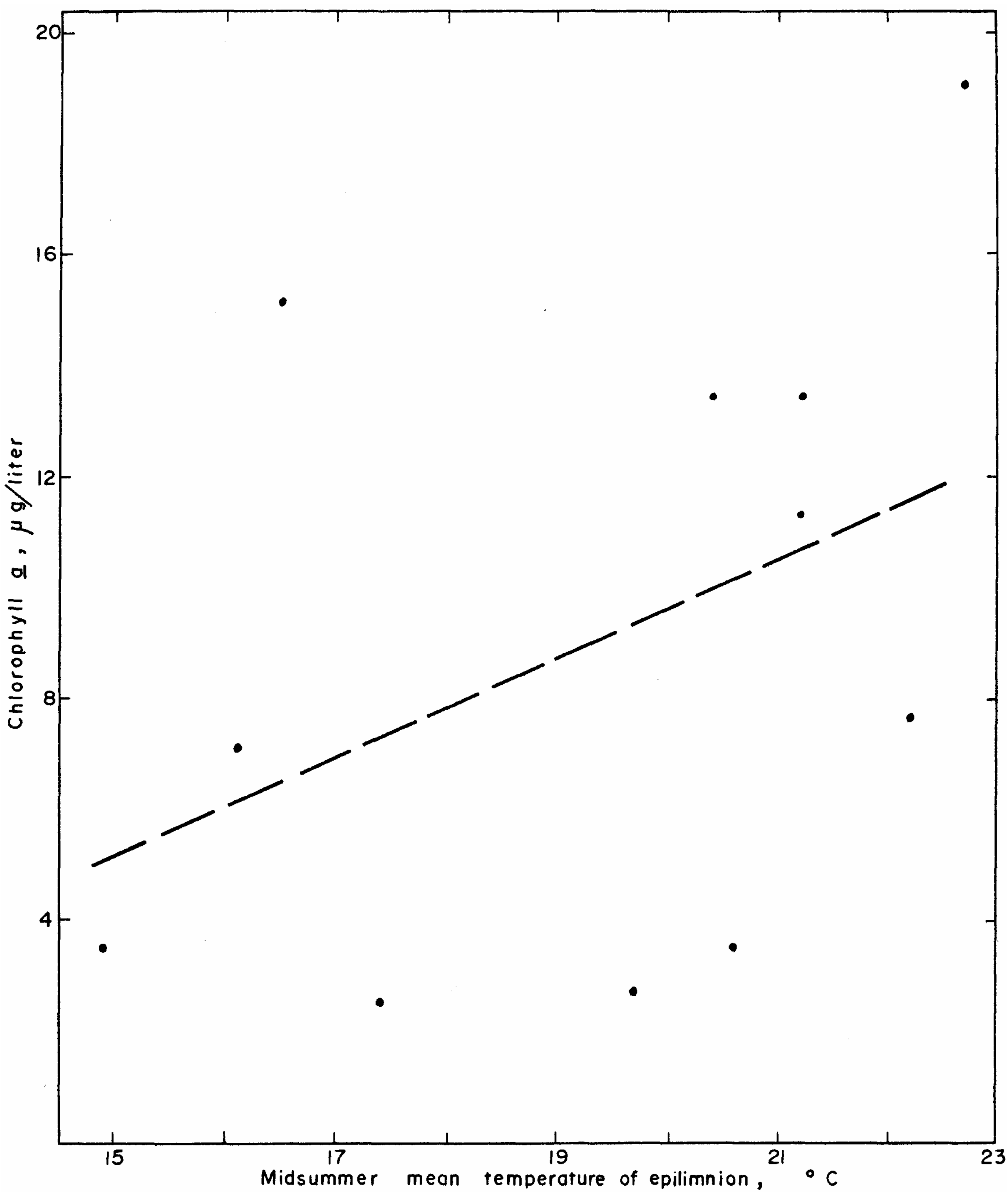

FIG. 17. Relation between chlorophyll concentration in the trophogenic zone in autumn, and observed mean temperature of the epilimnion at midsummer, for II selected headwater lakes in the Okanagan Basin,1971.

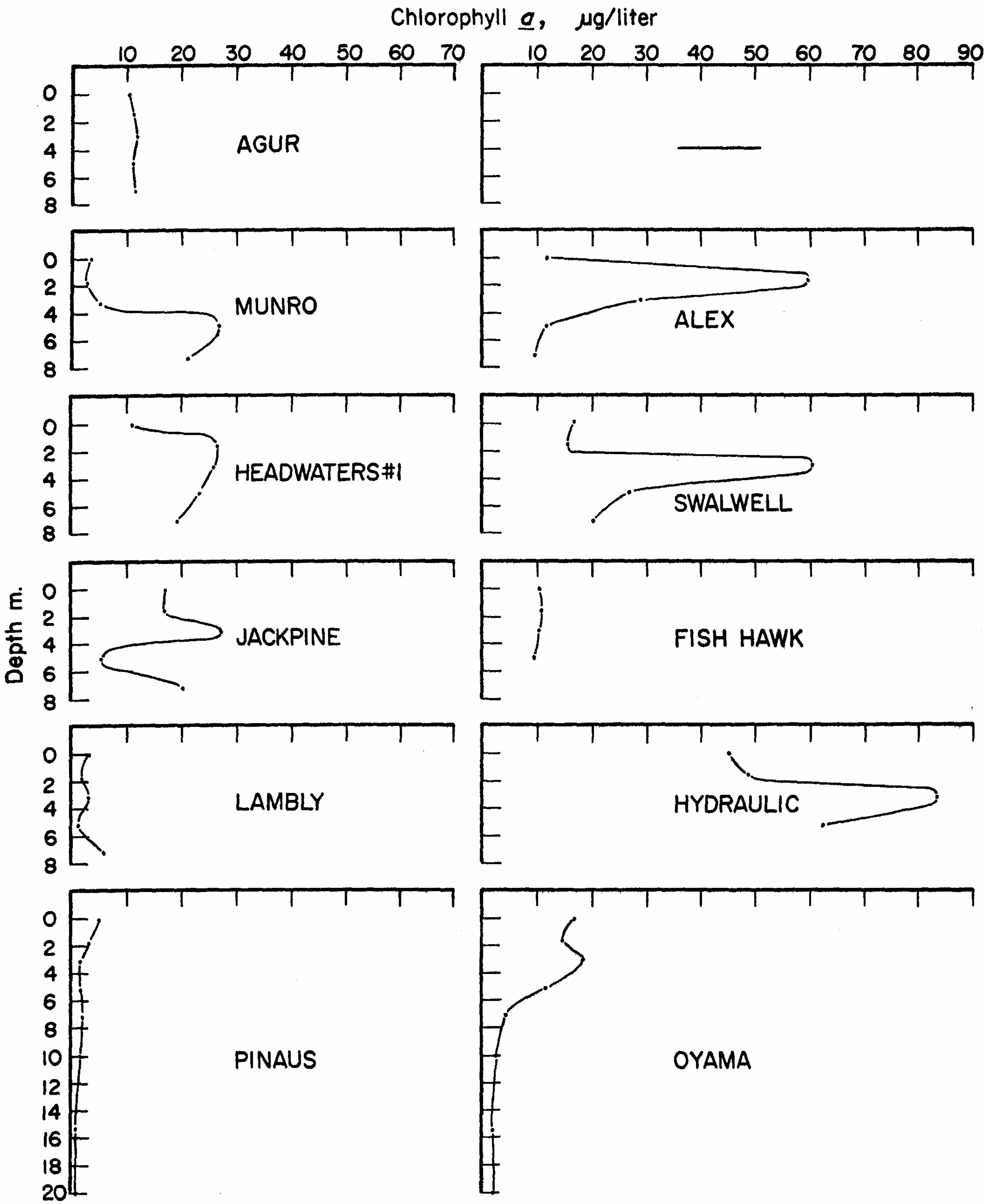

Fig.18. Depth distribution of chlorophyll *a* in 11 selected headwater lakes in the Okanagan Basin, mid-summer 1971.

Light inhibition prevents phytoplankton development near the surface in the latter case.

Agur, Pinaus, Fish Hawk and Lambly Lakes are characteristic of the Class II type of production -- depth curve (Findenegg 1964) in that there is no distinct maximum. This type of curve is expected to arise when nutrients or other factors (but not radiation) control plankton production. Agur and Fish Hawk Lakes both had undetectable ortho-phosphate concentrations in the epilimnion at the time of sampling (Table 7). Midsummer nutrient availability was not found to be particularly low in Pinaus and Lambly Lakes, however. Low epilimnion temperatures may be an important limiting factor in Pinaus Lake, whereas the high turbidity and discoloration of Lambly Lake is probably the predominant factor in its low midsummer phytoplankton standing crop.

Jackpine Lake, with its dichotomic chlorophyll-depth curve, reflects a situation in which the hypolimnion is notably enriched in nutrients (in this case phosphate; see Table 7) relative to the epilimnion. This nutrient situation apparently permits phytoplankton to maintain themselves even though adequate light may be limited to infrequent occasions (Schindler and Holmgren 1971).

11.3 Zooplankton.

The occurrence of Zooplankton groups and their abundance, based on total vertical net hauls during the autumn sampling series, are given in Table 9. As is common in north temperate lakes, the Zooplankton is of the rotifer-entomostraca type, with one protozoan (*Ceratium* sp.) also occurring. Rotifers were the most numerous group in all but two of the lakes, and the extent of their overall predominance seems to be inversely related to lake depth.

The list of rotifers presented (Table 9) is not complete; no attempt was made to identify or enumerate species occurring only very rarely in the samples. Among the common forms the most diagnostic distribution is probably posed by *Keratella cochlearis,* abundance of which is directly linked to the extent of reservoir manipulation (Fig. 19). Another rotifer of the same genus, *K. quadrata,* is virtually confined to lakes on the west side of the basin, with their higher ion levels. Among the rarer rotifers the observed distribution of *Filinia* is of some interest; it was found only in Alex and Swalwell Lakes which lie in the same drainage sub-basin.

The entomostraca (planktonic crustacea) are of special interest because these organisms are of a size-which renders them a potential item of fish diet. A very broad range of entomostracan abundance was observed among the 11 lakes but the differences are not readily rationalized. A weak tendency is apparent for this group to be more abundant in the most severely manipulated lakes; thus Lambly and Headwaters Lakes

	Rotifers						
	Kellicottia	Keratella cochlearis	Keratella quadrata	Polyarthra	Conochilidae	Asplanchna	Filinia
AGUR	1,300	2,600	31,600	1,300	0	0	0
MUNRO	27,500	700	0	4,300	0	700	0
HEADWATERS #1	1,500	80,000	1,500	11,900	4,400	1,500	0
JACKPINE	0	48,800	21,600	6,500	6,500	0	0
LAMBLY	3,600	32,000	14,200	2,400	45,000	0	0
PINAUS	200	0	0	0	0	0	0
OYAMA	600	13,000	0	1,800	0	900	0
ALEX	2,600	2,600	+	900	4,400	14,700	1,700
SWALWELL	900	4,600	200	1,100	3,700	1,700	400
FISH HAWK	25,200	0	0	7,400	74,000	0	0
HYDRAULIC	32,600	53,300	0	2,900	29,700	0	0

continued....

TABLE 9 . Standing crops (number per meter^3) of Zooplankton from total vertical hauls (autumn series) in 11 selected haadwater lakes in the Okanagan Basin, 1971.

TABLE 9. (continued). Standing crops (number per meter^3) of Zooplankton from total vertical hauls (autumn series) in 11 selected headwater lakes in the Okanagan Basin, 1971.

	Entomostraca				Protozoa	
	Cyclopoid	Calanoid	Nauplii	Cladocera	Ceratium	Total
AGUR	0	2,200	1,300	4,300	13,200	57,800
MUNRO	1,300	200	5,800	6,100	20,900	67,500
HEADWATERS #1	97,700	0	42,900	2,700	0	244,100
JACKPINE	4,800	300	3,200	1,800	0	93,500
LAMBLY	0	1,800	0	43,400	0	142,400
PINAUS	5,500	0	34,200	2,800	0	42,700
OYAMA	200	700	300	500	0	18,000
ALEX	100	100	0	900	0	28,000
SWALWELL	400	3,100	4,600	1,600	0	22,300
FISH HAWK	23,900	400	16,300	7,500	1,500	156,200
HYDRAULIC	4,400	5,300	8,900	900	0	138,000

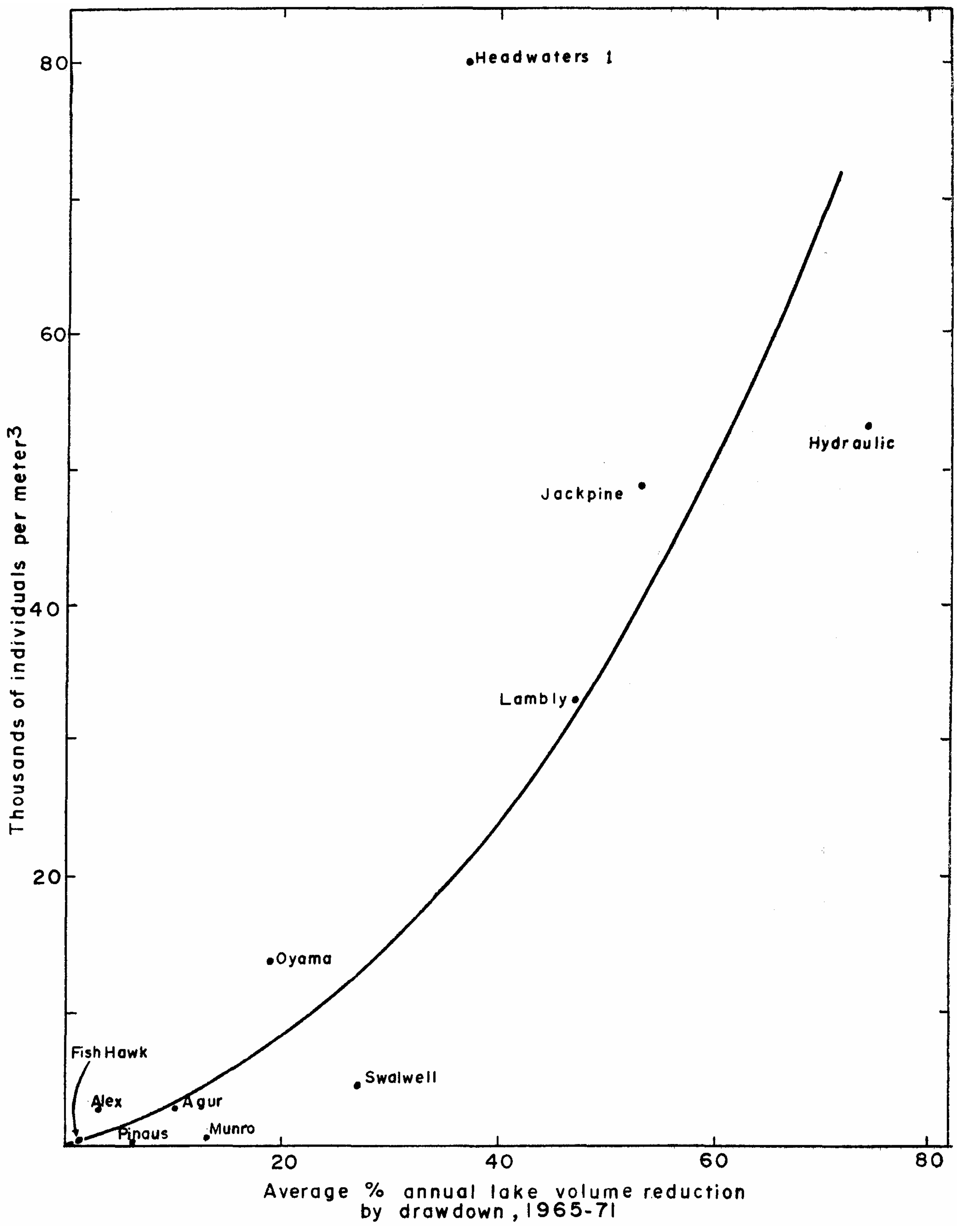

FIG. 19. Abundance of <u>Keratello cochlearis</u> relative to reservoir drawdown in II selected headwater lakes in the Okanagan Basin, autumn 1971.

have the highest concentrations of these planktonic crustaceans. Cladocerans are particularly numerous in Lambly Lake; this is considered to be a clear reflection of recent events in this basin. Increased abundance of planktonic crustaceans, particularly cladocerans, has been a commonly observed phenomenon following impoundment especially in the first few years (Axelsson 1961, Grimas 1965a). This phenomenon is believed to derive from increased availability of special food types (detritus from sediment and/or associated bacterial flora) in such situations.

12. BOTTOM FAUNA

The invertebrates populating the bottom of a lake are normally an important food source for fish. They are also very sensitive to events in the lake and its water" shed and serve as valuable clues to trophic and other conditions.

A total of 163 dredgings were taken to determine standing crops and composition of bottom fauna in the 11 representative lakes. The complete data are given in Appendix Table E_1. For purposes of comparison it was found to be more convenient and more meaningful to consider only that component of the benthic population occurring within the upper 6 m of each lake. This depth range is common to all the lakes, at least at full supply level. Furthermore, as an approximation of the "littoral" zone, it figures prominently in the management formulae utilized by the B.C. Fish and Wildlife Branch for stocking the lakes with fish. It should also be noted that only for Pinaus and Swalwell Lakes could the 0-6 m zone be considered unsatisfactorily representative of the lake as a whole. Over half the areas of these two lakes lie below 6 m (Appendix Table B). Bottom fauna standing crop comparisons on the basis of 0-6 m are summarized in Appendix Table E_2, and are presented graphically in Fig. 20. Results of the two sampling series (midsummer and autumn) were amalgamated and weighted by percent areas

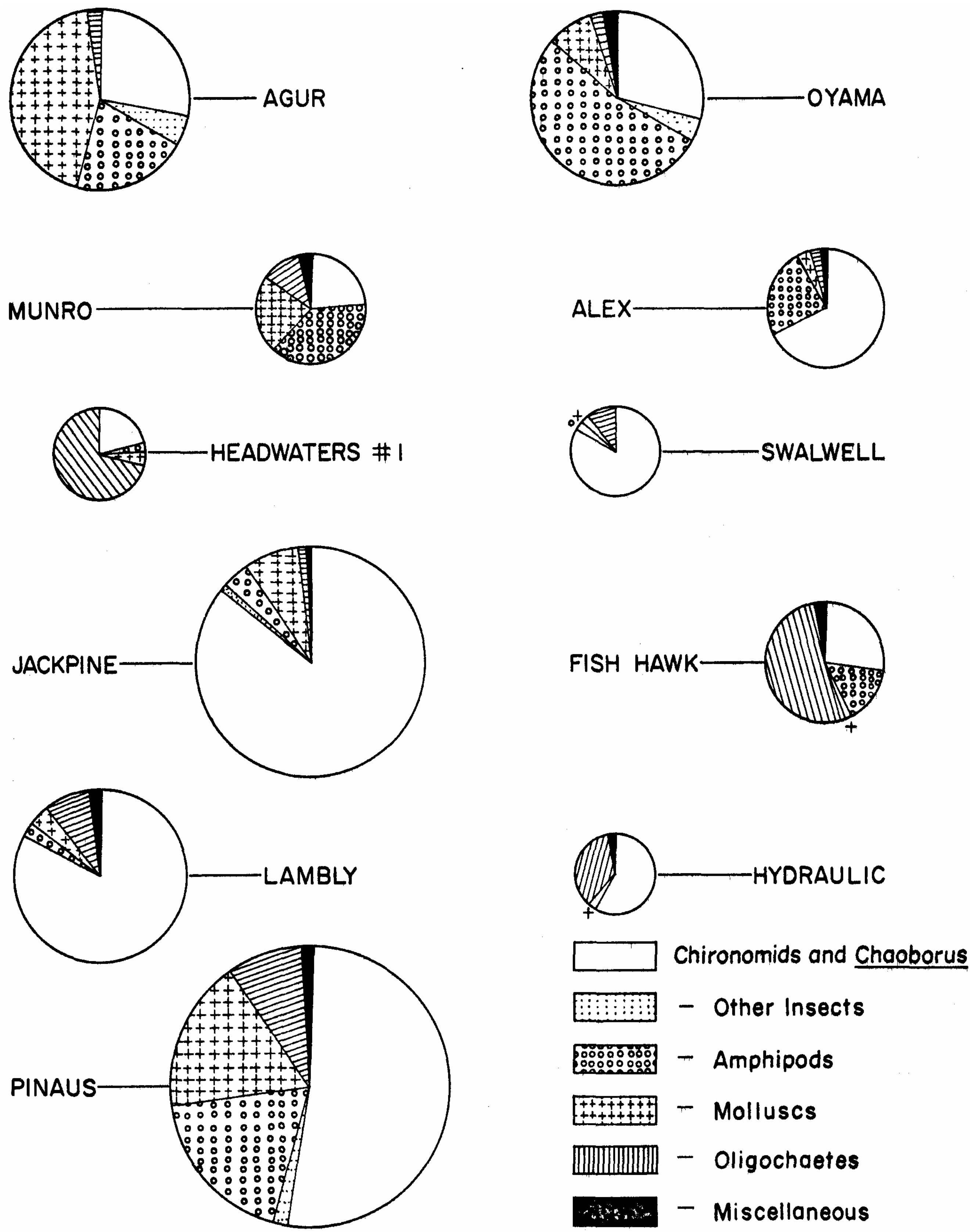

Fig.20. Standing crop and composition of bottom fauna in the 0-6m.zone in II selected headwater lakes in the Okanagan Basin,1971. See text for details.

of depth zones at 2-m intervals within the overall 0-6 m range. In instances where depth zones were eliminated by drawdown between summer and autumn, the accompanying elimination of the benthos is integral to the standing crop average values as derived. The circles (Fig. 20) are proportional in area to the standing crops (weight) of bottom organisms; the subdivisions represent numerical contribution by particular component groups.

The observed abundance of benthic organisms ranged from a low of 246 per square meter in Headwaters Lake No. 1 to 2550 per square meter in Oyama. Numbers of organisms do not closely parallel total weights, indicating that these organisms differ substantially in average size among the lakes. Hydraulic Lake has the lowest benthic biomass, a clear reflection of the extreme fluctuation in water levels experienced here (Table 4). Headwaters Lake No. 1 also has a very meager benthic fauna, and it, too, is extensively manipulated. A complicating factor is that both Hydraulic and Headwaters Lakes harbor coarse fish species which are known to utilize bottom fauna for food. Lambly and Jackpine Lakes, both of which undergo extensive water volume fluctuations, have high biomass of bottom fauna. These lakes are shallow, have particularly warm epilimnia, are situated in similar geological surroundings at low to moderate altitude, and are without coarse fish. These factors appear conducive to relatively heavy benthic populations. High altitude lakes (Munro, Alex and Fish Hawk) are, as would be anticipated, low in production of bottom fauna. Pinaus Lake has consistently high standing crops of all faunal indicators (Zooplankton, bottom fauna, and fish).

Immature Diptera, mainly chironomids, constitute over half the littoral benthic fauna in six of the lakes. Among those which are regulated, chironomid larvae contribute particularly heavily to the low-to-medium-altitude lakes (Lambly, Jackpine, Swalwell and Hydraulic). Chironomid larvae are relatively unimportant in the two highest lakes, Fish Hawk and Munro. Here their predominant role is replaced by oligochaetes in the former, and by a diversity of organisms in the latter. Chaoborus larvae contribute significantly to the dipteran fauna only in Alex Lake. These organisms were found to be reliable indicators of high coloration and dystrophic conditions among Shield lakes in Saskatchewan (Koshinsky MS 1968); this is consistent with their distribution among the Okanagan headwater lakes as well.

Except for Diptera, most aquatic insects are known to be adversely affected by impoundment and regulation; this was also noted in the present study. "Other aquatic insects" including seven different insect orders (see footnote, Appendix Table E_1), were encountered in low numbers in Agur and Oyama Lakes, with trace occurrences in Jackpine and Pinaus.

Oligochaetes are an important component of the benthos in Headwaters, Fish Hawk and Hydraulic Lakes, although not abundant in absolute terms in the latter. They are also abundant in the deep waters of Swalwell and Oyama Lakes (Appendix Table E). These organisms are generally considered to be indicative of disturbed trophic conditions. With the exception of Fish Hawk, the lakes mentioned share histories of significant shoreline disturbance due to impoundment. Oligochaete concentrations tend to peak in the very shallowest areas of the shallow impounded lakes. However, even more dramatic peaks occur in the deepest waters of the two deep lakes which undergo extensive manipulation (Swalwell and Oyama). The shallow-water peaks probably reflect a constant source of organic matter from flooded and fluctuating shores. The deep peaks reflect low oxygen values where depth is sufficient for development of stratification; occurrence of these deep-water peaks seems to be enhanced by impoundment. It should be noted that Pinaus Lake, which is not significantly manipulated, has no oligochaete peak at the bottom despite severe summer bottom oxygen depletion (Fig. 14). Enhancement of oligochaete and chironomid populations relative to other benthic invertebrate groups as a consequence of impoundment has been documented in numerous other instances (e.g. Grimas 1965a).

Amphipods (Hyalella azteca and/or Gammarus lacustris) were identified from all but one of the lakes, with sizeable populations in half of them. Amphipods made up less than 5% of the littoral fauna in the five lakes which rank highest in terms of volume manipulation through drawdown. The most drastically manipulated lake, Hydraulic, was the only one from which no amphipods were disclosed. Manipulated lakes in Sweden demonstrate the same negative effect regarding amphipods (Grimas 1965b). *Hyalella* constituted over 90% of the amphipods collected in all lakes except Pinaus, where over half the specimens were the larger *Gammarus.* No mysids were encountered in the dredgings or other collections from Pinaus Lake despite an earlier attempt to introduce them (Stringer 1967). Molluscs (mainly sphaeriids in these lakes) show a distribution akin to that displayed by amphipods in that they are poorly represented in the most heavily manipulated lakes. In addition, however, molluscs are consistently rare in all types of lakes examined on the east side of the basin. This, along with the fact that mollusc populations are particularly high in Agur and Pinaus Lakes, which have the highest calcium contents (Table 7) is clear evidence that ion distributions exert the primary control for this group. Munro Lake, also with a high calcium content, has a sizeable mollusc fauna despite its high altitude and very considerable water fluctuations. Molluscs require calcium carbonate for shell construction and, although there are exceptions, their geographical distribution is largely determined by water chemistry (Pennak 1953).