13. FISH POPULATIONS

13.1 Standing stocks.

The relative abundance of fish in the various lakes was determined by setting standard gangs of gillnets according to a consistent field procedure (see earlier Methods section). The results of this test-netting program, which was conducted during the summer and autumn visits, are summarized in Table 10 and Fig. 21. Fish taken by netting were also used in the derivation of various other population parameters (see below).

All the lakes harbor rainbow trout (Salmo gairdneri); this is by far the most common sport fish in the Okanagan headwaters. In addition, Hydraulic and Headwaters Lake No. 1 have fine scaled sucker (Catostomus catostomus), and Hydraulic Lake also has a species of dace, tentatively identified as Rhinichthyes osculus. These "coarse" fish species made up 96% and 73% of the gillnet catch (by numbers) from Hydraulic and Headwaters Lakes respectively.

The amounts of rainbow trout taken in the gillnets varied greatly among these lakes. Catches show some correlation with other productivity indices, but other factors are also intimately involved. Lambly Lake yielded the highest catches (48 trout, weighing 7.6 kilograms, per net) ; this is clearly the richest lake of the series investigated. Fish Hawk Lake,

TABLE 10. Summary of standard gang gillnet catches from 11 selected headwater lakes in the Okanagan Basin, 1971.

	No. of net sets	Rainbow trout catch					Coarse fish catch, total number	
		Total		Per net set		Avg. fish weight, grams		
		Number	Weight, grams	Number	Weight, grams		Fine scaled sucker	Dace
AGUR	6	26	4,157	4.3	693	159.9	0	0
MUNRO	6	32	6,086	5.0	1014	190.2	0	0
HEADWATERS #1	4	11	513	2.8	128	46.6	29	0
JACKPINE	6	35	10,091	5.8	1682	288.3	0	0
LAMBLY	4	192	30,523	48.0	7631	159.0	0	0
PINAUS	4	51	12,223	12.8	3056	239.7	0	0
OYAMA	6	30	10,554	4.6	1759	351.8	0	0
ALEX	4	50	13,225	10.8	3306	264.5	0	0
SWALWELL	6	44	7,555	7.2	1259	171.7	0	0
FISH HAWK	4	111	11,200	25.5	2800	100.9	0	0
HYDRAULIC	6	6	1,628	1.0	271	271.3	137	5

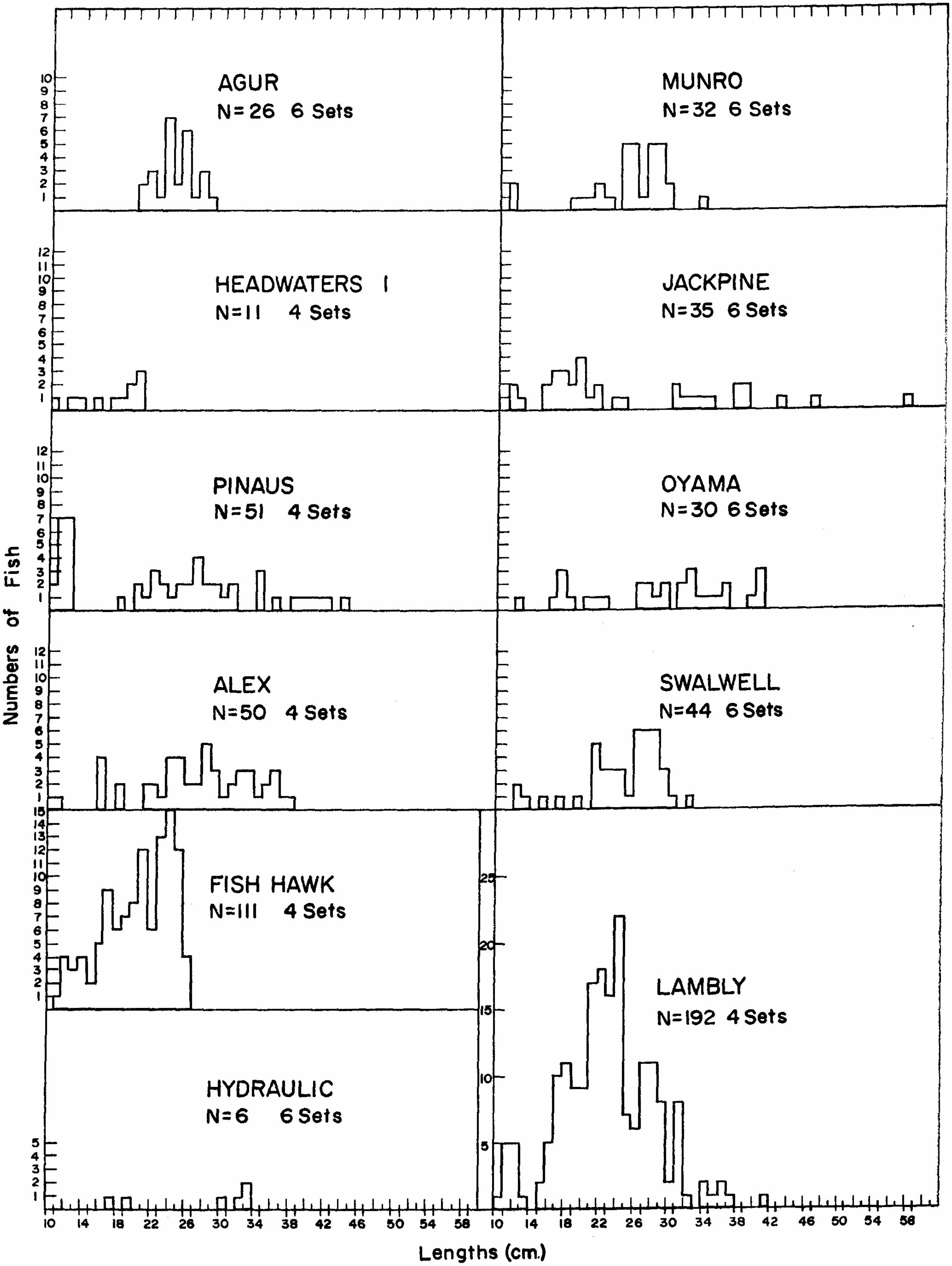


Fig.21. Length-frequency composition of Rainbow Trout in experimental gillnet catches, 11 headwater lakes in the Okanagan Basin, 1971.

despite an obviously low productive capacity, also yielded a high trout catch (25 fish weighing 2.8 kg per net). The relative inaccessibility of Fish Hawk Lake and its very low level of exploitation is undoubtedly responsible for this situation, along with favorable reproductive opportunities. The trout in Fish Hawk Lake, it might be noted, were among the smallest encountered. Alex and Pinaus Lakes also produced reasonably high trout catches (Table 10). Alex Lake is comparatively lightly exploited and also has good natural spawning habitat. Pinaus Lake is heavily exploited, but is also very heavily stocked (see below). The most meagre fish catches were realized from Hydraulic and Headwaters Lakes. These reservoirs combine a high degree of water manipulation with the presence of competing fish species. The average size of trout in Headwaters Lake was the smallest among the lakes investigated.

13.2 Growth.

Growth rates of rainbow trout were estimated by a combination of scale-reading and examination of length-frequency histograms (Fig. 21). A tabulation of mean length-at-age estimates was prepared (Table 11). Ageing was rendered difficult and somewhat uncertain due to inherent variations in scale patterns and stream-residence characteristics, and also by the interactions of stocking and exploitation. It is nonetheless apparent that growth of rainbow trout is exceptionally slow in the high-altitude, lightly-exploited lakes such as Fish Hawk and Alex with their good natural reproductive opportunities. Only in Pinaus Lake does growth approach that in the mainstem as indicated by the comparison with Okanagan Lake, and then only in the first 3 years. The generally slow growth in the headwater lakes is an important limiting aspect in their trout-producing capacities.

Growth is good, but not exceptional, in Lambly Lake with its demonstrated high productivity. Equivalent or better growth is achieved in some of the deeper lakes (Munro, Pinaus, Oyama). Such lakes provide opportunity for fish to avoid unfavorably high surface temperatures in summer (Fig. 13, 14). Among them, growth increases with increased content of solute materials in the water (Table 7). Reservoir manipulation and/or presence of competitor species severely depress growth as indicated particularly by Headwaters Lake.

TABLE 11. Lengths-at-age (growth comparison) of rainbow trout in 11 selected headwater lakes in the Okanagan Basin, 1971. Comparative data are given for Okanagan Lake. Entries are mean fork lengths in cm at midsummer.

	1	2	3	4	5
AGUR		25			
MUNRO	12	22	27	30	
HEADWATERS #1	10	14	18	21	
JACKPINE	11	18	25	33	41
LAMBLY	12	24	30	34	36
PINAUS		29	40	43	45
OYAMA	18	27	34	40	
ALEX		15	25	30	35
SWALWELL	12	21	25	27	
FISH HAWK	8	15	19	22	24
HYDRAULIC				32	
OKANAGAN[a]	11	29	41	54	66

[a] From Clemens (1939).

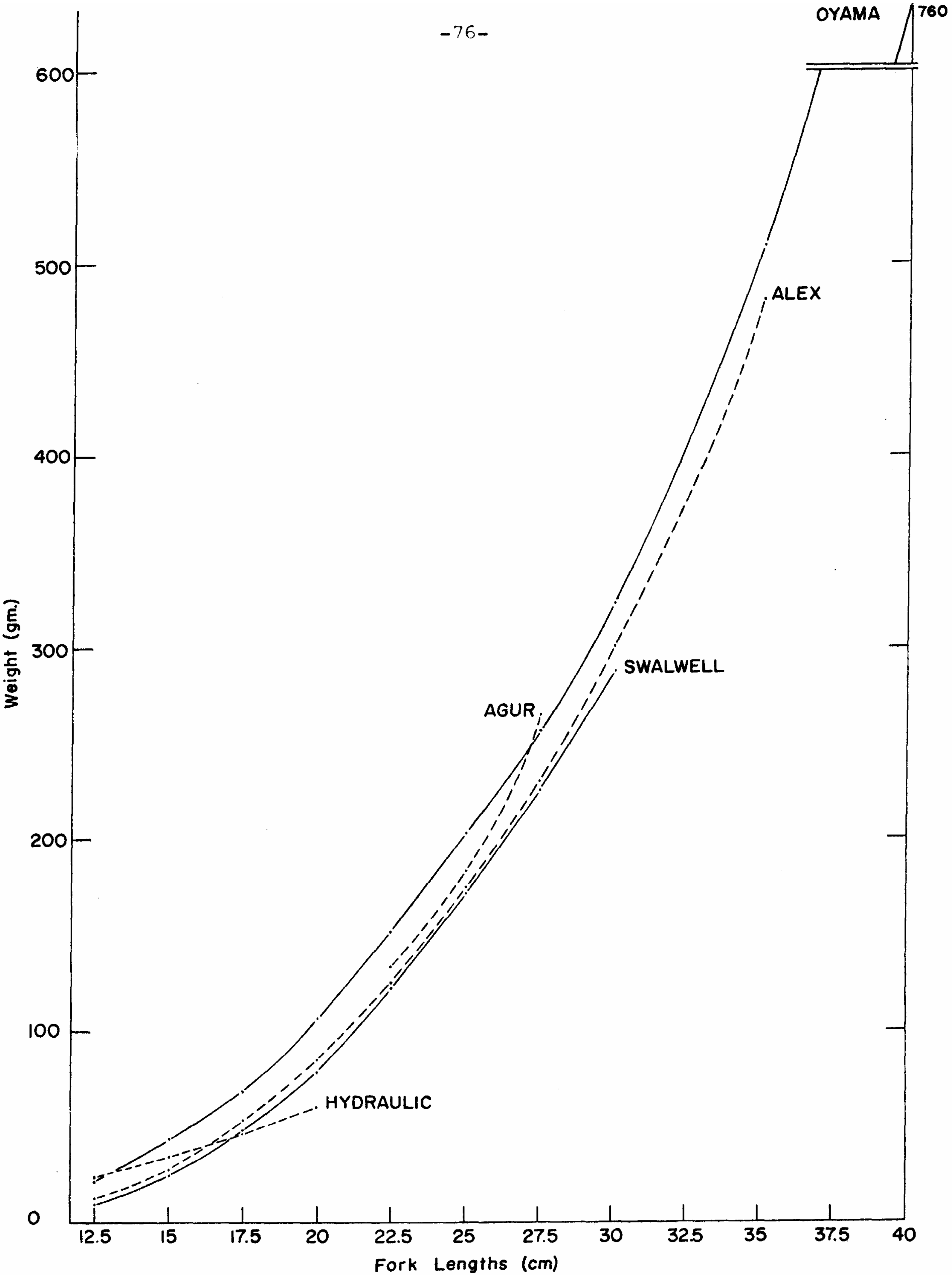
13.3 Length-weight relations.

Length-weight data were plotted for trout from each lake separately, and a chart of equivalents was prepared (Table 12). Curves for five of the populations are presented in Fig. 22. Trout are heaviest at specific lengths in Oyama and Pinaus Lakes, and generally lightest in Headwaters, Hydraulic and Fish Hawk Lakes.

The weight of a fish relative to its length can be taken as an indication of "plumpness" or "well-being". Thus the relatively emaciated condition of trout in Headwaters and Hydraulic Lakes undoubtedly reflects the severe habitat manipulations as well as the presence of competing fish species. In Fish Hawk Lake the relatively poor condition of the trout is attributable to the low productivity of the lake, along with the high trout population density. There is also some suggestion of below-average trout condition in Alex and Swalwell Lakes; both have good opportunities for natural reproduction and may suffer somewhat from over-crowding. Condition is very good at the small sizes in Lambly Lake, but falters badly in the larger size categories. The implication is that crowding may be exerting a negative impact and/or that forage conditions are relatively less suitable for the larger trout. Both influences are plausible in view of the recent management of the lake and the limnological consequences.

TABLE 12 . Comparative length-weight relationships for rainbow trout from 11 headwater lakes in the Okanagan Basin, 1971.

	Weight (gm) at particular fork lengths (cm)									
	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	35.0	40.0
Agur					133	183	265			
Munro	17	37	63	93	130	176	238	320		
Headwaters No. 1	23	35	47	60						
Jackpine	19	39	66	98	134	186	258	330	492	692
Lambly	22	40	63	93	129	178	231	293	436	632
Pinaus	23	40	63	96	136	188	247	314	467	700
Oyama	22	43	69	106	151	203	256	323	508	760
Alex	13	27	53	84	125	175	230	300	480	
Swalwell	10	25	48	78	123	172	225	287		
Fish Hawk	20	34	52	77	113	168				
Hydraulic			56	83	117	158	215	289		


OYAMA
760
600
500
400
300
200
100
0
Weight (gm.)
ALEX
SWALWELL
AGUR
HYDRAULIC
12.5
15
17.5
20
22.5
25
27.5
30
32.5
35
37.5
40
Fork Lengths (cm)

13.4 Fecundity.

Ovaries were excised from mature trout from seven of the lakes and the number of maturing eggs in each was enumerated. The individual values are plotted against weight of the fish in Fig. 23.

There are indications that the fecundity of trout species may be a function of the well-being of the fish and hence might serve as an index of environmental capability (Vladykov 1956). Among the present lakes, fish from Lambly, Jackpine and Oyama exhibit consistently above-average fecundity whereas those from Alex and Swalwell Lakes are consistently below the regression line. These values, then, serve to reinforce the other indications that Lambly Lake in particular is superior trout habitat whereas Alex and Swalwell Lakes typify more crowded, less productive trout habitat situations.

13.5 Food.

Stomach contents of trout were examined from each of the lakes. These contents were weighed in total, and were then apportioned visually into eight food item categories. The basic analysis was initially conducted on 10-mm trout length groupings from the separate summer and autumn sampling series. However, no specific trends in food consumption on the basis of size or season were apparent, and the data were accordingly amalgamated for brevity and ease of presentation (Fig. 24).

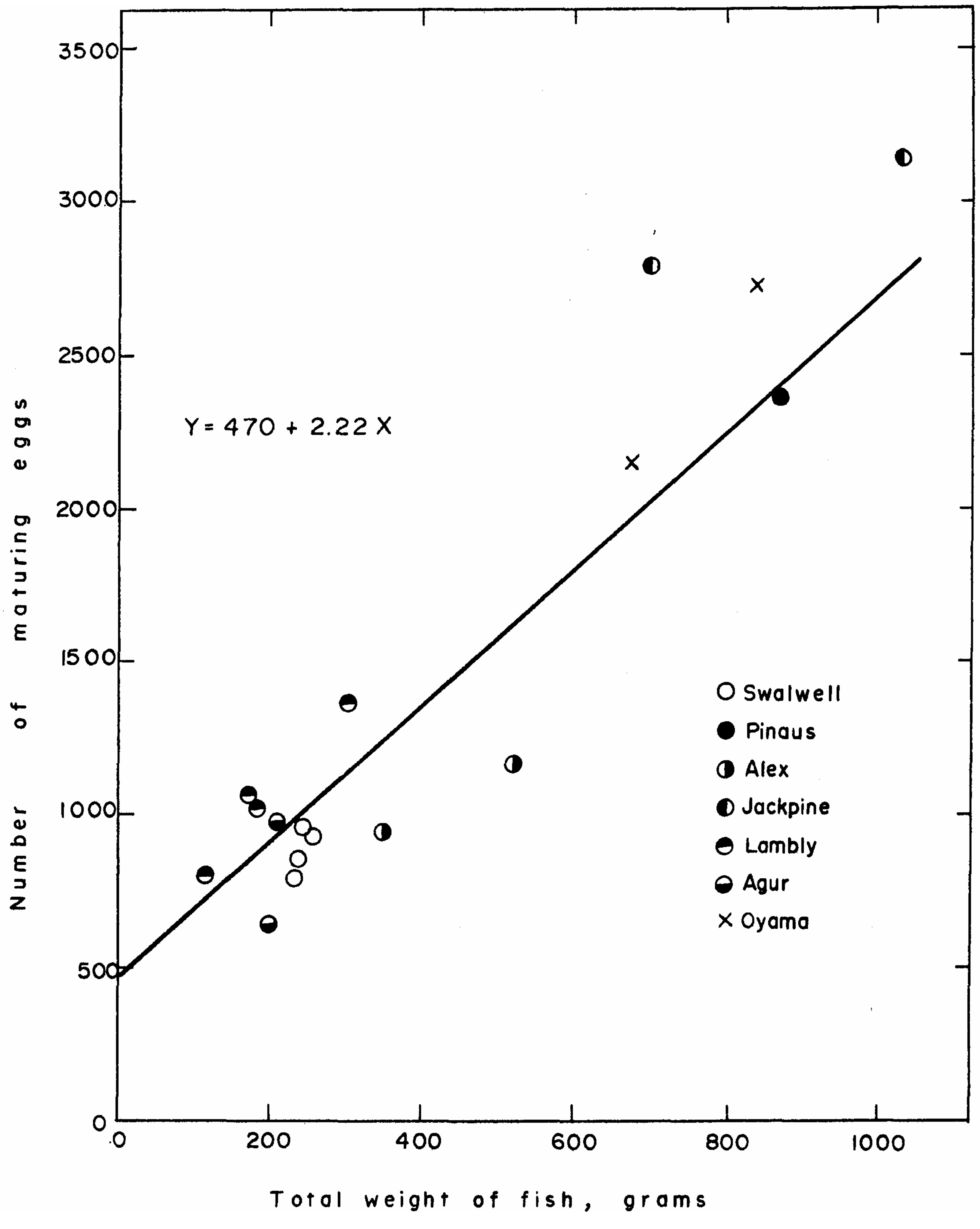


FIG. 23. Fecundity of rainbow trout as a function of total body weight in seven selected headwater lakes in the Okanagan Basin, 1971.

Several important generalizations pervade the patterns of trout food intake as recorded among these lakes. There is, first of all, a strong general tendency for trout to utilize for food the bottom fauna organisms occurring within the upper 6 m (compare Fig. 24 and 20). Two important exceptions concern utilization of amphipods and oligochaetes. Amphipods are typically consumed in proportions exceeding their abundance in the fauna, indicating that the trout actively select them. Importance of amphipods to rainbow trout culture in natural habitats has been clearly indicated in the course of trout farming experiments in Manitoba (J. Whitaker, pers. comm.). Decimation of amphipod populations as a consequence of lake manipu-. lation as has been indicated among the present lakes thus appears as a matter of concern. A converse pattern of utilization is evident for oligochaetes. These organisms were not found in any of the 398 stomachs examined, yet they contribute substantially to the benthic fauna particularly in the regulated lakes. The implication is that a predominance of oligochaetes, which tends to reflect cultural (human) disturbance, represents a largely wasted form of biological production from the viewpoint of rainbow trout bioenergetics.

Utilization of chironomids (immature Diptera) is of considerable interest and significance in view of the overall abundance of these organisms and their generally positive reaction to human interference. Chironomids are, in fact, heavily utilized by trout but not always in proportion to their abundance in the fauna. In general they appear to be

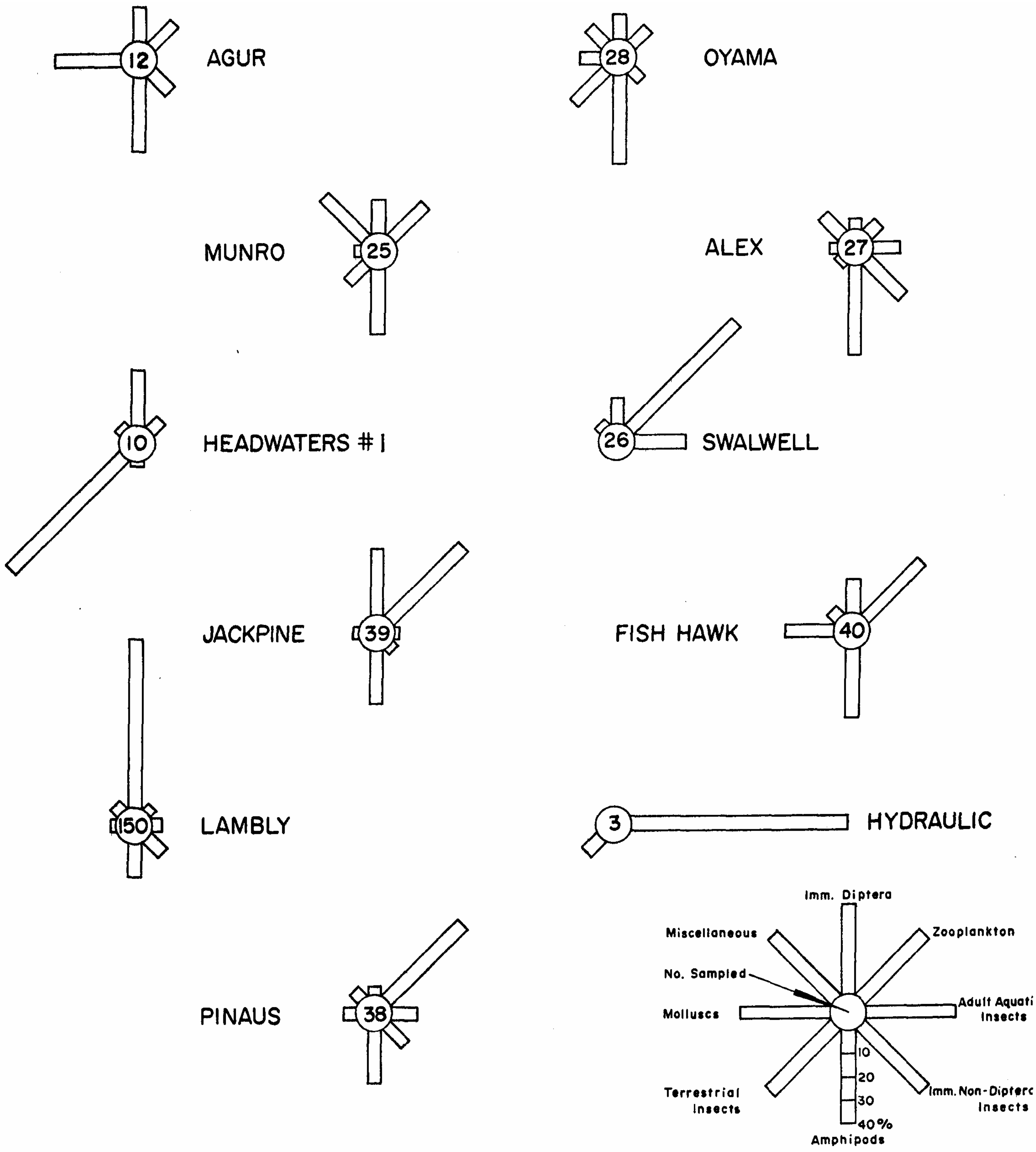


Fig.24. Stomach contents (average percent weight) of rainbow trout in II selected headwater lakes in the Okanagan Basin, 1971.

under-utilized in the deepest lakes (Pinaus, Swalwell, Oyama). It would appear, on the other hand, that the high biological productivity of Lambly Lake is being channeled to trout production mainly through the chironomids (Fig. 24), at least in summer. It has been shown (Efford 1969) that availability of chironomids to rainbow trout predation is highly dependent on the behavioural characteristics of particular chironomid species. Thus it may be presumed that the chironomids in Lambly Lake undergo the sorts of vertical movements which make them conspicuous and available to trout. This would be a potential avenue for profitable additional research.

Zooplankton entomostraca contribute substantially to the biology of rainbow trout in several of the lakes. Utilization of Zooplankton in summer does not correlate with Zooplankton population density (Table 9), but seems linked instead to the transparency of the lake waters (Fig. 25). This indicates that visual sighting is important for the utilization of these tiny planktonic organisms by trout. This potentially efficient avenue of food conversion is badly impeded in such lakes as Hydraulic, Lambly and Headwaters where continual and extensive water level manipulations operate to reduce transparency (Table 6). The potential effectiveness of Zooplankton in trout energetics is well illustrated in Pinaus Lake where a very high trout production is realized and where Zooplankton is the main summer food. Opportunities for feeding on Zooplankton in the highly regulated lakes probably improve under ice cover when

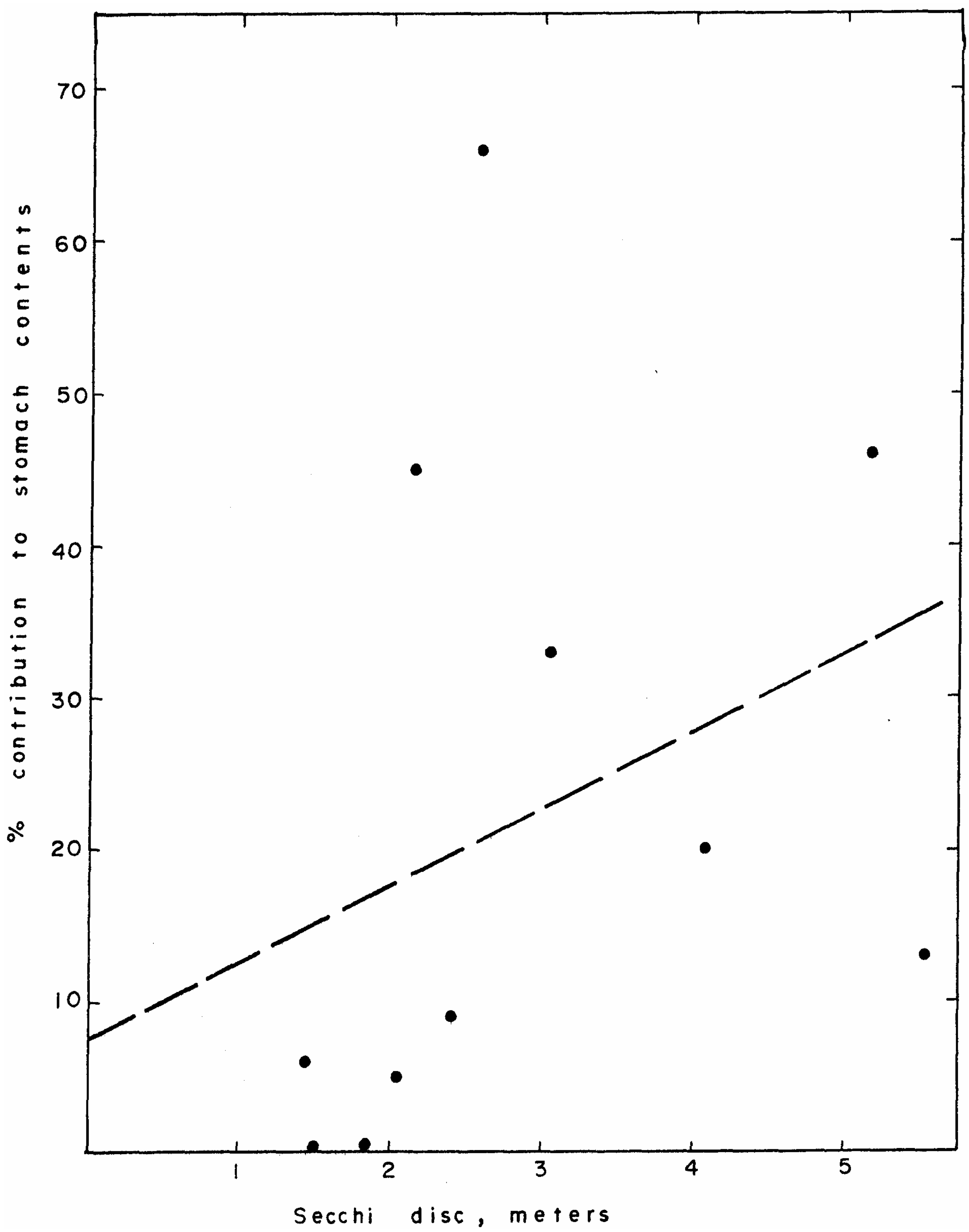


FIG. 25. Utilization of Zooplankton entomostraca by rainbow trout in summer in relation to water transparency in II selected headwater lakes in the Okanagan Basin, 1971. Transparency is expressed as the mean of the midsummer-autumn Secchi disc values.

turbidity diminishes through cessation of wind action. Seven trout taken from Lambly Lake on 23 January 1972 had consumed 60% cladoceran Zooplankton, whereas a concurrent sample from Oyama Lake had stomach contents virtually unchanged from the summer period.

In two of the most heavily manipulated lakes (Hydraulic and Headwaters), trout were observed to feed almost entirely on non-aquatic food items in summer (Fig. 24). Both lakes have extremely low and qualitatively poor bottom fauna populations (Fig. 20). Increased utilization of surface foods by rainbow trout in such situations is a mark of their high ecological flexibility. Norlin (1967), in a detailed review of this subject, describes how cool lake surfaces tend to cause air to sink above them, thereby precipitating the "aerial plankton". This material typically includes representatives of a large variety of insects, presence of which is linked to the productivity of the terrestrial surroundings and also to the energy developed by aerial turbulence in the neighborhood. Airborne insects may contribute little biomass to a lake in comparison with the resident bottom fauna, yet make a high contribution to fish food. Fauna drifting on the surface is highly available, it is concentrated in a specific layer (the surface), and is even compressed into lateral bands (wind streaks, and drift lines). It lacks protection and opportunity for escape, and is clearly visible against the surroundings (the sky). It is introduced at a high trophic level and, not surprisingly, makes its greatest relative contribution to fish food "in regulated mountain lakes" (Norlin 1967; Nilsson 1955).

13.6 Pesticide and metal residues.

Pesticide and heavy metal residues were determined for samples of rainbow trout from seven of the lakes; these results are given in Table 13. A total of 63 fish contributed to the analyses which were done on homogenates pooled according to fish size. Trout larger than 14 inches (356 mm) fork length were grouped separately from smaller ones.

Observed levels of mercury, copper, lead, and zinc; and of DDT and its derivatives, are all well below tolerance levels for freshwater animal products as set forth by the Canada Food and Drug Directorate (G. Halsey, pers. comm.). By way of perspective and with specific reference to mercury, it might be noted that Rucker and Amend (1969) considered 0.2 ppm mercury to be a "normal" level for rainbow trout. Wobeser et al. (1970) found up to 11.2 ppm in the muscle of fish from the Saskatchewan River system in conjunction with a known significant source of contamination.

Mercury concentrations in rainbow trout flesh as compared with values for the whole fish do not appear to differ consistently among the Okanagan headwater lakes. The analyses were run by separate laboratories, but agreement is quite close. Evidence presented by Wobeser et al.doc. cit.) suggests that mercury is concentrated in the viscera only in situations where significant contamination occurs.

TABLE 13 . Summary of heavy metal and pesticide residue analyses for rainbow trout from seven selected headwater lakes in the Okanagan Basin, 1971. Values are parts per million wet weight from composite homoqenates.

Lake	Size of fish, mm[a]		No. of fish	Whole fish[b]	Musculature[c]					
	Range	Mean		Mercury	Mercury	Copper	Lead	Zinc	DDT, DDD, opDDT	DDE
AGUR	215-275	253	8	.03	.07	.20	ND	5.40	ND	.01
JACKPINE[d]	190-345	280	8	.04	.05	.70	ND	6.00	ND	.02
	380-570	435	4	.15	.10	.90	ND	6.70	ND	.03
PINAUS[d]	265-340	284	8	.04	.05	.30	ND	6.40	ND	.03
	360-445	401	5	.05	.07	.30	ND	3.70	ND	.03
ALEX[d]	225-345	273	8	-	.07	.50	ND	5.00	ND	.07
	360-375	365	3	-	.09	.80	ND	7.00	ND	.10
SWALWELL	195-260	241	7	.08	.05	.30	ND	6.80	ND	.06
FISH HAWK	180-250	225	8	.07	.10	.70	ND	13.70	ND	.18
HYDRAULIC	190-330	286	4	.13	.11	1.00	ND	6.10	ND	.15

[a] Fork length.

[b] Analyses by Fisheries Research Board of Canada, Freshwater Institute, on whole fish.

[c] Analyses by B.C. Department Agriculture, on 1-oz. wedge-shaped samples just behind head.

[d] Distinctions between the two groups of fish (large and small) were not recorded in the course of musculature analyses. The results have accordingly been "assigned" on the assumption that levels of contaminants increase with increasing size of fish. This assumption is supported by the mercury values for whole fish(b).

Of the DDT derivatives, only DDE was present in detectable amounts. It is of interest that among the trout sampled, DDE was invariably more concentrated in those headwater lakes lying in the northeast part of the Okanagan basin. Winds in the Okanagan tend to parallel the valley profile, but air transport aloft tends to be from southwest to northeast (Kelley and Spilsbury 1949 ; D. Richier, pers. comm.). This, together with the distribution of observed concentrations suggests that the minor DDT contamination in trout in the Okanagan headwater lakes is probably attributable to air-borne fallout originating mainly within the basin. Presumably such contaminants could be air-transported as minute droplets or in association with "aerial plankton". It was noted earlier that lake surfaces tend to cause "precipitation" of such items as wind-borne insects, and the propensity of rainbow trout to feed on such materials was also demonstrated.

If the above interpretation has validity it might be ejected that pesticide levels in fishes in Kalamalka-Wood Lakes might be relatively higher than would be anticipated on the basis of historical pesticide use in those particular watersheds. High DDT levels do in fact exist in fishes in Kalamalka (G. Halsey, pers. comm.).

14. DISCUSSION: PRODUCTIVITY OVERVIEW

A variety of factors have been examined for their impact on biological processes in these 11 selected headwater lakes. Some understanding has been gained of the operation and relative importance of these factors, and of how their manipulation might affect lakes, particularly their capacities to produce fish. To complete this overview a system was devised of ranking the lakes for the various parameters which were measured, and amalgamating these rankings to obtain composite "scores". The lakes were first ranked from 1 to 11 for each of 14 factors pertaining to physiography, morphometry, hydrologic manipulation, physical phenomena, and chemical features (Appendix Table F_1). These rankings were then added to obtain a "physical-chemical" score. "Bio-productivity" scores were derived in the same manner on the basis of six features relating to plankton and bottom fauna (Appendix Table F_2). Similar procedures have been used by Rawson (1960) and others.

Comparison of the physical-chemical, and bio-productivity scores (Fig. 26) shows a high degree of correlation (r=0.97) if three of the lakes are disregarded. The dispositions of these three non-conforming lakes, then, are of particular interest in elucidating limiting factors in productivity.

Agur Lake is unique in the series in that it is landlocked (i.e. it has no surface outflow). It has the highest transparency, the lowest discoloration, and a unique chemistry.

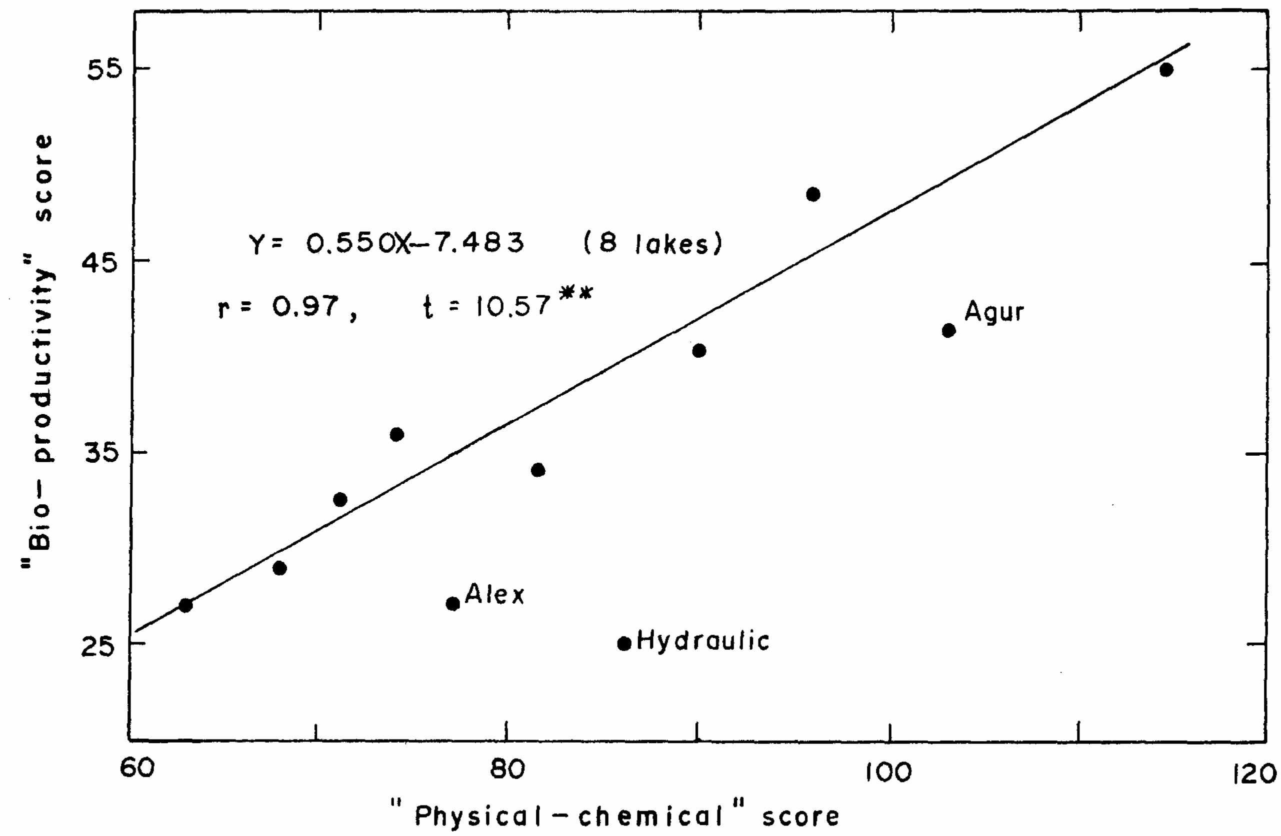


FIG.26. Relation between " bio-productivity " and "physical-chemical" scores for II selected Okanagan headwater lakes.

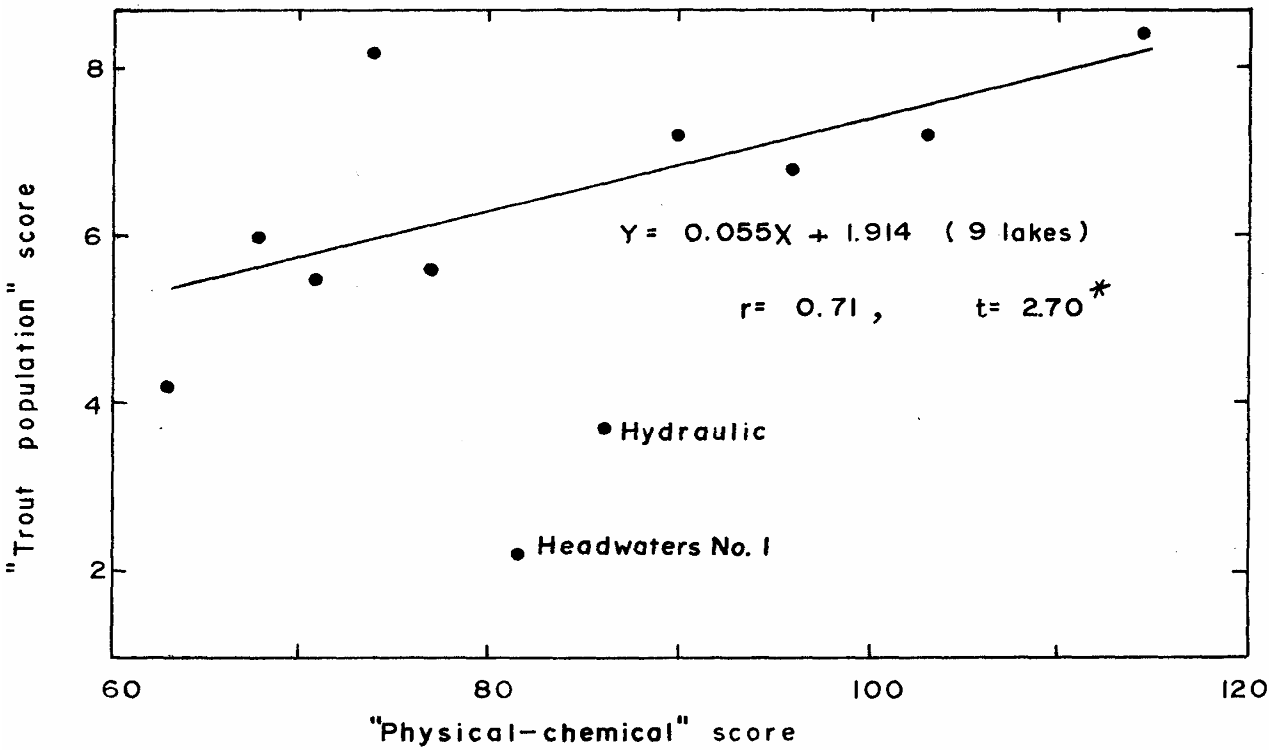


FIG.27. Relation between "trout population" and "physical-chemical" scores for II selected Okanagan headwater lakes.

Although its "bioproductivity" is high (Fig. 26), it is not quite as high as might be predicted from the measured physical-chemical characteristics. The drainage basin of Agur is the smallest among these lakes. In conjunction with the low precipitation (also minimal) and high evaporation at this altitude and latitude, the basin does not yield enough water to ensure a surface outflow from the lake. It is postulated, therefore, that the yield of trace nutrient items is similarly handicapped, and that this results in some reduction in capacity for primary production. This "handicap", however, is not reflected in the bottom fauna of Agur Lake and hence is presumably not of major importance in the ecology of fish.

Alex Lake, too, has a lower bio-productivity score than would be expected from its documented physical-chemical features. It is highly discolored and has high nitrogen (humic) concentrations. These features suggest a strong tendency toward "dystrophy", a conclusion supported by the significant numbers of *Chaoborus* in the benthos. An unsophisticated consideration of lake volume, drainage basin area, and precipitation, suggests that the water of Alex Lake is replaced at a faster rate than for any of the other lakes. The relatively rapid displacement by runoff is apparently responsible for the rather humic character of the lake water. This has negative effects on productivity beyond the more direct impacts associated with rapid flushing (such as low TDS) that were incorporated in the physical-chemical score.

Hydraulic Lake displays the greatest discrepancy between physical-chemical and bio-productivity scores. Hydraulic is an impounded reservoir which is very severely manipulated. The percent lake area exposed by drawdown has averaged 51% over the past 7 years. Annual volume reductions have averaged 74% (range of- 48-97%). It is concluded that the biological impacts of this regime are very profound. Lakes manipulated in the mean annual range of ± 15-30% for area, and ± 20-50% for volume (e.g. Headwaters, Jackpine, Lambly, Oyama, Swalwell) do not display this dramatic reduction in productivity. Except for Hydraulic, Headwaters shows the greatest negative deviation from the regression line (Fig. 26) among the manipulated lakes. Volume reduction in Headwaters, although averaging only 37% since 1965, has been as high as 76% in one year.

"Trout population" scores were derived for each lake on the basis of standing crop, growth, condition, fecundity, and angling catch per unit effort (Appendix Table F_3). These values are plotted against the physical-chemical scores in Fig. 27. It is apparent that- two of the lakes, Headwaters No. 1 and Hydraulic, have discordantly low trout population scores. This is attributable in part to the severe hydrologic manipulation, particularly for Hydraulic Lake. It was noted earlier that several of these lakes are manipulated as much or more than Headwaters on a mean annual basis, but Headwaters has a history of especially heavy manipulation in occasional years. Another common factor shared by these two lakes is the presence of coarse fish species (Table 10). The interference by such fishes with trout production in small mountain lakes is well documented (e.g. Larkin and Smith 1954). Average size, growth and condition of trout are all lowest in Headwaters among the lakes of this series. Growth of trout is not notably diminished in Hydraulic Lake, but condition is very poor. The evidence suggests that the small numbers of trout (apparently all constituting one year-class) which are found in Hydraulic may actually be migrants from adjoining lakes.

The high trout score for Oyama Lake is of interest. Oyama has the best population of amphipods (Fig. 20), the preferred food of trout in these lakes.

Among the parameters which contribute to the physical-chemical scores as derived above, three factors alone -- altitude, mean depth and TDS -- serve nearly as well for the prediction of bio-productivity and trout population characteristics among the "conforming" lakes. The values of the correlation coefficients are compared below:

	Bio-productivity score	Trout population score
Physical-chemical score, 14 factors:	r =0.97	r =0.71
Physical-chemical score, 3 factors:	r =0.89	r =0.58

The abbreviated index demonstrates the overriding importance of altitude (which in turn largely determines TDS), along with depth (or depth-linked factors) in the basic productivity of these lakes. It, of course, again fails to take into account the unusual impacts of very low inflows, dystrophy, or severe water-level manipulation.

15. THE HEADWATER FISHERIES

15.1 Fishery management.

Most, if not all, the Okanagan headwater lakes were initially barren of fish. This resulted from geologic and glacial events coupled with denial of access from the mainstem by topographic features. An active program of fish introductions was initiated by the British Columbia Government about 1920, and is continued by the B.C. Fish and Wildlife Branch today. Some 60 of the Okanagan headwater lakes (plus several small ponds) are stocked on a regular basis, with sport-fishing opportunities in the remaining ± 70 lakes deriving from earlier or adjacent introductions. The bulk of the fish handled are rainbow trout which occur in at least 126 of the waters listed in Appendix Table A_1. At least 27 of the Okanagan headwater lakes contain fish species other than, or in conjunction with, rainbow trout. Most notable among these other species is eastern brook trout (*Salvelinus fontinalis*). Brook trout have recently received increased consideration in the local stocking program in anticipation that they might prove more resistant to winter-kill conditions. "Warm-water fish" and "coarse fish" species have also gained access to some of the lakes. Known occurrences of species other than rainbow trout in these 129 waters are summarized in Appendix Table G.

Some of the most basic considerations in the management of the Okanagan headwater fisheries involve the dimensions of the lakes. A critical question is what depth characteristics are necessary to ensure over-wintering survival of stock. Lakes without an adequate oxygen reservoir per unit of area to meet the respiratory requirements of trout will "winter-kill". In general, the more productive the lake the more depth is required.

Some appreciation of this "critical depth" can be gained by considering lakes which are actually known to support fish over winter. A plot was prepared (Fig. 28) of the frequency distribution in terms of maximum depth of such headwater lakes in the Okanagan. It is immediately apparent that lesser depths are required to maintain fish at the higher elevations. This is mainly a reflection of the lesser productivity of the higher lakes, which in turn relates to the lower solute contents, lower temperatures and shorter growing season. Also involved is the greater probability of significant flow-through (winter discharge) at the higher elevations. As a general rule it would appear that maximum depths of 25 feet or more are necessary to consistently ensure fish survival over winter below 4000 feet, whereas depths of 15 feet, and sometimes even 12 feet, are usually adequate above this elevation. This model could serve as a crude basis for setting minimum depth requirements for fisheries in reservoirs subject to drawdown. A complicating factor would be the elevated productivity associated with early impoundment (e.g. Lambly Lake), at which time greater over-wintering depth would be required.

Current fish stocking practice in the Okanagan region embodies a consideration of survival potential, anticipated utilization, and the estimated carrying capacity of the parti-

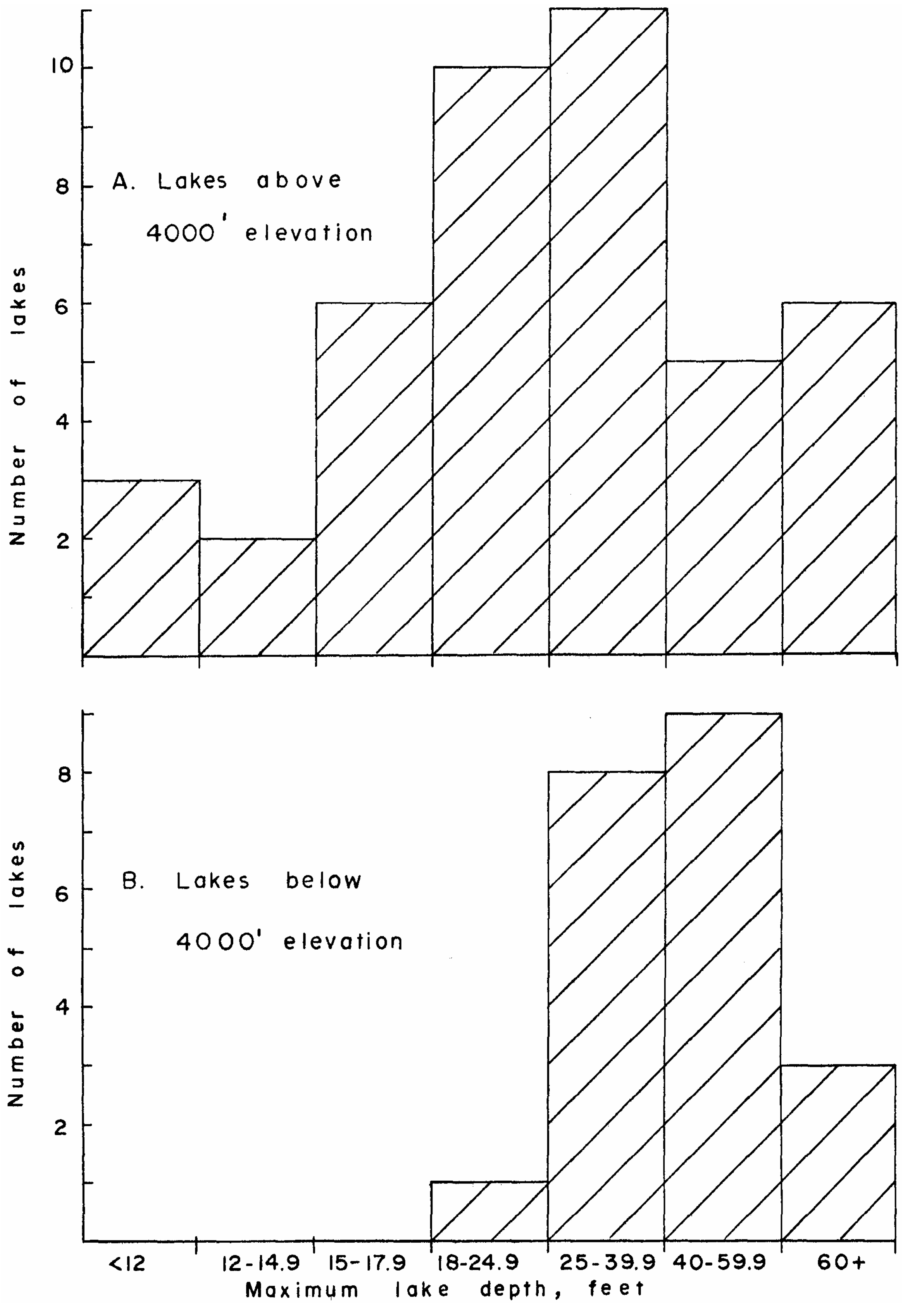


FIG. 29. Frequency distribution, in terms of depth, of Okanagan headwater lakes harbouring fish populations.

cular lake. The "stocking formula" which forms the background for present management takes into account total surface area, littoral area, and total dissolved solids content of the receiving water (S. ,MacDonald, .pers. comm.). This formula has the following components:

Basic number of fry required

(Total surface area in acres) + (10 x littoral area)

(K)

Where K is a stocking intensity factor based on TDS as follows:

TDS	K
50	150
100	200
150	250
200	300
250	350

On this basis (Formula 1), and defining littoral area as 0-6 m (as is done in local practice), basic annual stocking requirements were derived for the 11 key lakes. These are presented in Table 14.

A revamped stocking formula, developed from earlier studies by Mottley (1932), Northcote and Larkin (1956), and other observations, has recently been put forward by Smith et al. (MS 1969). The basic stocking requirement is estimated from shoreline length on the basis of 30,000 fry per mile. Values are adjusted according to carrying capacity as indicated by TDS using the empirical curve reproduced in Fig. 29. Stocking requirements for the 11 lakes on the basis of this formulation (No. 2) are included in Table 14. It will be noted that Formula 1 yields consistently higher estimates than Formula 2; the discrepancy averages + 210% and is greater among the larger lakes.

In practice, several other factors are given subjective consideration in stocking, namely the extent (if any)

Table 14. Calculation of trout fry stocking requirements, and recent historical introductions, 11 selected headwater lakes in the Okanagan Basin.

Lake	Basic annual fry requirement[a]			Adjustment factor[b]	Adjusted fry requirement	Mean annual introduction 1967 - 1970[c]	Introduction as % of calc. requirement
	Formula No. 1	Formula No. 2	Average				
AGUR	29,600	41,600	35,600	1.00	35,600	35,400	99
MUNRO	52,700	16,800	34,800	.60	20,900	27,400	131
HEADWATERS #1	251,200	75,600	163,400	.80	130,700	144,700	111
JACKPINE	203,600	48,400	126,000	.60	75,600	69,600	92
LAMBLY	376,600	85,200	230,900	1.00	230,900	91,600	40
PINAUS	188,000	131,700	159,800	.80	127,800	398,800	312
OYAMA	601,500	178,300	389,900	.20	78,000	26,700	34
ALEX	26,300	15,600	20,900	.00	nil	nil	--
SWALWELL	645,800	166,000	405,900	.60	243,500	400,500	165
FISH HAWK	71,000	19,200	45,100	.00	nil	nil	--
HYDRAULIC	1,026,600	248,000	637,300	1.00	637,300	33,700	5

[a] Calculated from dimensions at full supply level

[b] On basis of access conditions and natural spawning opportunities

[c] Fry equivalents on the basis of conversions given by Smith et al. (1969)

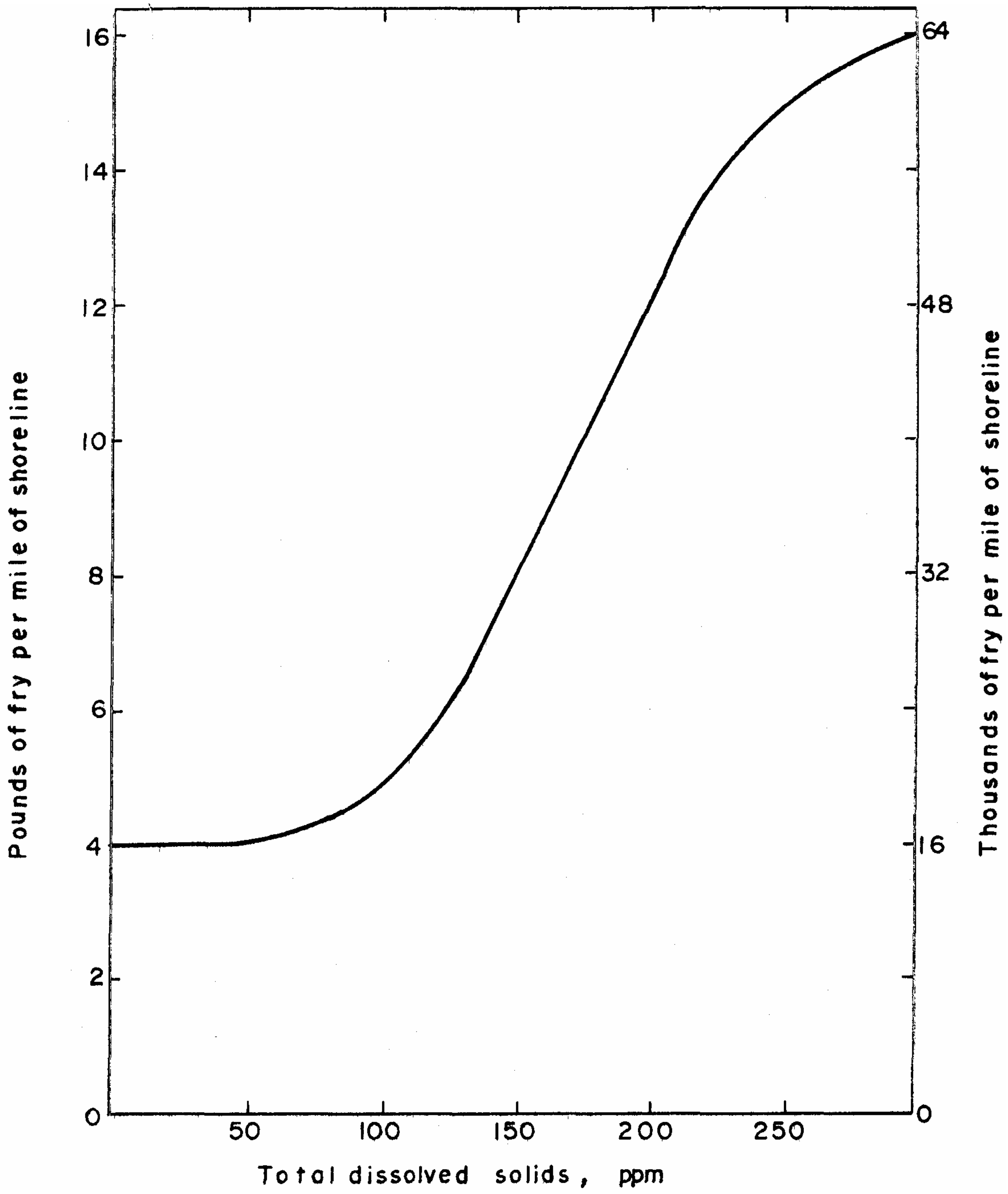


FIG. 29 . Basic rainbow trout clocking requirement (fry at 4000 per lb.) relative to TDS. Empirical curve redrawn from Smith et al . MS 1969.

of natural reproduction, the nature of access to the lake, the actual fishing pressure, and the angling success being experienced. Availability of stock forces additional modifications from year to year. Several significant headwater sport-fishing lakes are not planted with government stock because the lakes are entirely bounded by private or Indian lands and hence are not accessible to the public. Examples are Aeneas, Brent, Farleigh, Gallagher, Marron, and Shannon Lakes. Others, including Fish Hawk and Alex of the present key series are not stocked because natural recruitment is deemed adequate to maintain a suitable population.

Adjustment factors on the basis of access and conditions for natural reproduction are suggested for the 11 key lakes in Table 14. These factors have been applied to the mean basic fry requirement as derived from Formulas 1 and 2, and the results are compared (Table 14) with the average historical introductions over the period 1967-1970. It will be noted that there is considerable difference for some of the lakes between actual introductions and introductions predicted from either or both of the empirical formulations. The significance of some of these "discrepancies" is noted in the ensuing section.

The impacts of reservoir manipulation on fisheries have already been noted in several contexts. The matter is also of concern to the fishery manager conducting a stocking program. If dimensional changes are severe it is not clear on what basis stocking should be conducted. Stocking according to dimensions at full supply level would result in an undesirable concentration of fish at drawdown. Stocking to minimum pool dimensions would result in an unfavorably low density at other times of the year. The problem is largely self-resolving for the most severely manipulated reservoirs (e.g. Hydraulic) in that these do not warrant any significant stocking input. Loss of fish from reservoirs via the outlet is also of some concern. Some reservoirs which have no over-wintering potential probably play a role in enhancing the fisheries of the associated stream. Thirsk Reservoir provides good summer habitat and appears to promote rapid growth of trout. When it is drained in autumn these fish become part of the Trout Creek fauna,

A management tool that has in the past been employed with reasonable success among Okanagan headwater lakes that had become populated with coarse fish was the treatment of such lakes with fish toxicants followed by re-introduction of game trout species. Stringer and McMynn (1958, 1960) review this practice for British Columbia waters. At least 17 of the Okanagan headwater lakes, plus a few small ponds, have been so treated. These activities are summarized in Appendix Table H. This practice is no longer actively pursued.

15.2 Fish exploitation.

The numbers of anglers utilizing the Okanagan lakes in 1971 was determined under another task (MacDonald and Molnar MS 1972). Similarly the angling catch itself was (and continues to be) sampled under Task 66C. Exploitation figures for the period June through freeze-up in 1971 are given for the 11 key lakes in Table 15.

No overall relationship could be demonstrated between catch per unit effort (in terms of numbers or weight) and trout standing crop, population score, or stocking. Similarly, no clear links were apparent between total angling harvest and the various trout population or stocking indicators. Comparisons are difficult because the parameters are interrelated. Stocking and intrinsic factors (such as growth) are not readily separated as to their individual impacts on trout availability and production capacity. Similarly, trout availability (as measured by catch per unit effort) may reflect feeding opportunities, competition, etc. as much or more than population status. Total harvest in turn is heavily influenced by "external" factors such as access, accommodation, and scenery.

Examination of the extreme values of stocking and harvest (Table 15) is instructive, however. Thus it is apparent that a substantial stocking effort at Headwaters Lake, although resulting in a favorable numerical trout catch per hour, does not overcome (and may even have aggravated) the impact of competition with the coarse fish present. Hydraulic Lake does not appear capable of benefitting from even the token amount of stocking which has been conducted; this lake is governed completely by its extreme water regime. Lambly Lake, of exceptional productivity, has responded very well to what has been only a moderate stocking input. Lambly appears at present to have potential to accept and convert introduced trout stock beyond that predicted from the ordinary indicators (morphometry and TDS).

Table 15. Comparison of angling activity, angling success, and recent stocking of rainbow trout in 11 selected Okanagan headwater lakes.

	Angling Pressure, hr/acre	Angling success, catch per hour		Total harvest, lb/acre	Recent stocking as % of calculated requirm
		No.	lb.		
AGUR	77	.78	.31	23.8	99
MUNRO	15	.63	.26	4.0	131
HEADWATERS #1	17	.66	.09	1.5	111
JACKPINE	38	.21	.18	6.9	92
LAMBLY	46	.81	.34	15.6	40
PINAUS	183	.26	.21	37.1	312
OYAMA	12	.43	.28	3.3	34
ALEX	6[a]	1.00[a]	.65[a]	3.8[a]	(100)
SWALWELL	51	.72	.28	14.3	165
FISH HAWK	2[a]	3.25	.78	1.6[a]	(100)
HYDRAULIC	1	.10	.06	0.1	5

[a] Estimated

A high stocking intensity for Swalwell Lake (165% of predicted intensity) along with the existing natural recruitment, produce a relatively high yield of trout (14 lb per acre in 1971) despite the rather low productive capacity. Pinaus Lake, with its much greater productivity, demonstrates an even higher conversion of introduced stock. This lake yielded 37 lb per acre of trout in 1971 on the basis of a recent stocking program which has exceeded "calculated" stocking requirements by 300%.

16. GLOSSARY OF TERMS

(as utilized in this report)

Anaerobic:	Without free oxygen.
Bottom fauna:	Animals inhabiting the bottom of a lake (= zoobenthos).
Bloom:	A concentration of algae sufficiently dense to notably discolor the water.
Catch per unit effort:	The amount (number or weight) of fish caught in one standard unit of fishing activity (such as one angling-day).
Chlorophyll:	The coloring matter of plant cells, essential for photosynthesis.
Coarse fish;	Species of no direct value to humans (but often acting as food, competitors, or predators for other species).
Drainage lake:	A lake with a visible surface outlet.
Dystrophic:	Brown-water condition, characterized by low calcium and high humus content, and usually with low nutrients.
Edaphic factors:	Conditions determined by soil characteristics.
Eutrophic:	Waters with a good supply of nutrients and a high potential for organic production.
Epilimnion:	The turbulent upper layer of a thermally stratified lake.
Fecundity:	Number of eggs produced by a female (fish).
Hypolimnion:	The deep layer of a thermally stratified lake.
Limnology:	The study of inland waters.
Morphometry:	The dimensional characteristics of a lake*
Oligotrophic:	Waters with a small supply of nutrients and/or a limited capacity to promote utilization of nutrients for organic production.
Plankton:	The more or less free-floating plant (phytoplankton) and animal (Zooplankton) organisms in a lake.

Primary production:	The synthesis of organic matter from its constituents utilizing radiant energy.
Productivity:	The ability of a water body to promote or sustain organic production.
Standing crop:	The amount of organisms existing per unit of space at a given time.
Thermal stratification:	The occurrence of a density layering of lake waters as a consequence of surface warming.
Thermocline:	The zone of rapid temperature (and density) transition between the epilimnion and hypolimnion of a thermally stratified lake.
Total dissolved solids:	(=TDS). A measure of the total (usually non-volatile) solute material in water (= filterable residue).
Trophic level:	The position at which an organism operates in the food chain.

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Blagborne, K. Alderman, Summerland Municipality, Summerland.

Botham, J. Engineering Technician, Office of the District Engineer. Water Rights Branch, B.C. Water Resources Service, Kelowna.

Halsey, G. Biologist, Fisheries Research and Technical Services Section, B.C. Dep. Recreation and Conservation, Vancouver.

Munro, P. Secretary-treasurer, Meadow Valley Irrigation District, Trout Creek.

Obedkoff, W. Hydraulic Engineer, Water Investigations Branch, B.C. Water Resources Service, Victoria.

Pomeroy, M. (Formerly) Fisheries Technician, Fisheries Research Board Freshwater Institute. Environment Canada, Winnipeg.

Richier, D. Officer in charge, Penticton Weather Office. Environment Canada, Penticton.

Small, C. Secretary, Westbank Irrigation District, Westbank.

Stockner, Dr. J. Research Scientist, Fisheries Research Board Pacific Environment Institute, Environment Canada, West Vancouver.

Whitaker, J. Biologist, Fisheries Research Board, Freshwater Institute. Environment Canada. Winnipeg.