CANADA BRITISH COLUMBIA – OKANAGAN BASIN AGREEMENT

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Fish as Indicators of Water Quality in the Okanagan Basin Lakes, British Columbia

PREPARED FOR THE
OKANAGAN STUDY COMMITTEE

CANADA - BRITISH COLUMBIA OKANAGAN BASIN AGREEMENT

TASK 115

Fish as Indicators of Water Quality in the Okanagan Basin lakes, British Columbia

by

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NOTICE

This report was prepared for the Okanagan Study Committee under the terms of the Canada-British Columbia Okanagan Basin Agreement. The information contained in this report is preliminary and subject to revision. The Study Committee does not necessarily concur with opinions expressed in the report.

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ABSTRACT

The abundance, growth rate, and composition of fish species in the major Okanagan Basin Lakes was documented and evaluated during 1971. The results of this study will be used along with other limnology task findings to provide an overall assessment of the current ecology and trophic state of the five Okanagan mainstem lakes.

Associated studies reviewed in this report include an assessment of the present abundance of kokanee spawning stocks, and the levels of chlorinated hydrocarbons, heavy metals, and other contaminants found in various fish species.

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SUMMARY AND CONCLUSIONS

1. Four attributes of fish populations - relative abundance, average length, weight-length regression, and growth rate were used together with other of their characteristics as indices of eutrophication of Okanagan basin lakes.

2. All point towards Skaha Lake as now being the most eutrophic followed by Osoyoos and Vaseux. Kalamalka would seem the least eutrophic and then Okanagan.

3. Changes in the four attributes and other characteristics of the fish populations suggest a marked increase in eutrophication of Skaha Lake since 1948 but little change in Okanagan Lake since 1935.

4. Although Wood Lake now ranks nearly as low as Kalamalka in eutrophication index, several lines of evidence suggest that it has reached this position after passing through a more eutrophic state with respect to its fish populations.

5. In 1971 approximately half a million kokanee spawned in streams tributary to the Okanagan basin lakes, 77% in Okanagan, 12% in Kalamalka, 7% in Skaha tributaries.

6. In 1971 approximately half a million kokanee spawned along special sections of Okanagan Lake shoreline, mostly at depths less than 2 meters (6 feet). Apparently none shore-spawned in any of the other basin lakes.

7. For most lakes, availability of suitable spawning habitat, rather than water quality of the lakes seemed to determine abundance of kokanee spawners.

8. In 1971, 15 out of 107 analyses, representing 50 out of 671 fish sampled from the basin lakes, exceeded 5.0 ppm total DDT - the allowable limit for human consumption. Very high concentrations (15 - 50 ppm) were recorded in large rainbow trout from Kalamalka Lake; high concentrations occurred in Kalamalka mountain whitefish and Okanagan rainbow trout; most other species examined from the basin lakes contained relatively low DDT concentrations.

9. In 1971, 7 out of 107 analyses, representing 10 out of 671 fish sampled from the basin lakes, exceeded heavy metal limits set for human consumption. High concentrations of mercury (0.52 - 1.79 ppm) were found in some rainbow trout and squawfish from Okanagan, Skaha and Osoyoos lakes; most other species examined from the basin lakes contained relatively low heavy metal concentrations.

10. Levels of pesticides and heavy metals found in Okanagan basin fish probably have deleterious effects on their reproduction and survival.

INTRODUCTION

The objectives of this study, "Task 115 – Fish Population and Analysis", under the Limnology Task Force of the Canada - British Columbia Basin Agreement, were to (1) use fish to assess the present status of eutrophication and pollution in the major Okanagan basin lakes; (2) estimate present abundance of kokanee spawning stocks; and (3) check selected species of fish for chlorinated hydrocarbons, heavy metals and other possible contaminants.

That fishes respond to changes in the trophic nature of their environment has long been known, but their use as indices of eutrophication has only recently been considered (Larkin and Northcote, 1969). Limitations in their use arise from their position near or at the top of the food chain (making them often the last and perhaps least affected), their mobility, and their flexibility and variability in feeding, growth and other population parameters. Nevertheless they do attract a significant focus of public attention and concern, especially when dead; they often have had some background of previous study, either in the specific field situation or the laboratory; finally, they may serve as convenient summators, temporally, spatially or both, of the more general effects of eutrophication. Characteristics of fishes which reflect changes in their environment include the relative abundance of species, their length-frequency distribution, their length-weight relationship, and their growth rate. To this end, fish were studied as indices of eutrophication by making comparisons between major lakes of the Okanagan basin at the present time. Then, where possible, comparisons were made over long periods of time within particular lakes.

In the time available it was not possible to obtain reliable population estimates for any of the fishes except kokanee. Because this species at maturity congregates in the autumn, either in streams or along lakeshores, it is relatively easy to make estimates of the spawning component of the various populations.

Because of the considerable public concern over pesticides and heavy metals, particularly mercury, in sport fishes of the Okanagan basin – a partial ban on eating large trout already had been placed on Okanagan Lake - it seemed logical to broaden the information available in this area. The ability of fish to concentrate some natural and foreign materials from their surrounding environment enables us to view changes in the environment before they become catastrophic or unmanageable. Species for analysis were selected firstly on the basis of their importance as sport fish and utilization for human consumption. Others then were added which might become important in the future or which by their predatory nature might be expected to better exhibit exposure to contaminants.

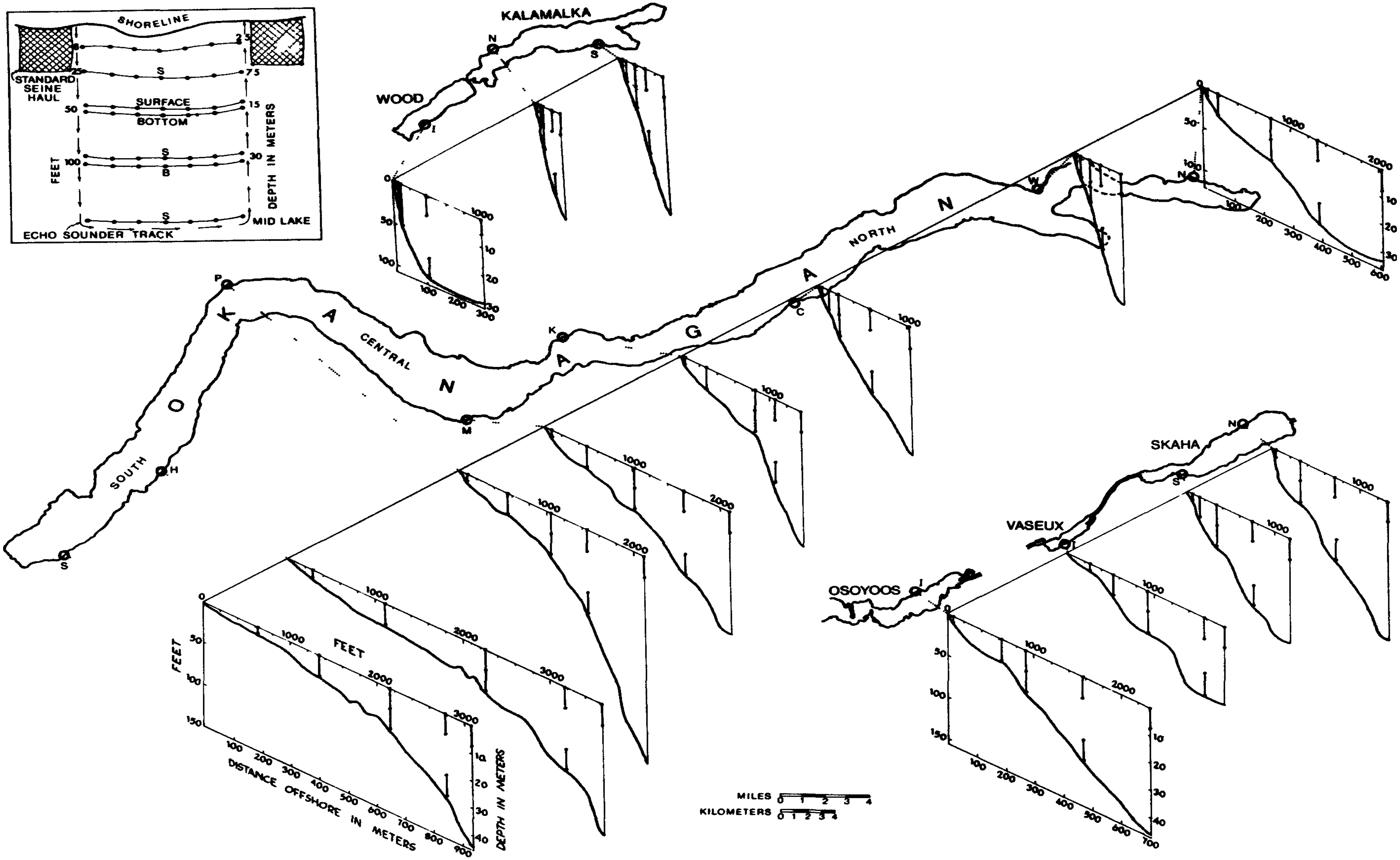
METHODS

FISH SAMPLING

Lake Netting And Beach Seining

Standard netting stations were established on the study lakes (Fig. 1) early in April, 1971. For the smaller lakes, one or two stations were located near the deeper basins but for Okanagan they were spread out to cover the northwest arm (1 station), the northern area (2 stations),

Fig. 1. The Okanagan basin study lakes showing location and depth profiles for the standard netting



stations, as well as position of the gill nets (↨) set at regular depth intervals offshore. Inset shows typical plan view of gill nets, beach seine sites, and echo sounding track.

the central area (3 stations) and the southern area (2 stations). Despite the fact that an attempt was made to place stations over only moderately sloping bottom there was wide variation in bottom profile between stations (Fig. 1). Often other considerations (marinas, swimming beaches, shipping and boating lanes, etc.) dictated station location.

At each station a standard series of gill net sets were made (Fig. 1). All gangs were set approximately parallel to shore, following the designated depth contours. At the 2.5 and 7.5 m (ca 8 and 25 ft) contours, nets of those respective depths were set, at the 15 m contour (ca 50 ft) surface and bottom gangs each 7.5 m deep fished the whole depth zone. At the 30 m contour (ca 100 ft) floating and bottom gangs each 7.5 m deep, left a 15 m midwater stratum unfished. Further offshore a 7.5 m 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 m (50 ft) 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 more scales for some species, to obtain additional samples for pesticide or heavy metal analysis or for other purposes.

An echo sounder tracing was usually made around the whole netting area (Fig. 1) in the evening after the nets were set and again in the morning before they were lifted. A 50 Kc/sec Furuno F701 sounder was used at gain 6 to make all tracings. In conjunction with each standard netting station (spring and autumn only), one or two beach hauls were made in late evening with a 32 m seine. The seine had a central panel of 6 mm stretched mesh 6 m in length and depth joined at each end by a 2.4 m length (6 m deep) of 12 mm stretched mesh and a 10 m "wing" section of 25 mm mesh which tapered to 0.9 m 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 on a Mettler P3 balance (9 kg + 2 kg tare). Exceptionally large or long fish were weighed on a Swiss spring scale (Oskar L•di Co., "Pesola"). 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 (Appendix 1) as well as from a few other species (lake trout, kokanee).

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 (Mettler K7 T balance) and scale sampled (where feasible) 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 present 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 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, 1257 from 1935; 2,406 from 1948; 755 from 1949 to 1970, and 18,870 from 1971.

KOKANEE SPAWNER ENUMERATION

Stream Spawners

Of 26 streams inspected in autumn, 1971 only 9 supported more than 500 spawning kokanee and the runs in these streams were subsequently enumerated. Additional streams have provided kokanee spawning habitat in other years when sufficient water has been available.

In Mission Creek the kokanee were counted through a fish fence across the stream 1.2 km upstream from the lake. In the Okanagan River between Okanagan and Skaha lakes kokanee were counted from a helicopter. In all other streams, estimates of kokanee were made visually (using Polaroid sun glasses) while walking the length of stream used by spawners.

These counts were made about weekly until numbers decreased on two consecutive counts. An average of 6 counts were made over the spawning period on each stream (Appendix 3).

A measure of the residence time of spawners in the creek was made by tagging newly-arrived fish and recording the time that they died after spawning. This was done in Peachland Creek only and the average residence time (12.6 days) used for estimating total spawner population in all streams. The numbers of fish for each day were summed, the number of "fish-days" computed and then divided by the residence time to obtain an estimate of the total number of spawners (Method 1). This method was checked by comparing it with a technique (Method 2) developed by the International Pacific Salmon Commission (Goodman, MS 1965). Estimates in Okanagan River at Penticton and Equesis Creek (Fig. 15) were made using this technique.

In addition to estimated spawner population, fork length, weight, and fecundity were determined on samples from each spawning population (Appendix 4).

Shore Spawners

Visual estimates of numbers in several spawning groups were made from vantage points on cliffs bordering spawning sites. One group was then captured by beach seine and a count made of individuals. Several spawning sites were then marked with one square meter areas that were readily visible from the air. The shoreline of all basin lakes was inspected from the air for the presence of shore-spawning kokanee on October 28, 1971. Some spawning groups were recorded on 35 mm film from an altitude of about 30 meters; the number in each group and the area covered by it was visually estimated using the one meter-square areas as reference points. Location of sites was recorded on maps. An estimate was made of the total shore spawning population by multiplying the total spawning area by the spawner density estimate as outlined above.

About 25 males and 25 females taken from one spawning group were tagged with spaghetti-type tags to determine residence time of individual fish on the spawning site. At about 5 sites, the type of substrate, distribution of spawning groups and spawning behavior and egg deposition were briefly investigated by the use of SCUBA. A small sample of kokanee was taken for determination of size, weight and fecundity.

PESTICIDE AND HEAVY METAL ANALYSES

Sampling Procedure

Analyses of 284 samples was planned using pooled samples of 10

individuals of selected sizes, rather than single fish. Fish were taken from a sample of gill netted fish taken from the regular net catches and some additional nettings.

A pooled sample was made up of 10 one-ounce sections taken from the epaxial musculature of 10 individual fish. The samples of flesh including skin and adipose tissue were preserved in ethyl alcohol in glass bottles with aluminum foil under plastic lids; samples analyzed for organphosphates were preserved in alcohol and kept at about 0°C.

Analytical Methods

Analyses were conducted by the Pesticide Laboratory, B. C.

Department of Agriculture. Difficulty was experienced with the analysis of cadmium copper and zinc particularly, in the first 30 samples (indicated in Table 9 by an asterisk). It was decided that the temperature at which these samples were ashed was too high. Subsequent samples were treated as outlined in Appendix 2. Nonetheless, in the first 30 samples analyzed, cadmium was detected, copper undetected and the highest zinc concentrations recorded. In all subsequent samples (same species from same lakes), cadmium was undetected, copper detected and zinc, where detected, was generally in lower concentrations.

RESULTS

ATTRIBUTES OF FISH POPULATIONS

Species Composition

A total of 26 species of fish (kokanee and sockeye salmon counted separately) were taken during the 1971 sampling program on the Okanagan basin lakes (Table 1). Several other species are known to occur in the system, but were not found in our survey. These include the bridgelip sucker (*Catostomus columbianus*) which is recorded from Osoyoos Lake (and may have been confounded with the longnose sucker in our records), tench (*Tinca tinca*) also from Osoyoos Lake, and lake chub (*Couesius plumbeus*) from Okanagan Lake. Other species possibly present but without definite record of occurrence include the white sturgeon (*Acipenser transroontanus*), brook trout (*Salvelinus fontinalis*) and coho salmon (*Oncorhynchus kisutch*).

At least 9 of the 26 species were caught in all of the lakes sampled

(Table 1), namely mountain whitefish, rainbow trout, kokanee, largescale sucker, carp, squawfish, peamouth chub, chiselmouth and prickly sculpin. Lake whitefish, which were introduced to the system in 1894, were not taken during 1971 in Wood or Kalamalka lakes, nor were any caught there by netting in 1929 or 1935 (Clemens et al. 1939). Only two pygmy whitefish were taken, one from Skaha and one from Osoyoos Lake. This species had not been recorded previously from the Okanagan system. Lake trout caught in Kalamalka came from 1500 hatchery reared stock (Riding Mountain Park, Manitoba via Jasper Hatchery). They were nearly 3 years of age when introduced to the lake in October, 1970. Three juvenile chinook salmon were caught in Osoyoos Lake, as well as four adult sockeye salmon. Representatives of the catfish, perch, bass and sunfish families were confined to the lower two lakes in the system except for pumpkinseed which were found in Skaha as well. Pumpkinseed were not taken in Skaha during extensive summer collections in 1948. Smallmouth bass have not been recorded before from the system. Burbot were frequently caught in Okanagan and Skaha but never in the other lakes. The slimy sculpin, seined from Kalamalka and Okanagan lakes, had not been recorded previously in the drainage.

Relative Abundance

1. Within-lake comparisons, 1971

Comparisons of relative abundance are possible between the two stations in Kalamalka and in Skaha as well as between the eight Okanagan Lake stations (Table 2). At Kalamalka, the south station consistently showed larger catches than did the north for each of the seasons and for most of the species, especially peamouth chub. Chi-square analyses showed

Table 1. Species[1] of fish taken from Okanagan basin lakes at designated stations[2] during the 1971 survey

FAMILY	COMMON NAME	SCIENTIFIC NAME	WOOD I	KALAMALKA S	KALAMALKA N	KALAMALKA Σ	OKANAGAN N	OKANAGAN W	OKANAGAN C	OKANAGAN K	OKANAGAN M	OKANAGAN P	OKANAGAN H	OKANAGAN S	OKANAGAN Σ	SKAHA N	SKAHA S	SKAHA Σ	VASEUX	OSOYOOS
Whitefishes (Coregonidae)	**Mountain Whitefish**	*Prosopium williamsoni*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Pygmy Whitefish	*Prosopium coulteri*															✓	✓		✓
	Lake Whitefish	*Coregonus clupeaformis*					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Trout and Salmon (Salmonidae)	**Lake Trout**	*Salvelinus namaycush*		✓	✓	✓														
	Rainbow Trout	*Salmo gairdneri*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Chinook Salmon	*Oncorhynchus tshawytscha*																		✓
	Sockeye Salmon	*Oncorhynchus nerka*																		✓
	Kokanee	*Oncorhynchus nerka*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Suckers (Catostomidae)	**Largescale Sucker**	*Catostomus macrocheilus*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Longnose Sucker	*Catostomus catostomus*			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Minnows (Cyprinidae)	**Carp**	*Cyprinus carpio*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Redside Shiner	*Richardsonius balteatus*	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓	
	Northern Squawfish	*Ptychocheilus oregonensis*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Peamouth Chub	*Mylocheilus caurinus*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Chiselmouth	*Acrocheilus alutaceus*	✓	✓		✓	✓	✓	✓						✓	✓	✓	✓	✓	✓
	Leopard Dace	*Rhinichthys falcatus*							✓						✓					
	Longnose Dace	*Rhinichthys cataractae*			✓	✓														
Catfishes (Ictaluridae)	**Black Bullhead**	*Ictalurus melas*																	✓	✓
Codfishes (Gadidae)	**Burbot**	*Lota lota*					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Perches (Percidae)	**Yellow Perch**	*Perca fluviatilis*																	✓	✓
Basses and Sunfishes (Centrarchidae)	**Smallmouth Bass**	*Micropterus dolomieui*																		✓
	Largemouth Bass	*Micropterus salmoides*																		✓
	Pumpkinseed	*Lepomis gibbosus*														✓		✓	✓	✓
	Black Crappie	*Pomoxis nigromaculatus*																		✓
Sculpins (Cottidae)	**Prickly Sculpin**	*Cottus asper*	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Slimy Sculpin	*Cottus cognatus*		✓	✓	✓		✓	✓			✓			✓					
TOTAL	26	26	10	12	13	14	12	14	15	12	10	12	11	12	15	14	14	15	15	20

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

[2] see Figure 1 for name and location

Table 2. Number of fish taken in combined spring, summer and autumn (standard) net sets at designated stations in Kalamalka, Okanagan and Skaha lakes.

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

that the differences in relative abundance of species were highly significant ($p < 0.001$).

Although the north Okanagan station had the highest total catch, this was chiefly a result of large kokanee catches in the autumn and of lake whitefish throughout the netting period. Centre, Kelowna and Peachland stations were among the lowest in total catch. Indeed had not the latter station shown an especially large kokanee catch in the autumn (probably a result of its location near the mouth of a kokanee spawning stream), it would have exhibited the lowest total catch. After excluding kokanee and peamouth chub (schooling species probably not caught in gill nets as independent individuals), a series of chi-square and F tests (by chi-square rations; $p = 0.05$) were run on the Okanagan Lake stations to determine appropriate within-lake groupings. Relative abundance of species in catches at Whiteman and Centre were not significantly different but together were so when compared with North or Peachland. Catches combined for Kelowna and Mission did not differ significantly in relative abundance from those at Peachland, whereas those at Hatchery and South did when compared either to Peachland or to Kelowna. Catches of rainbow trout, mountain whitefish and lake whitefish were generally higher in the southern stations than those in central or northern regions of Okanagan Lake. Thus combinations of northern (N, W, C), central (K, M, P) and southern (H, S) stations would seem reasonable.

Although there were not large differences in total catch between north and south Skaha Lake stations, those for rainbow trout, largescale suckers and squawfish were higher in the north while the reverse was evident for mountain whitefish and lake whitefish. Relative abundance of species (with or without kokanee and peamouth chub) was significantly different ($p < 0.001$) between the two stations.

2. Between-lake comparisons, 1971

There were marked differences between the lakes in the total number of fish caught in the standard net sets (Fig. 2). The lowest total catch was from Wood Lake, followed by that at the south Kalamalka station. Those at Kalamalka north as well as Okanagan C and K were only slightly higher, while the highest catches in Okanagan itself came from the northern and southern ends. Catches at both Skaha stations, the highest in the system except for Vaseux, were nearly double those for most Okanagan stations. Those at Osoyoos were lower than Skaha or Vaseux but higher than most from Okanagan Lake. Summer catches in general were much lower than those in spring or autumn. In some cases, notably some central Okanagan stations (M, P) autumn catches (dominated by mature kokanee) far exceeded those in spring and summer combined.

An independent measure of total fish abundance may be inferred from echo sounder tracings (Fig. 3). These tracings show numerous inverted V marks, most of which probably represent individual fish (Northcote et al., 1964). Counts of such marks (Fig. 4) again show the Wood Lake station to be the lowest, followed by those on Kalamalka. As previously indicated by netting, the highest abundance of "fish" (marks) on Okanagan Lake occur near its north and south ends. Surprisingly, the echo soundings did not

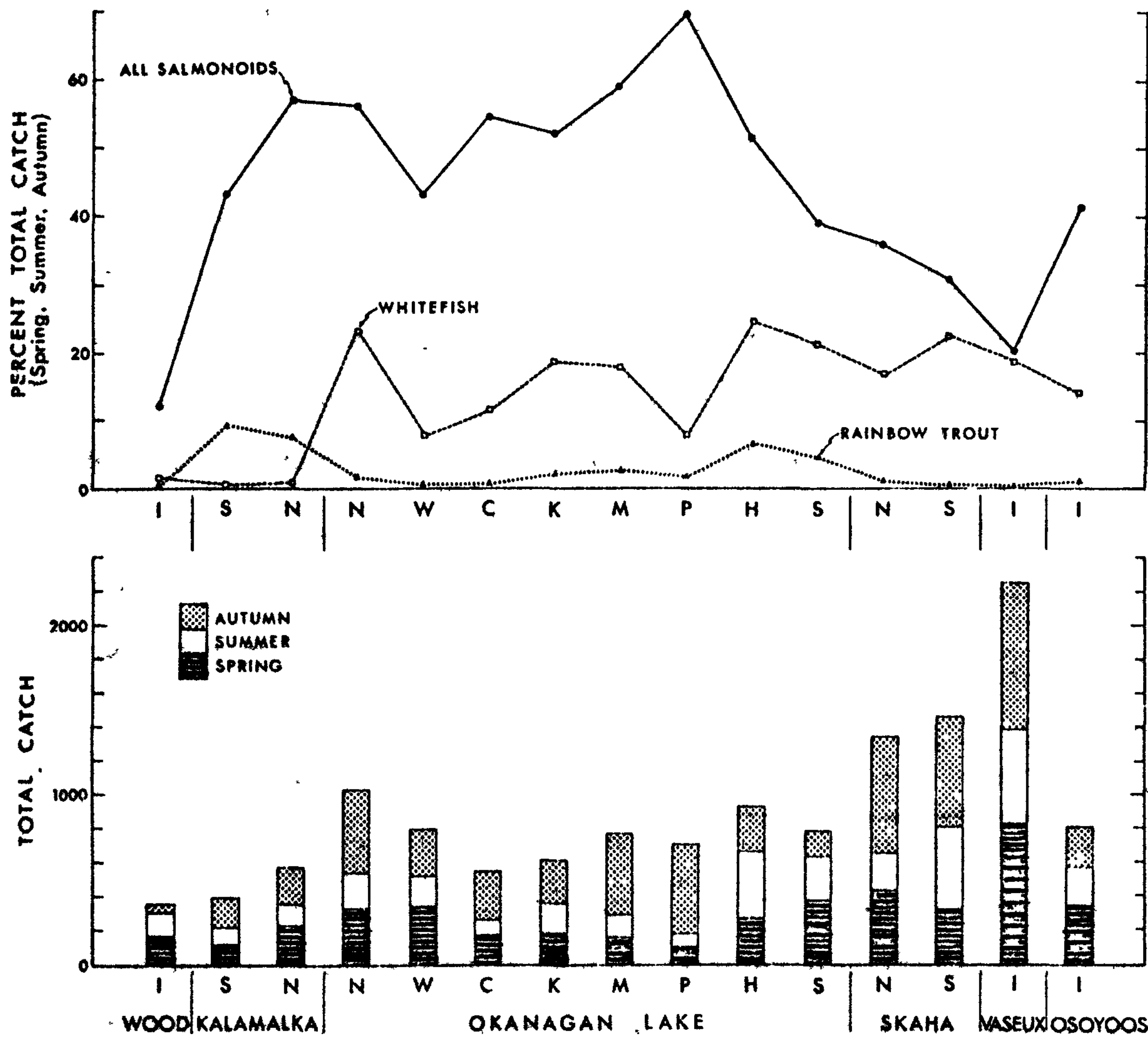


Fig. 2. Catch of fish in standard net sets at designated stations in Okanagan basin lakes, 1971. The histogram shows total and seasonal catch of all species; upper graph shows percent catch of selected groups (salmonoids = Salmonidae + Coregonidae; whitefish = mountain + lake + pygmy).

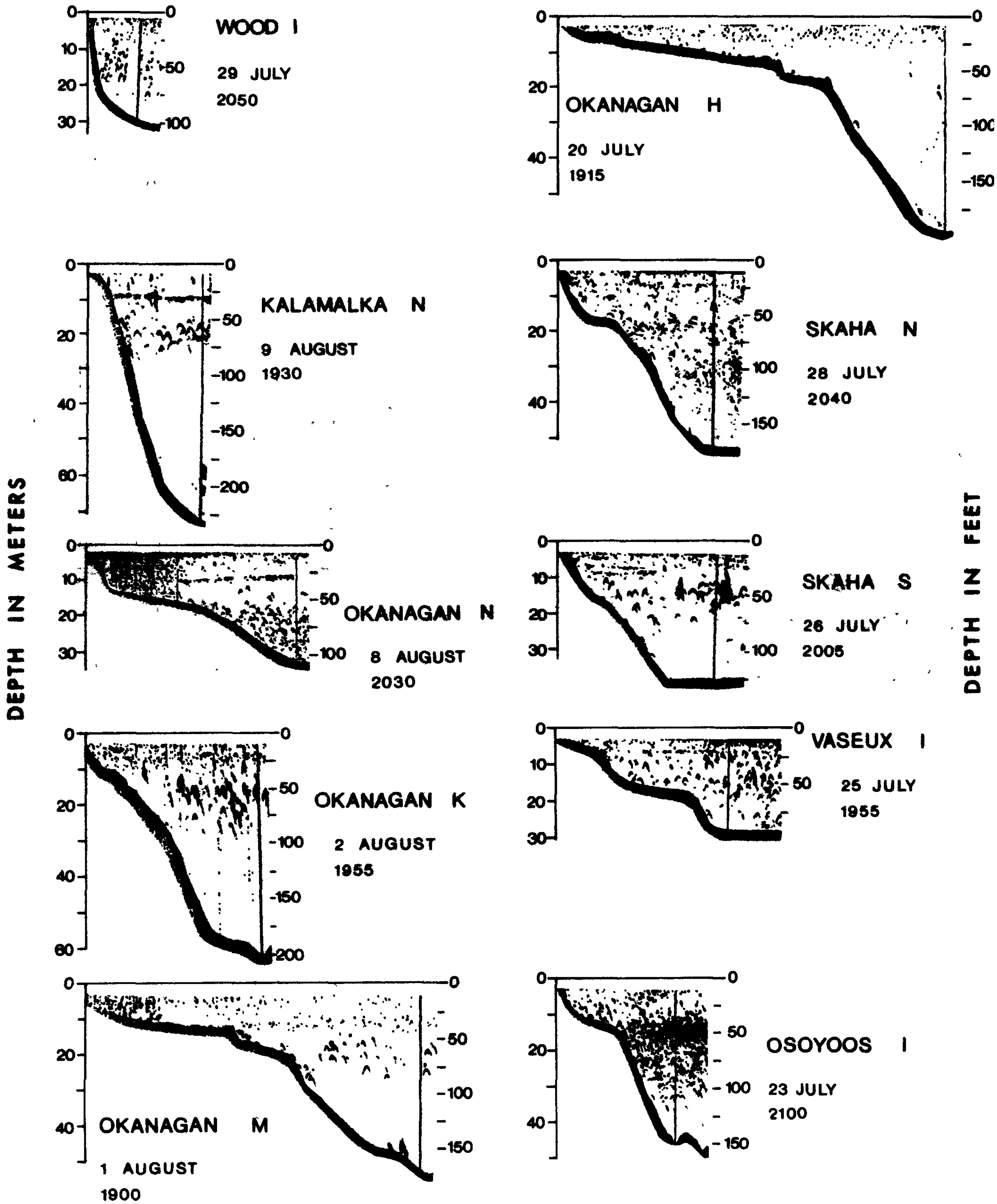


Fig. 3. Evening echo sounder traces at designated stations in the Okanagan basin lakes in summer, 1971. Time (Pacific Standard) tracing started shown below date; vertical line near offshore end indicates outer limit of netting station, depths in feet given at right of tracing; upper 3 meters not recorded by sounder.

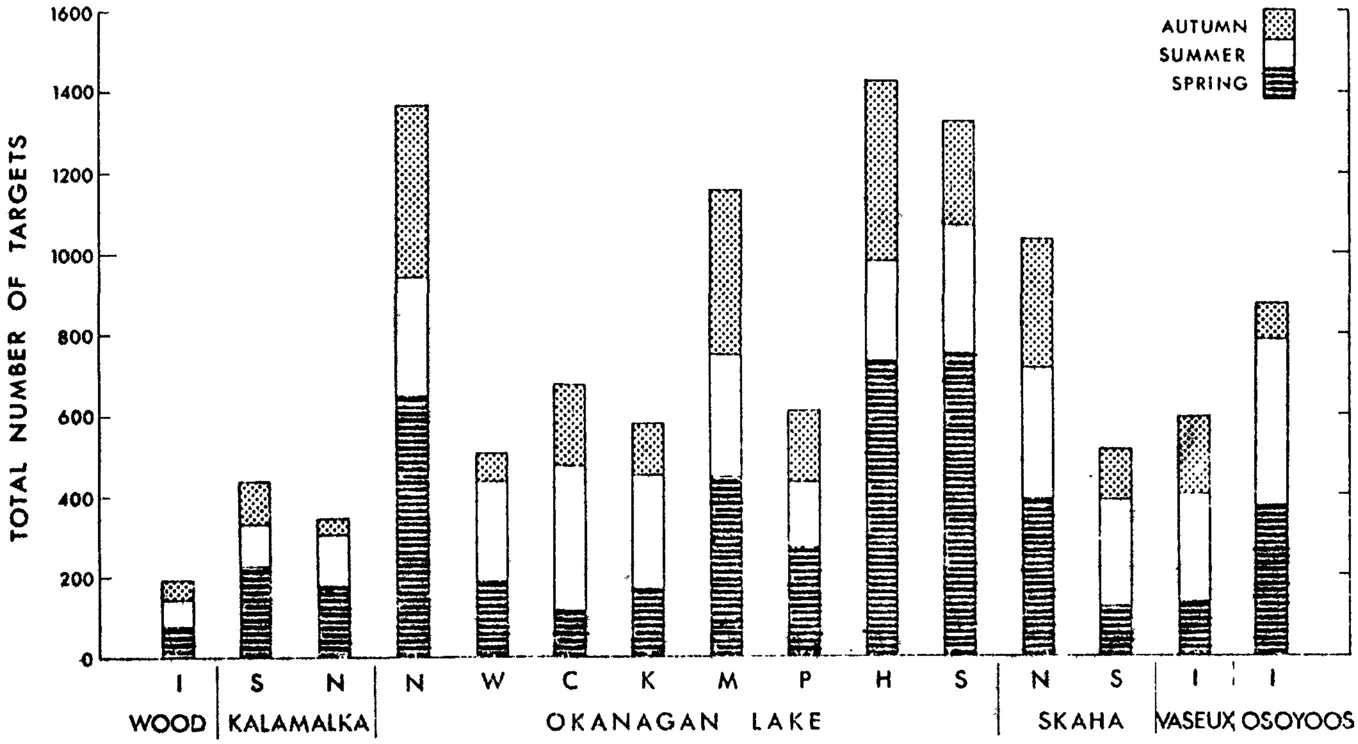


Fig. 4. Number of "targets" (fish marks) counted on evening echo sounder profiles at designated stations in Okanagan basin lakes, 1971.

record particularly large numbers of fish in either Skaha or Vaseux lakes. Peamouth chub, which are especially numerous in the latter lake and which migrate into near-surface layers in the evening (Northcote et al., 1964) in some lakes, may not have been recorded by the sounder.

The relative abundance of salmonoids (as opposed to "coarse fish" - largely catostomids and cyprinids) taken by netting in the basin lakes is given in Fig. 2. Lowest percentages of salmonoids were taken in Wood and Vaseux lakes (about 12 and 19 percent, respectively). In Kalamalka and in all Okanagan stations except at the south end, salmonoids made up well over 40 percent of the total catch and usually over half of it. Their contribution dropped to about a third in Skaha, but rose again to 40 percent in Osoyoos, largely a result of sizable kokanee catches there.

Whitefish were scarce in catches from Wood or Kalamalka lakes (Fig. 2) but in the other lakes ranged between 8 and 25 percent of the total. Rainbow trout contributed significantly to the catch at both Kalamalka stations and as well to stations H and S at the southern end of Okanagan; elsewhere they usually made up less than 2 percent of the total.

Three species of salmonoids (rainbow trout, kokanee, mountain whitefish) and four of "coarse fish" were common to gill net catches from the major basin lakes (Fig. 5). Highest and second highest total catches of salmonoids invariably were taken in either Okanagan or Kalamalka lakes whereas those for coarse fish always came from Skaha, Vaseux or Osoyoos lakes. This trend generally applied to catches from each of the three seasons considered separately (Fig. 5).

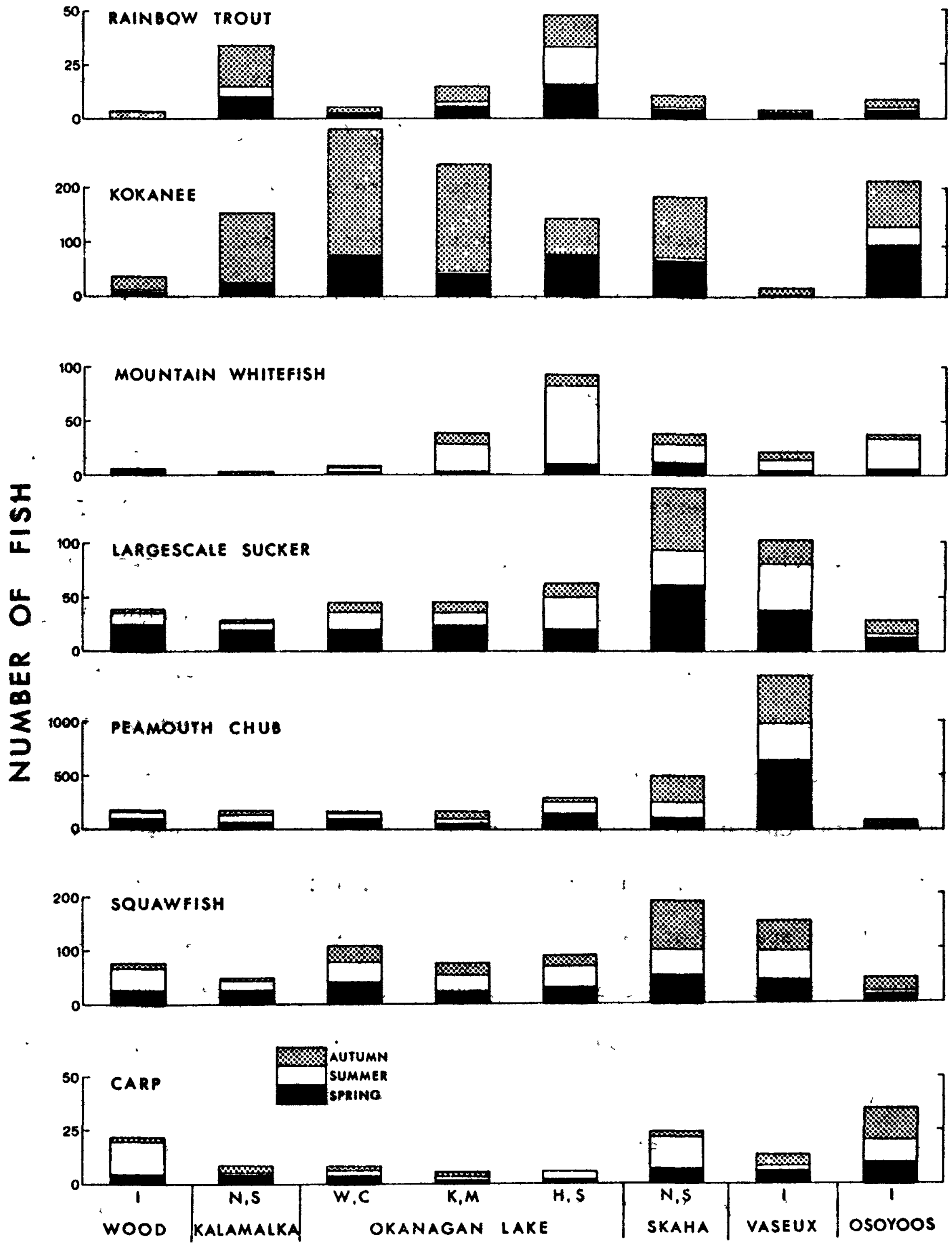


Fig. 5. Catch in standard gill net sets at designated stations (averaged for combinations shown) of seven species of fish common to the Okanagan basin lakes, 1971.

Lack of replication restricted opportunities to statistically compare differences in relative abundance of species between the basin lakes. An appropriate test was determination of F from the ratio of chi-square values calculated between lakes and within lakes (Table 3). Differences in relative abundance of species within the two stations for Kalamalka and Skaha were large so that rarely could a statistically significant difference be demonstrated between these stations and those for other lakes. Okanagan Lake northern (W, C), central (K, M) and southern (H, S) stations all showed significant differences in relative abundance when compared with Skaha, Vaseux and Osoyoos stations. Inspection of the contingency tables showed that larger catches of coarse fish species relative to salmonoids in the latter lakes probably accounted for most of the differences.

3. 1948 to 1971 comparisons

(a) Skaha Lake

Comparisons of species relative abundance between the 1971 netting program and data collected by Ferguson (MS 1949) from Skaha Lake in the summer of 1948 can be made, but not without considerable adjustment for differences in amount of net used, in depth distribution of the sets, and in type of net webbing (cotton in 1948; monofilament nylon in 1971). Approximately the same sequence of mesh sizes were fished in 1948 and 1971 but different depths and lengths of net were used. The catch data from 1948 was appropriately weighted to allow for differences in area of net fished. Then for comparison with 1948 data, the most similar combination of depth intervals from 1971 were selected and only catches from those sets

Table 3. Differences[1] in relative abundance of species caught in standard net sets in Okanagan basin lakes, 1971

LAKE & STATION		KL N-S	OK W-C	OK K-M	OK H-S	SK N-S
Wood	I	N.S.	N.S.	N.S.	N.S.	N.S.
Kalamalka	S	-	N.S.	N.S.	N.S.	N.S.
	N	-	N.S.	N.S.	N.S.	N.S.
Okanagan	N	N.S.	N.S.	N.S.	**	N.S.
	W	N.S.	-	N.S.	*	N.S.
	C	N.S.	-	N.S.	*	N.S.
	K	N.S.	N.S.	-	N.S.	N.S.
	M	N.S.	N.S.	-	N.S.	N.S.
	P	N.S.	N.S.	*	*	*
	H	N.S.	*	N.S.	-	N.S.
	S	N.S.	*	*	-	N.S.
Skaha	N	N.S.	N.S.	N.S.	*	-
	S	N.S.	**	**	*	-
Vaseux	I	*	**	**	**	N.S.
Osoyoos	I	N.S.	**	**	**	N.S.

[1]N.S. = not significant, $p > 0.05$; * = significant @ $p < 0.05$; ** = significant @ $p < 0.01$.

considered. Finally to adjust for differences in efficiency between monofilament nylon and cotton webbing, the 1948 catches were quadrupled. Molin (1953) gives data comparing catches in monofilament nylon nets similar to those used in the 1971 Okanagan study with cotton nets. For several Swedish lakes he showed that monofilament nylon nets usually took more than 7 times the total catch of cotton nets, and 3.7 times more for the three lakes roughly similar to Okanagan basin lakes in species composition and other characteristics.

From the series of netting data available for 1948 (Ferguson, MS 1949) the two sets were selected which most nearly approximated those made at the north and south stations in summer, 1971. Then the 1948 catches were appropriately adjusted for differences in net area and efficiency as outlined above, and compared with the 1971 data (Table 4). Chi-square tests show the difference between years (1948 > 1971) to be highly significant ($p < 0.001$), although the data are sparse. Numbers of mountain whitefish appear much lower in 1971 than 1948 at both stations. Also, no carp were taken in any of the lake net sets (8 different series in all) during the summer of 1948, although one was netted from the Okanagan River nearby. Several were caught by lake netting in 1971. The combined catch for both stations was somewhat lower in 1971 than in 1948 (adjusted catches). Furthermore the contribution of salmonoids was considerably lower in 1971 compared to 1948 (4.6% vs. 14.8%, respectively).

4. 1935 to 1971 comparisons

(a) Wood and Okanagan lakes

Adjustments similar to those described above for 1948 netting

Table 4. Number of fish taken in standard summer net sets near designated stations in Skaha Lake, 1948 and 1971

SPECIES	NORTH 1948[1] 20 July	NORTH 1971 29 July	SOUTH 1948[2] 22 July	SOUTH 1971 27 July	LAKE (N & S) 1948	LAKE (N & S) 1971
Rainbow Trout		2				2
Mountain Whitefish	36	2	24	3	60	5
Lake Whitefish		1		7		8
Largescale Sucker	72	33	56	29	128	62
Longnose Sucker				3		3
Peamouth Chub	96	59	80	128	176	187
Squawfish	24	33	16	24	40	57
Carp		12		5		17
Chiselmouth		1				1
TOTAL	228	144	176	199	404	343

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

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

data from Skaha Lake were required for the 1935 data of Clemens et al., (1939) from Wood and Okanagan lakes (Table 5). There apparently were marked differences in relative abundance at Wood Lake between years (pooled chi-square significant @ $p < 0.001$), and even if adjustment factors are only approximately correct, the 1935 catch would still far exceed that in 1971. No carp were netted in the summer 1935 sets (although they were certainly in the lake then) but 12 were caught in 1971. However, comparisons are based on single sets with large adjustments required for 1935 data, so again the changes apparent cannot be taken as any more than suggestive. The contribution of salmonoids to total catch on each year was about the same (2.3 and 2.4% for 1935 and 1971 respectively.

Somewhat more reliable comparisons of relative abundance can be made between 1935 and 1971 for Okanagan Lake because more netting data are available for the former year. There is little difference in total catch (combined stations) between the two years (Table 5), although a pooled chi-square test showed relative abundance by species to be significantly different ($p < 0.001$). No carp were netted at any of the stations shown for 1935 (only one was caught in nets all that summer) whereas single summer sets in 1971 took carp at three of the four 1971 stations shown (Table 5). Otherwise little consistent difference is apparent in relative abundance between each of the stations for 1935 and 1971.

Length-Frequency Distribution

1. Within-lake comparisons, 1971

There was no significant differences ($p < 0.05$) between the two Kalamalka stations in average lengths of netted rainbow trout, mountain

Table 5. Number of fish taken in standard summer net sets near designated stations in Wood and Okanagan lakes, 1935 and 1971

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

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

whitefish, largescale suckers, carp, peamouth chub or squawfish. Kokanee and lake trout were the only species showing significant differences, those from the southern station being larger.

For the Okanagan Lake stations where numbers were adequate to permit comparisons (Fig. 6), there were no significant differences in average length of rainbow trout caught. Kokanee from southern stations (H, S) were significantly smaller than those from all other stations, whereas for mountain and lake whitefish, largescale suckers, peamouth chub and squawfish those from southern stations were significantly larger than those from most other localities sampled in Okanagan Lake.

For the two Skaha Lake stations no consistent pattern of differences in size emerged, some species (kokanee mountain whitefish, peamouth chub and squawfish) being significantly larger in the north, some (lake whitefish and carp) being significantly larger in the south, and others (rainbow trout and largescale sucker) showing no significant differences.

2. Between-lake comparisons, 1971

Differences in average length of 8 species captured by netting in the basin lakes (Fig. 6) were compared statistically; only some of these will be noted specifically. Rainbow trout caught in Kalamalka were significantly smaller than those from Okanagan stations (W, C, N, K, M, P, H, S) but not Skaha or Osoyoos. Kokanee from Wood and Kalamalka were significantly smaller than those from any of the other lakes in the system except Osoyoos. Those from Skaha were the largest in the system. The average length of mountain whitefish from Okanagan increased towards the south; those from

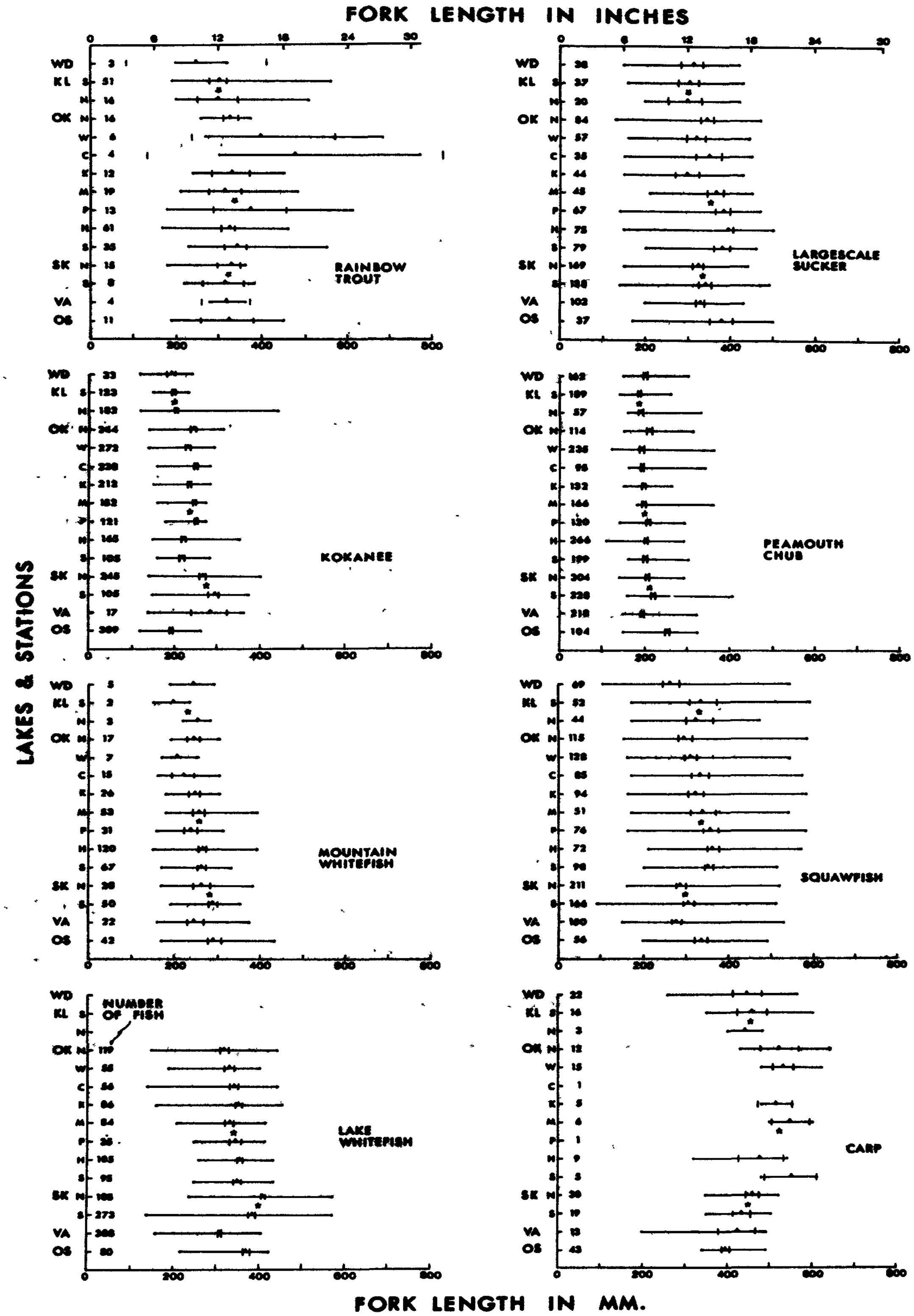


Fig. 6. Length characteristics (based on 10 mm class intervals) of fish taken at standard net sets from Okanagan basin lakes at designated stations (arranged from uppermost to lowermost in the drainage system), 1971. Symbols: •—• = range; • = average; |_| = 95% confidence intervals, where sample size (given at left) > 10; * = average length for lakes with 2 or more stations.

northern and central stations (N, W, C, K, P) were significantly smaller than southern Okanagan (H, S), Skaha or Osoyoos. Except for Vaseux, a distinct trend for increasing average length towards the south was evident in lake whitefish. Those from Skaha (N, S) were significantly larger than any other station, followed by Osoyoos.

The largest average lengths of largescale suckers were those from central - southern Okanagan (M, P, H, S) and Osoyoos, while the smallest were found in Okanagan (K), Kalamalka and Wood. Peamouth chub averaged the largest in Osoyoos Lake, followed by Skaha (S); the smallest came from Kalamalka (S). Changes in average lengths of squawfish within the system paralleled those for largescale sucker (Fig. 6); those from central - southern Okanagan and Osoyoos being the largest and those from Wood and Skaha the smallest. The largest carp (average length) were taken from Okanagan and the smallest from Osoyoos Lake.

3. Between-year comparisons

Both the average and maximum length of several species, netted from Skaha Lake increased between 1948 and 1971 (Fig. 7). Although very few kokanee were netted in 1948, many were taken by dynamiting. Even the largest of these did not attain the average length of the netted sample in 1971. Lake whitefish were much larger in 1971 as were large-scale suckers. Although other species (mountain whitefish, peamouth chub and squawfish) averaged slightly larger in 1971 compared to 1948, the differences were not significant ($p > 0.05$).

Small sample sizes (1935) prevented comparison of average

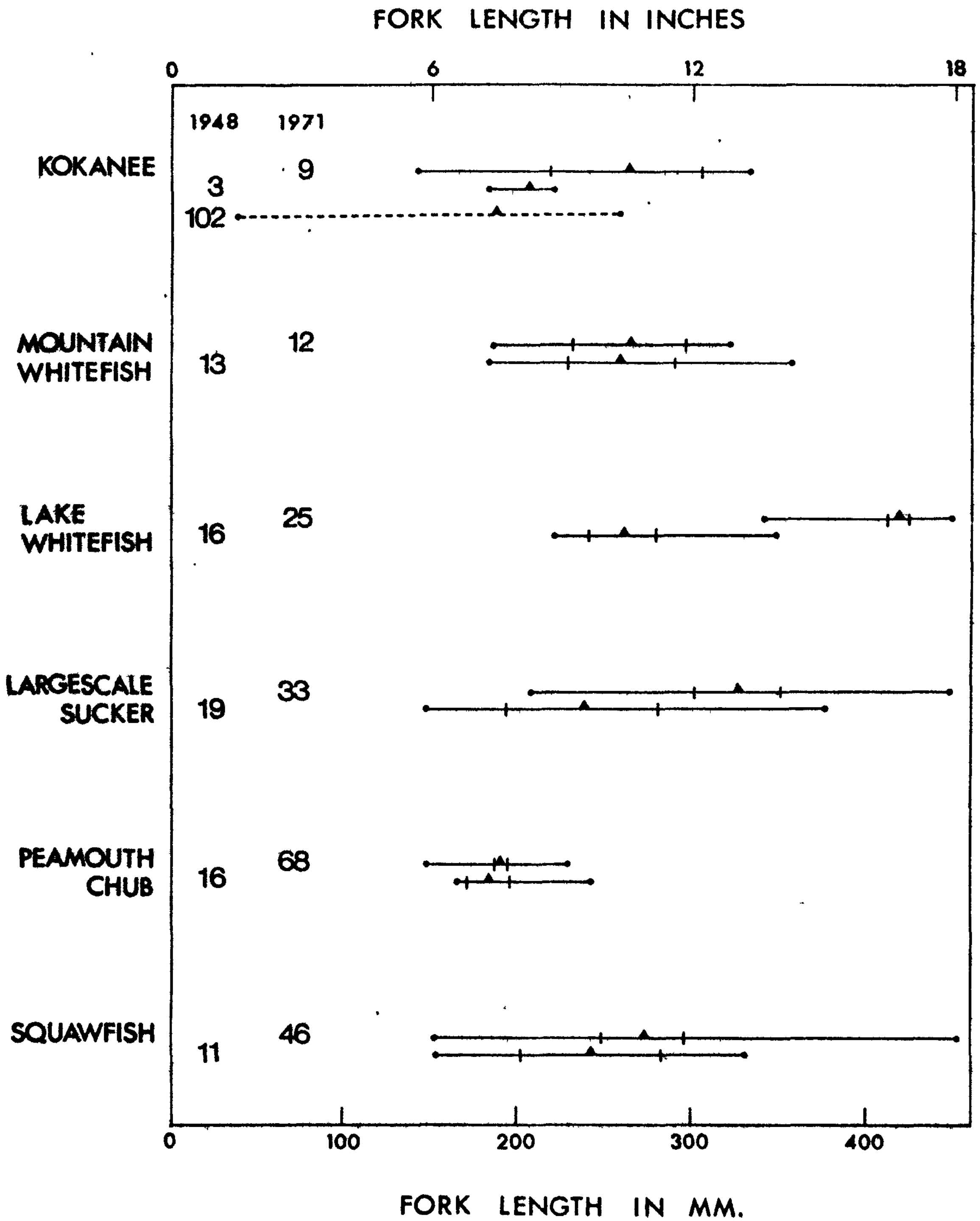


Fig. 7. Average (•) and range (•—•) in length of fish caught by standard net sets in Skaha Lake (Station N) in summer 1971 (upper) and 1948 (lower). Vertical marks on range line show 95% fiducial limits; sample size given at left; broken range line show statistics for 102 kokanee taken by dynamite blasting, summer 1948.

length of most species netted in standard sets from Wood or Okanagan lakesin 1935 and 1971. For peamouth chub (Fig. 8), a slight increase was indicated in the 1971 Okanagan sample.

Weight-Length Relationships

1. Within-lake comparisons, 1971

Weight-length regressions ($\log_{10}$ data) were compared for the salmonoids (kokanee, rainbow trout, mountain whitefish, lake whitefish) and coarse fish (largescale suckers, peamouth chub, squawfish, carp) at north and south stations in Kalamalka and Skaha lakes as well as for the 8 Okanagan Lake stations. Statistically significant differences ($p < 0.05$) in slope of the weight-length regressions were found only for rainbow trout (N > S) and peamouth chub (S > N) in Kalamalka Lake and for lake whitefish (S > N) and largescale suckers (S > N) in Skaha Lake. Within Okanagan the species showing the largest difference between stations was kokanee. Those from stations K and M, while themselves not significantly different were lighter in weight at the same length compared to the other 6 stations (i.e., they had a lower regression slope). Although two other species, mountain whitefish and squawfish, exhibited some significant differences in slope of weight-length regressions, these were often a result of comparing groups with widely disparate individuals.

2. Between-lake comparisons, 1971

Only 3 of the 4 salmonoids common to the lakes could be used for comparisons with Wood Lake because of the small number of rainbow trout taken there. In many (17 out of 27) of the comparisons with other lakes

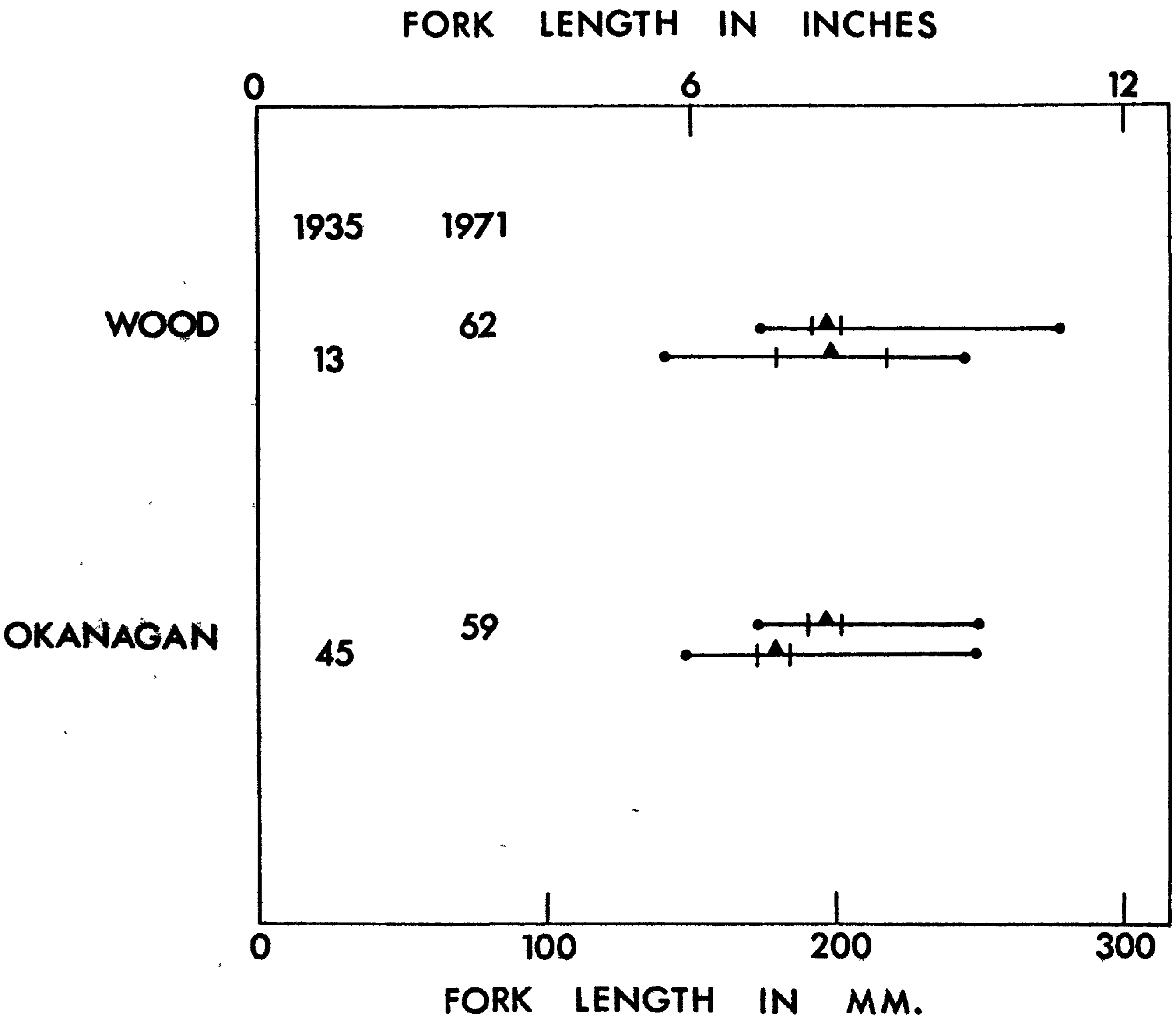


Fig. 8. Average (•) and range (•—•) in length of peamouth chub caught by standard gill net sets in Wood Lake and Okanagan Lake (Stations K, M) in summer, 1971 (upper) and 1935 (lower). Vertical marks on range line show 95% fiducial limits; sample size given at left.

where sample size was adequate, Wood Lake salmonoids and coarse fish either had a lower weight-length regression slope or were distinctly lighter in weight over most of the length range considered (i.e., showed negative displacement). In no case did Wood Lake fish show higher regression slopes or positive displacement compared with other lakes. Figure 9 shows a typical example of a lower regression slope for Wood Lake kokanee compared to those from Osoyoos Lake and of a negative displacement of the weight-length regression for Wood compared to Skaha Lake carp (1971). Weight-length regressions for Kalamalka fish were either lower than those in other lakes (by slope or displacement) or showed no significant difference as in that for squawfish in Figure 9. The only exception was shown in comparison between Kalamalka and Wood lake regressions where in 4 of the 6 cases Kalamalka had higher slope than Wood, and not significantly different in the remaining 2. Weight-length regression lines for Okanagan species were the same or higher than those for all lakes except Skaha. In most cases fish from Skaha had the highest weight-length regression slope or positive displacement; lake whitefish showed this most clearly (Fig. 9). Regressions for Vaseux fish tended to fall below those for Okanagan, Skaha and Osoyoos but were usually higher than Wood or Kalamalka. Those for Osoyoos followed the same trend as Okanagan but with more cases of little or no difference in slope or displacement.

3. Between-year comparisons

Weight-length regressions for Skaha kokanee, lake whitefish, (Fig. 9) peamouth chub and squawfish in 1971 showed significantly higher

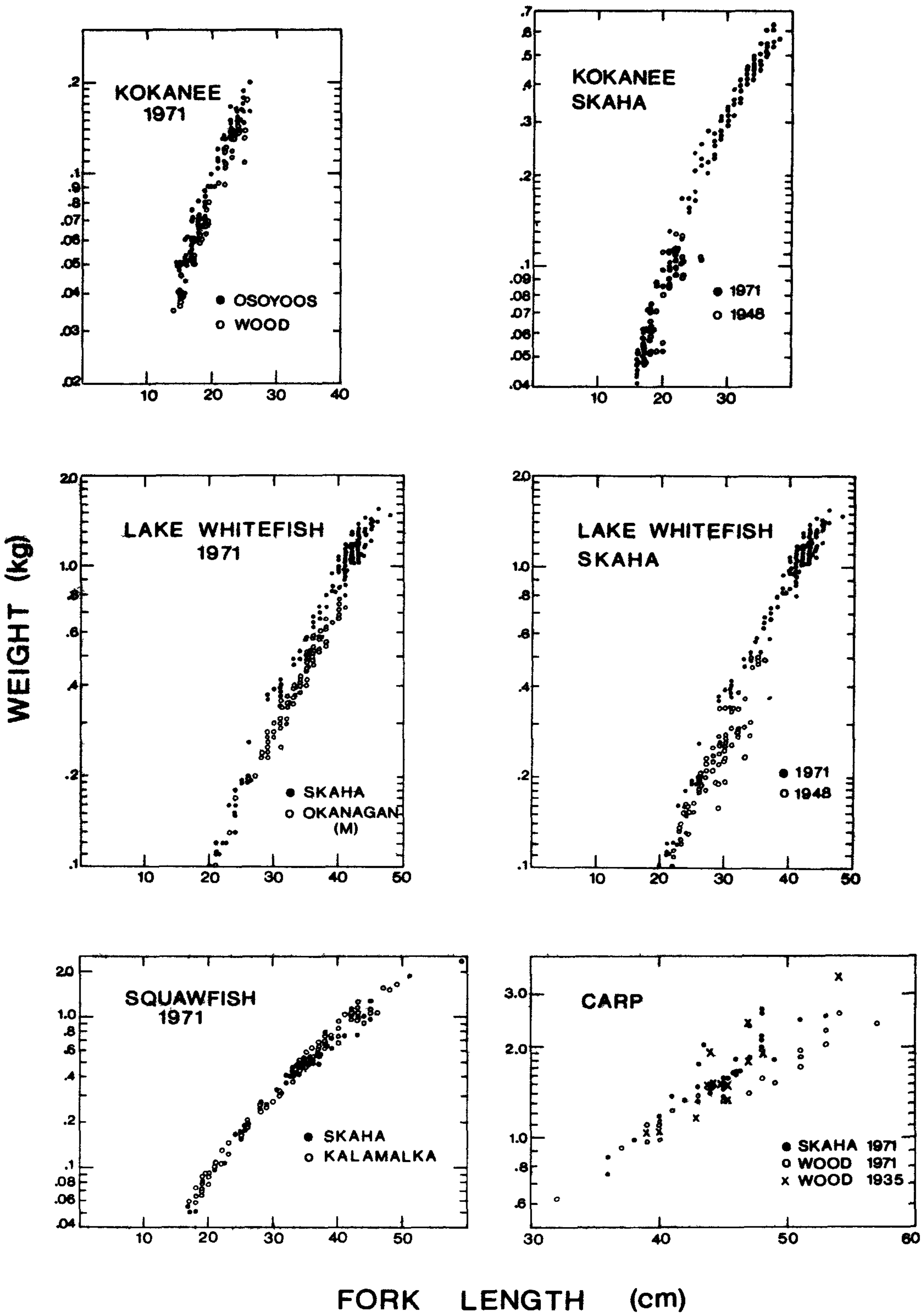


Fig. 9. Typical weight-length regressions for selected species of fish from the Okanagan basin lakes.

slopes or displacement than those in 1948. There was either no significant difference in other species or data were inadequate for comparisons (carp).

The weight-length data for Wood Lake carp in 1935 suggest that they then had a regression slope similar to that for Skaha in 1971 and not nearly as low as that shown by present day Wood Lake carp (Fig. 9). There has been no significant change in the weight-length regression for Okanagan rainbow trout between 1935 and 1971 (Fig. 10).

Age-Length Relationships

1. Within-lake comparisons, 1971

For Kalamalka Lake there were no significant differences between stations N and S in length for age groups where numbers were large enough to permit comparison (age 4, 4 rainbow trout; age 3, 4 kokanee). Okanagan data were grouped into 3 regions - north (stations N, W, C), central (stations K, M, P) and south (stations H, S). For several age groups of rainbow trout and mountain whitefish there was a trend towards increasing size from north to south in Okanagan Lake (Fig. 11). Differences in average size of age groups were significant for some of the trout comparisons (ages 2 and 5 between central and south areas) and most of those for mountain whitefish (ages 3 and 4 between north, central and south areas), In contrast, 3 year old kokanee were largest in the north area, especially those from stations N and C; central and south areas kokanee were not significantly different in size at age 3. There were no significant differences in size of various age groups of lake whitefish between the three regions of Okanagan Lake. Because of insufficient data no comparisons could be made between Skaha Lake stations N and S except for 2 year old

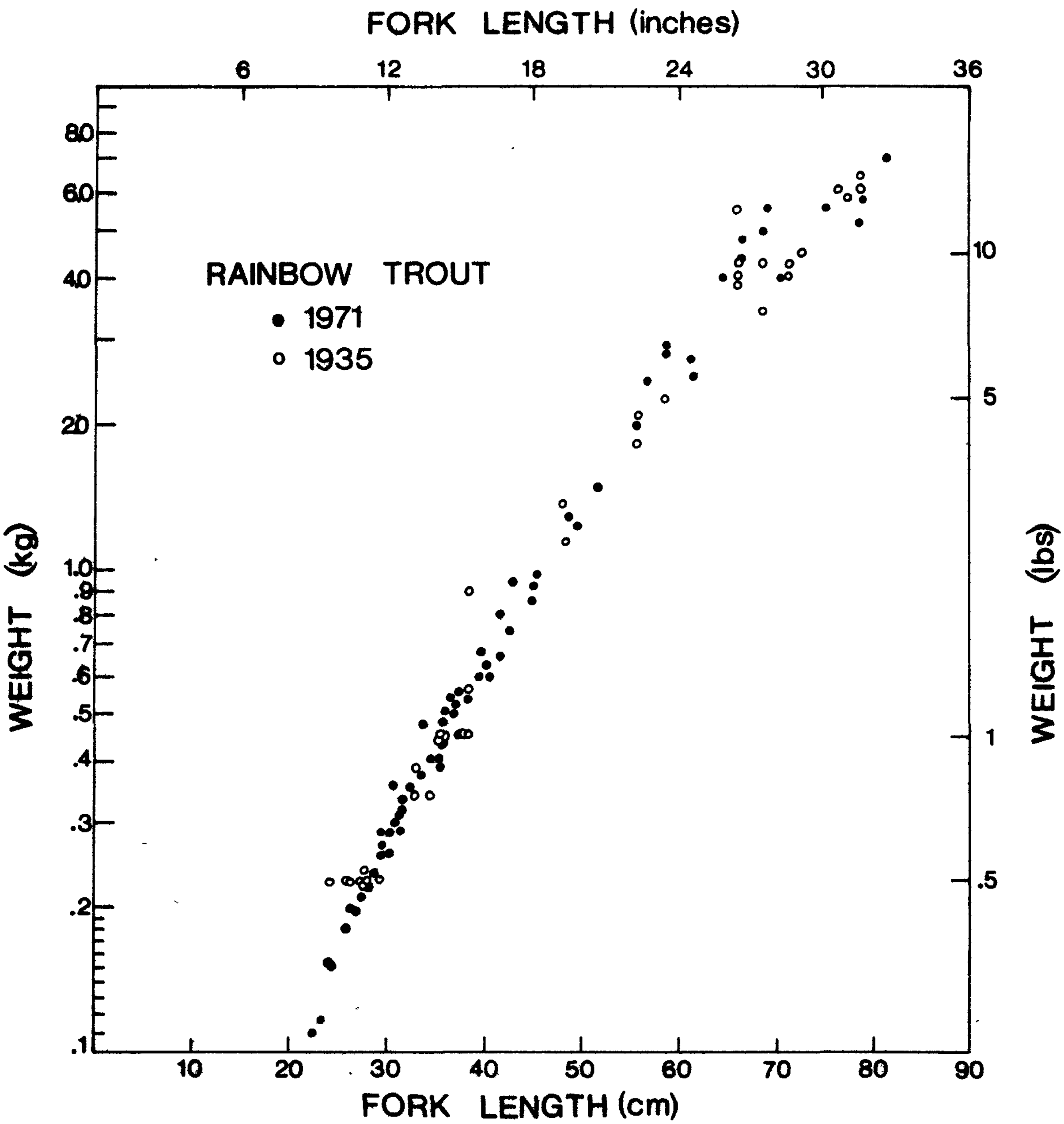


Fig. 10. Weight-length regression of Okanagan Lake rainbow trout.

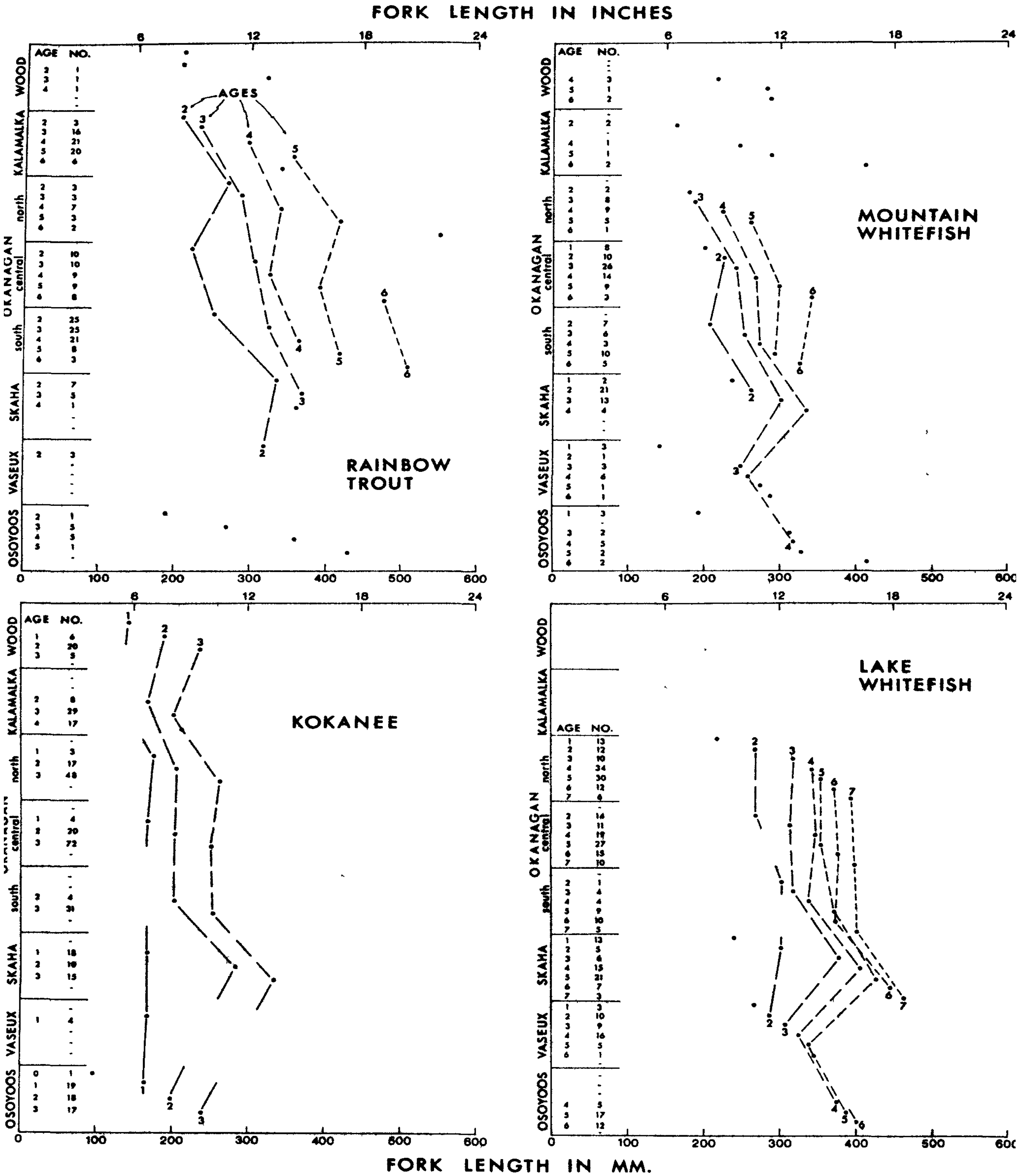


Fig. 11. Average size of different age groups of four Okanagan basin lake salmonoids in 1971. Sample size for age groups given at left; Okanagan north = Stations N + W + C; central = Stations K + M + P; south = Stations H + S.

kokanee; they showed no significant difference in average size.

2. Between-lake comparisons, 1971

Wherever sample size permitted, the average length of the various age groups shown for the species in Figure 11 were compared statistically between lakes or major lake areas (Okanagan). Most age groups of trout and whitefish showed an obvious trend for increasing size from north to south. Kalamalka trout (ages 3, 4, 5) were significantly smaller than those from north and central Okanagan combined or from south Okanagan. Age 2 and 3 mountain whitefish from Skaha were significantly larger than those from Okanagan Lake, as were all age groups of lake whitefish tested (ages 2-6). The average size of whitefish, especially lake whitefish, sharply decreased in Vaseux, compared to Skaha or Osoyoos lakes. Kokanee had the smallest average size in Kalamalka and the largest in Skaha for all age groups (1-3) where comparisons could be tested.

3. Between-year comparisons

All four Skaha Lake salmonoids showed significant increases in average length especially in older age groups between 1948 and 1971 (Fig. 12), despite small sample sizes on both years. Two year old mountain and lake whitefish in 1971 averaged nearly as large as their respective 4 year olds in 1948. No 3 or 4 year old kokanee caught in 1948 exceeded 240 mm in length whereas in 1971 none was less than 290 mm, and many were over 350 mm (some even at 2 years of age).

There has apparently been little change in the average length attained by the various age classes of Okanagan mountain whitefish, lake

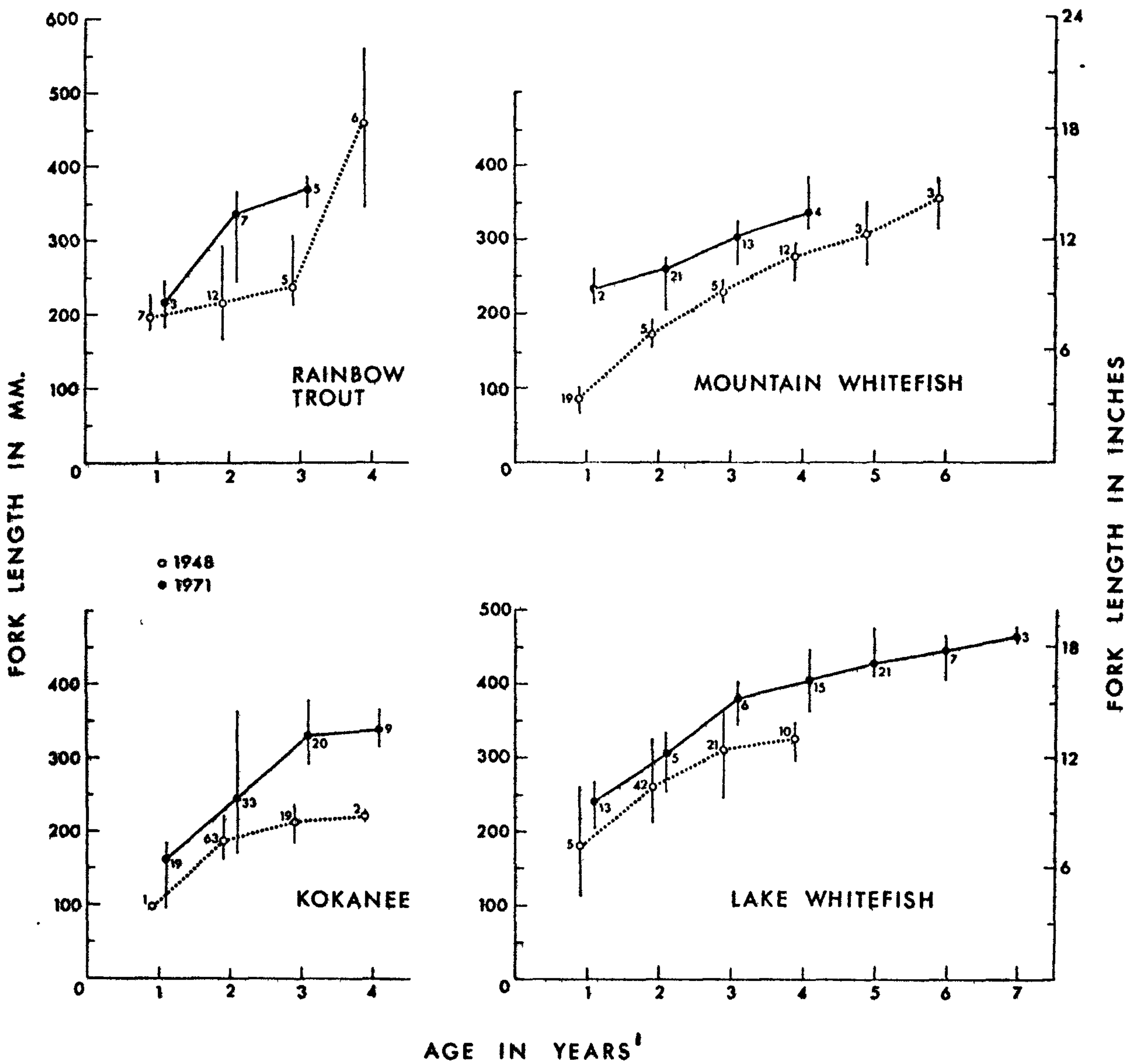


Fig. 12. Average and range (vertical lines) in length for designated age groups of Skaha Lake fish in 1948 (o) and 1971 (•). Sample size given near respective average. [1] refers to full years completed.

whitefish or even rainbow trout up to 3 years between 1935 and 1971 (Fig. 13). Older rainbow trout however are considerably smaller in 1971,and the sharp increase in length evident between 3 and 4 year olds in 1935, now appears to have been delayed at least 2-3 years. By lumping data from several years, slightly larger sample sizes are obtained for the early period and an intervening time period is obtained (Fig. 14). Again the same trend noted above between 1935 and 1971 data is shown. Interestingly, the sharp length increase for the 1946-55 period occurs between age 4 and 5, rather than a year earlier as in the 1935-45 period or a year later, as in 1971.

The average age of rainbow trout, kokanee and mountain whitefish caught in the netting program is highest in Kalamalka Lake (Table 6). For rainbow trout at least, this is in part related to the longer stream residence of Kalamalka fish, compared to others in the system such as Skaha (Table 7). Low average ages of the salmonoids are characteristic of Vaseux, Wood and to some extent, Skaha Lake.

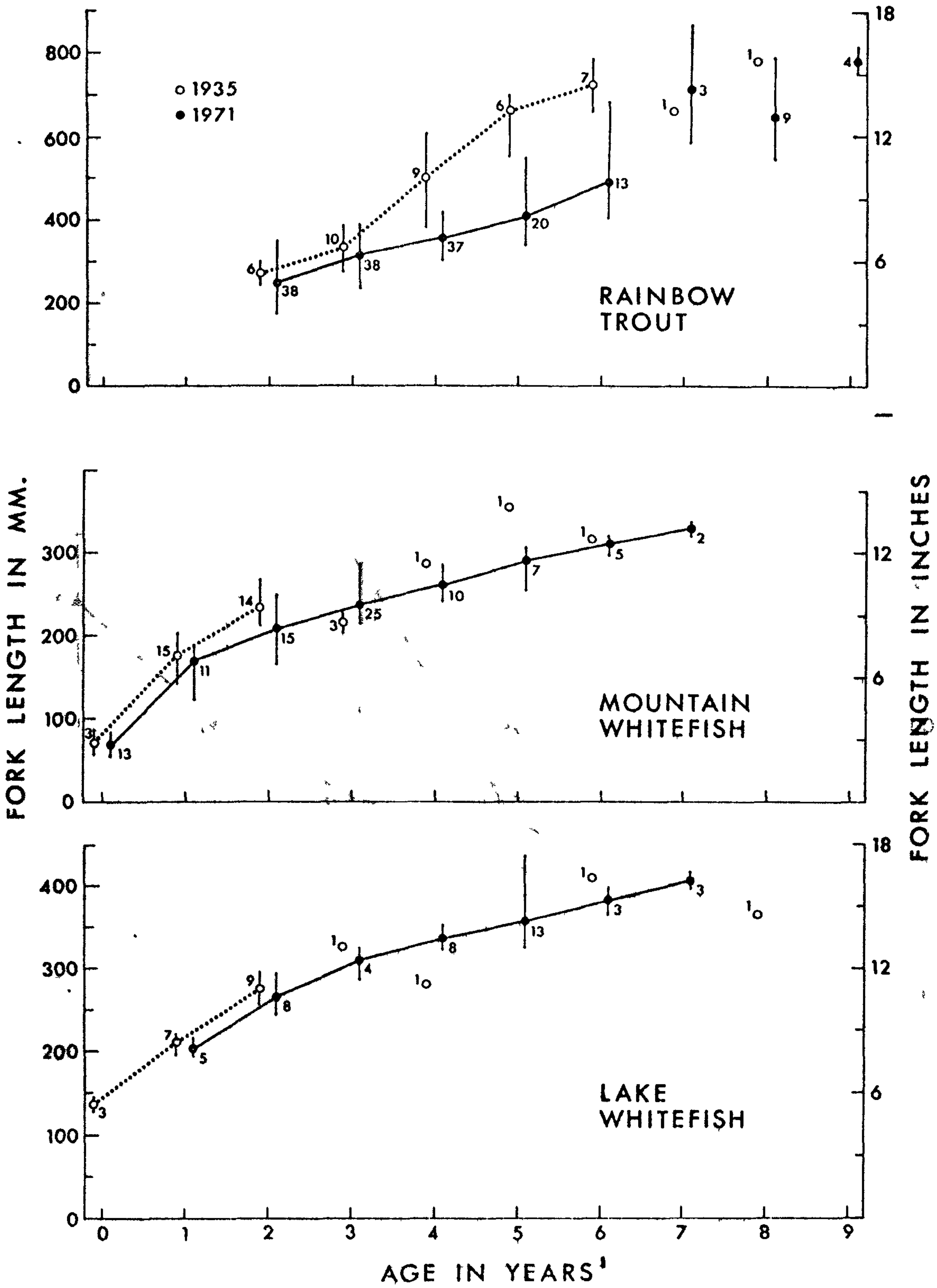


Fig. 13. Average and range (vertical lines) in length for designated age groups of Okanagan Lake fish in 1935 (o) and 1971 (•}. Sample size given near respective average. [1] refers to full years completed.

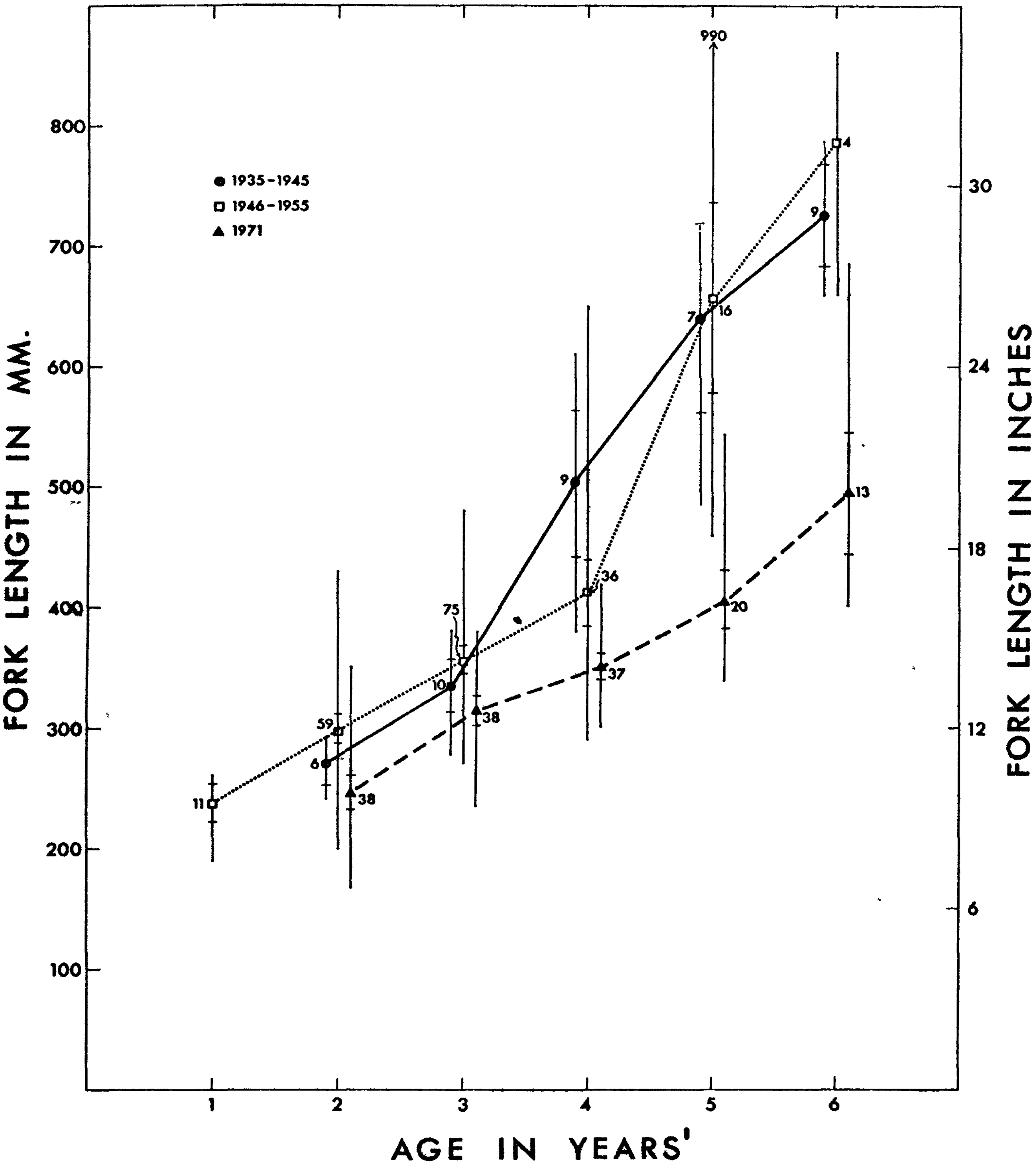


Fig. 14. Average and range (vertical lines) in length for the first six age groups of Okanagan Lake rainbow trout for three time periods. Sample size given near respective averages; 95% fiducial limits indicated on range lines. [1] refers to full years completed.

Table 6. Average age of four salmonoids caught in standard gill net sets in Okanagan basin lakes, spring autumn, 1971

LAKE	RAINBOW TROUT			KOKANEE			MOUNTAIN WHITEFISH			LAKE WHITEFISH		
	n[1]	$\bar{x}$[2]	r[3]	n	$\bar{x}$	r	n	$\bar{x}$	r	n	$\bar{x}$	r
Wood	3	2.0	1-3	41	2.2	1-4	3	3.3	1-5			
Kalamalka	67	4.3	2-8	73	3.2	2-4	5	4.6	1-6			
Okanagan	140	3.7	2-8	281	2.8	1-4	126	3.4	1-8	235	4.3	1-8
Skaha	15	2.2	1-4	74	2.2	1-4	22	2.7	2-4	73	3.8	1-7
Vaseux	4	1.7	1-2	5	1.0	1	13	3.8	2-6	48	3.3	1-6
Osoyoos	12	3.8	2-6	64	1.8	1-4	12	4.1	1-6	34	5.2	4-6

[1] number of fish

[2] average

[3] range

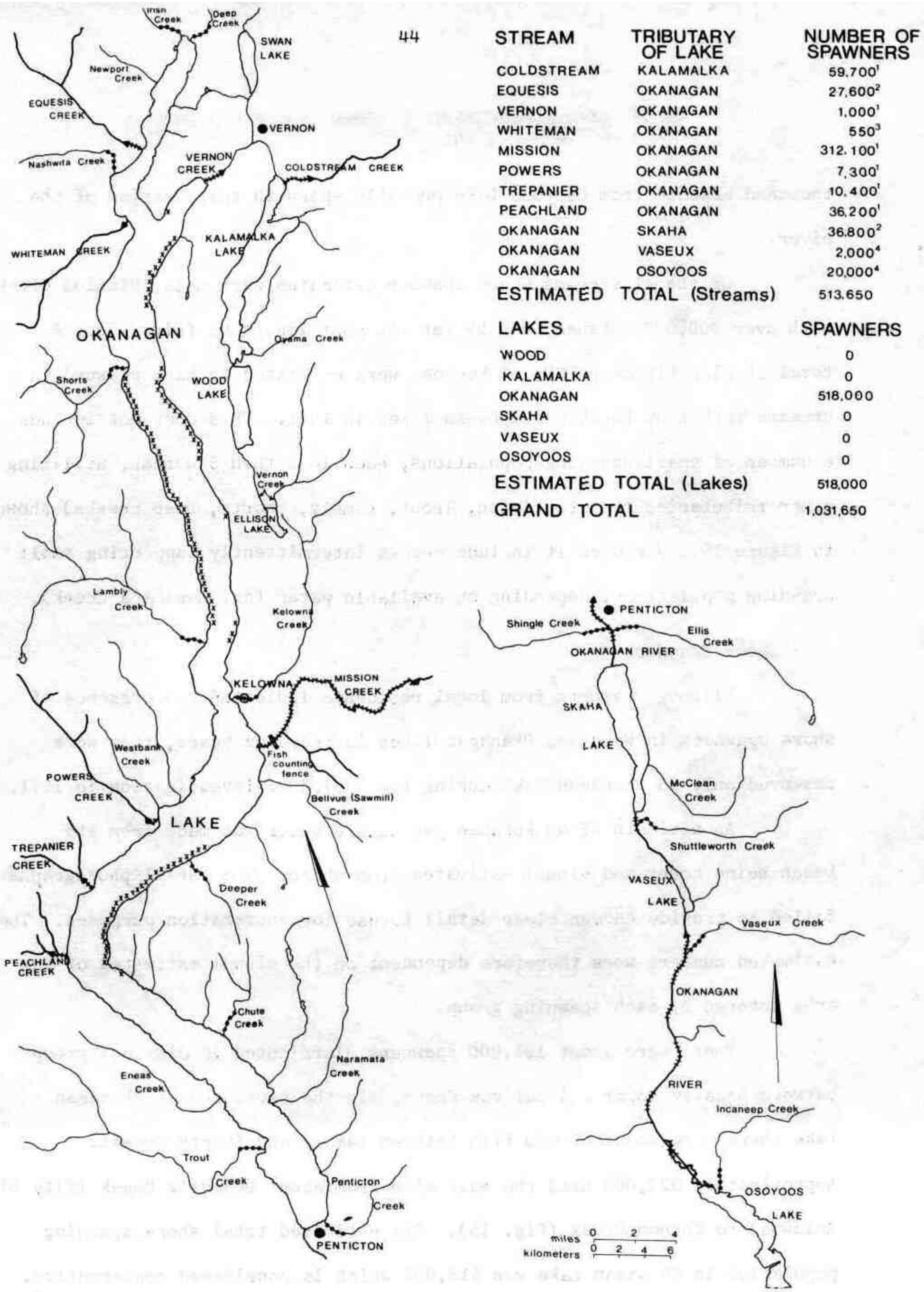
Table 7. Differences in minimum number of years which Okanagan basin rainbow trout reside in streams before lake entry (based on scale reading evidence).

LAKE	SAMPLE SIZE	MINIMUM YEARS OF STREAM RESIDENCE (%) 0+	1+	2+
Wood	2	100		
Kalamalka	67	6	88	6
Okanagan (N, W, C, K, M, P)	58	43	55	2
Okanagan (H, S)	81	32	68	
Skaha	17	53	47	
Vaseux	4	100		
Osoyoos	13	23	77	

KOKANEE SPAWNING ENUMERATION

Stream Spawners

Kokanee in spawning condition were observed in relatively few numbers (less than 2000) in the Okanagan River between Okanagan Falls and Vaseux Lake (Fig. 15). Spawning kokanee also were observed in the Okanagan River downstream from Maclntyre Dam, the upstream limit for fish coming from Osoyoos Lake. Because they were mixed with sockeye salmon spawning at the same time, it was impossible to obtain a good estimate but several



STREAM	TRIBUTARY OF LAKE	NUMBER OF SPAWNERS
COLDSTREAM	KALAMALKA	59,700[1]
EQUESIS	OKANAGAN	27,600[2]
VERNON	OKANAGAN	1,000[1]
WHITEMAN	OKANAGAN	550[3]
MISSION	OKANAGAN	312,100[1]
POWERS	OKANAGAN	7,300[1]
TREPANIER	OKANAGAN	10,400[1]
PEACHLAND	OKANAGAN	36,200[1]
OKANAGAN	SKAHA	36,800[2]
OKANAGAN	VASEUX	2,000[4]
OKANAGAN	OSOYOOS	20,000[4]
ESTIMATED TOTAL (Streams)		513,650

LAKES	SPAWNERS
WOOD	0
KALAMALKA	0
OKANAGAN	518,000
SKAHA	0
VASEUX	0
OSOYOOS	0
ESTIMATED TOTAL (Lakes)	518,000
GRAND TOTAL	1,031,650

Fig. 15. Spawning habitat and estimated populations of spawning kokanee in the Okanagan basin lakes and streams in 1971. [1] Estimation Method 1. [2] Estimation Method 2. [3] Count in one day only. [4] Very approximate estimates. (+++++) streams with > 500 spawning kokanee; (•) limit of accessable spawning habitat in those streams. (•—•) streams with < 500 spawning kokanee; (XXXX) shore spawning areas.

thousand kokanee from Osoyoos Lake probably spawn in that section of the river.

Of the 11 streams where spawner estimates were made, Mission Creek with over 300,000 kokanee, was by far the most important (Fig. 15). A total of slightly over 500,000 kokanee were estimated to have spawned in streams tributary to Okanagan basin lakes in 1971. This does not include a number of small spawning populations, each less than 500 fish, utilizing other tributaries (eg. Penticton, Trout, Lambly, Shorts, Deep creeks) shown in Figure 15. Nor does it include creeks intermittently supporting small spawning populations, depending on available water (eg. Naramata Creek).

Shore Spawners

Although reports from local residents indicated the presence of shore spawners in Wood and Okanagan lakes in previous years, they were observed only in Okanagan Lake during the period of investigation in 1971.

An estimate of 40 kokanee per square meter was made from the beach seine count and visual estimates from shore. The aerial photographs failed to provide enough clear detail to use for enumeration purposes. The estimated numbers were therefore dependent on the visual estimates of the area covered by each spawning group.

There were about 135,000 spawners distributed in distinct groups between Squally Point and Bellevue Creek. In the north end of Okanagan Lake there were about 60,000 fish between Lambly and Shorts creeks. Approximately 323,000 used the east side from about Brandt's Creek (City of Kelowna) to Vernon Creek (Fig. 15). The estimated total shore spawning population in Okanagan Lake was 518,000 which is considered conservative.

Because the estimate of total numbers of shore spawners is based on only one observation from the air, it is probably a minimum number. The estimate was probably made prior to the peak of the spawning period because only about 6-10 dead kokanee were observed in one area, just prior to making the estimates. If shore spawning kokanee follow the same pattern as stream spawning fish, one would see comparatively more dead spawners near the peak of spawning. It is therefore likely that maximum numbers were present after the count was made.

The tagged fish were observed 13 days after being tagged and the majority of them were over the same spawning site.

The substrate utilized by shore spawning kokanee differs dramatically from that used by stream spawners. The stones on the beaches appeared to be fractured material and had jagged, rough edges. The stones were loosely stacked without smaller gravels in the interstices. Several areas investigated with SCUBA gear, were composed of stones approximately 5 - 13 cm in diameter while other sites were composed of small boulders from about 20 to 40 cm in size. In both kinds of areas, live eggs were found down to a depth of about 30 cm. There was no evidence of redd construction such as one observes in stream spawning; eggs appeared to have trickled down into the interstices.

No spawners were observed in deep areas (10 m) bordering shore spawning sites; all those observed were in 0.5 to 2.5 meters and over 80 percent of all groups used areas 0.6 to 1.5 meters deep.

PESTICIDE AND HEAVY METAL ANALYSES

In 1970 fish samples were analyzed for chlorinated hydrocarbons by the B. C. Fish and Wildlife Branch and the B. C. Department of Health at the same laboratory. Some species from the 6 basin lakes were analyzed but not all species from all lakes. A number of analyses of individual fish from 3 of the lakes made it possible to calculate mean concentration and ranges (Table 8). Out of 75 analyses which included 10 species of fish, including those in Table 8, only one, a rainbow trout from Osoyoos Lake, exceeded the maximum allowable concentration (5.0 ppm) of total DDT. Concentrations of total DDT in these samples ranged from 0.03 ppm (a mountain whitefish from Okanagan Lake) to 6.85 ppm (a rainbow trout from Osoyoos Lake). Analyses of musculature collected from Okanagan Lake kokanee in 1966 (16 individuals and 11 analyses) indicated a range of total DDT from 1.99 to 5.00 ppm.

Analyses conducted in 1971 showed total residues of the DDT group to be extremely high in samples of the three principal sports fishes in Kalamalka Lake; samples of rainbow trout and squawfish in Okanagan Lake exceeded limits for total DDT residues as did lake whitefish in Skaha Lake (Table 9). Limits for mercury were exceeded in samples of rainbow trout from Okanagan Lake and in squawfish from Okanagan, Skaha and Osoyoos lakes. Of all analyses conducted on samples of main basin lakes in 1971, 22 percent (24 out of 107) showed concentrations of one of the heavy metals or total DDT or a combination of both in excess of set limits (Table 9). Organophosphates, herbicides, fungicides and P.C.B.'s were not detected.

Comparisons of analyses of fish collected 14 to 24 years ago with similar-sized fish collected in 1971 are probably too few in number to indicate any meaningful trend in time. Although a rainbow trout caught

Table 8. Mean concentration and range of total DDT in muscle tissue of mountain whitefish (Wood Lake), rainbow trout (Okanagan Lake) and kokanee (Skaha Lake) collected in 1970

SPECIES OF FISH	NUMBER OF ANALYSES	WEIGHT RANGE OF INDIVIDUALS (gm)	MEAN CONCENTRATION OF TOTAL DDT (ppm)	RANGE OF DDT CONCENTRATION (ppm)
		WOOD LAKE		
Mountain Whitefish	3	900 - 1135	0.65	0.31 - 1.09
		OKANAGAN LAKE		
Rainbow Trout	5	341 - 2497	0.99	0.21 - 2.27
		SKAHA LAKE		
Kokanee	4	227 - 341	0.79	0.62 - 1.06

Table 9. Concentration (parts per million wet tissue weight) of heavy metals and chlorinated hydrocarbons in samples of fish musculature, including skin and adipose tissue, in fish from Okanagan Basin lakes. NA = not analyzed; ND = not detected; *Cadmium - undetermined error in analysis; *Copper - error in analysis; *Zinc - values probably overestimated by about 30%. Enclosed ( ) numbers exceed limits (given in bold face at head of table) for marine and fresh water animal products set by Canada Food and Drug Directorate.[a,b]

SPECIES OF FISH	NUMBER OF INDIVIDUALS IN SAMPLE ANALYZED	MEAN FORK LENGTH (mm)	MEAN WEIGHT (gm)	AGE RANGE IN YEARS	CADMIUM	COPPER	LEAD	MERCURY	ZINC	TOTAL DDT (DDD + DDE + DDT + op DDT)
					Under Review	**100**	**10**	**0.5**	**100**	**5.0**
WOOD LAKE										
Rainbow Trout	1	215	83	2	ND	2.00	ND	0.07	43.60	0.01
Kokanee	10	201	82	2 - 3	ND	1.10	ND	0.06	25.20	0.98
	8	221	118	2 - 4	*1.21	*ND	*ND	0.08	[*117.00]	0.94
KALAMALKA LAKE										
Rainbow Trout	1	711	6512	9	NA	NA	NA	NA	NA	[19.18]
	1	-	6000	-	NA	NA	NA	NA	NA	[17.85]
	1	-	6000	-	ND	3.30	ND	0.05	0.64	[17.43]
	2	538	2019	5 - 7	ND	0.60	ND	0.06	6.00	[7.81]
	1	510	1415	8	*0.96	*ND	*ND	0.02	*100.00	[56.67]
	9	380	557	4 - 6	ND	0.60	ND	0.04	8.70	0.91
	2	350	495	5 - 6	*0.20	*ND	*ND	0.05	*ND	[6.32]
	5	310	297	3 - 5	ND	0.50	ND	0.04	19.30	1.08
	10	308	295	4 - 6	*2.15	*ND	*ND	0.01	*100.00	2.22
	10	300	259	3 - 5	ND	1.40	ND	0.04	11.00	0.23
Kokanee	1	445	849	3	ND	1.90	ND	0.11	13.80	[68.72]
	10	209	94	3 - 4	ND	1.70	ND	0.04	*2.50	1.12
	10	191	76	3 - 4	*2.10	*ND	*ND	0.02	*20.00	3.88
	10	188	73	3 - 4	*1.06	*ND	*ND	0.01	*69.10	4.59
Mountain Whitefish	2	414	1033	6	ND	1.00	ND	0.05	24.90	[15.81]
	1	284	251	5	*ND	*ND	*ND	0.01	*ND	[12.25]
Carp	10	476	1746		*ND	*ND	*ND	0.07	[*120.00]	2.73
	4	386	1702		ND	1.60	ND	0.09	5.20	4.18
Largescale Sucker	6	359	489		ND	0.90	ND	0.12	15.00	0.14
Peamouth Chub	2	248	171		ND	2.60	ND	0.22	8.70	2.07
Lake Trout	5	506	1704	5	ND	0.90	ND	0.06	3.20	4.61
	10	411	748	5	*1.50	*ND	*ND	0.02	*100.00	[5.28]

Table 9 (cont'd)

OKANAGAN LAKE

Rainbow Trout	1	889	8674	6	ND	3.60	ND	0.13	15.00	1.34
	1	813	7021	9	ND	3.60	ND	[0.62]	6.70	[11.60]
	1	787	5216	9	NA	NA	NA	NA	NA	4.48
	1	ca 787	ca 5216	-	ND	16.00	ND	[0.89]	2.50	2.20
	1	ca 787	ca 5216	-	ND	13.00	ND	[0.62]	3.60	1.38
	10	675	4459	6 - 9	ND	0.50	ND	0.09	5.30	[5.43]
	6	493	3287	6 - 9	*0.49	*ND	*ND	0.15	*64.50	[5.91]
	1	505	1150	6	ND	8.10	ND	0.22	16.00	0.76
	8	401	720	4 - 7	ND	0.90	ND	0.06	8.90	1.58
	10	383	547	4 - 7	*ND	*ND	*ND	0.17	*57.70	2.92
	7	371	526	4 - 7	ND	0.30	ND	0.07	8.90	0.42
	7	376	479	5 - 7	ND	1.30	ND	0.25	10.00	1.13
	8	242	291	2 - 3	ND	0.80	ND	0.06	19.60	0.21
	10	291	285	2 - 7	ND	0.80	ND	0.06	10.60	0.54
	10	301	284	3 - 4	*0.96	*ND	*ND	0.06	*30.70	3.11
Kokanee	10	285	283	2 - 3	ND	1.40	ND	0.08	15.10	0.32
	9	288	220	3	ND	1.10	ND	0.05	13.70	0.64
	10	270	218	3	ND	1.10	ND	0.08	19.80	0.31
	10	261	190	3	*2.10	*ND	*ND	0.06	*ND	0.88
	11	126	130	3	*3.35	*ND	*ND	0.07	*45.80	2.86
	10	217	114	2 - 4	*ND	*ND	*ND	0.06	*18.70	1.60
	10	212	108	2 - 3	*0.88	*ND	*ND	0.11	[*104.00]	2.99
	10	274	102	2 - 3	ND	1.00	ND	0.15	13.00	0.41
	10	181	60	1 - 3	ND	1.00	ND	0.06	15.60	0.29
Mountain Whitefish	2	360	616	2 - 6	ND	1.20	ND	0.15	18.10	1.82
	9	269	267	3 - 8	*0.86	*ND	*ND	0.06	*44.50	2.05
	6	274	229	3 - 5	ND	0.90	ND	0.02	8.50	1.39
	1	273	202	5	*ND	*ND	*ND	0.07	*ND	0.92
	7	ca 270	ca 200	-	ND	1.60	ND	0.09	17.00	0.08
	4	265	182	2 - 4	ND	2.60	ND	0.06	26.00	0.86
Lake Whitefish	10	378	613	5 - 7	*0.86	*ND	*ND	0.07	*ND	1.88
	10	365	515	1 - 6	ND	0.20	ND	0.05	6.70	0.57
	10	363	480	4 - 6	*ND	*ND	*ND	0.14	*ND	0.90
	10	355	476	4 - 6	ND	0.80	ND	0.07	11.20	4.16
Carp	9	523	2366		*1.90	*ND	*ND	0.11	*8.70	1.00
Burbot	5	741	3748	7 - 8	ND	0.40	ND	0.28	4.90	0.39
	8	632	1929	4 - 10	ND	0.60	ND	0.11	5.70	0.14
Largescale Sucker	2	421	835		ND	1.50	ND	0.27	26.80	0.20
	10	406	798		ND	0.70	ND	0.16	12.30	0.99
Peamouth Chub	5	232	147		ND	1.50	ND	0.21	33.70	0.27
Squawfish	1	530	1817		ND	0.50	ND	[1.79]	64.60	[5.50]
	3	471	1458		ND	1.00	ND	[0.59]	5.90	3.61
	5	447	1268		ND	1.60	ND	0.13	14.00	0.45
	3	376	607		ND	1.60	ND	0.45	12.00	2.25
	3	358	544		ND	1.50	ND	0.24	29.00	1.60

Table 9 (cont'd)

VASEUX LAKE

Kokanee	10	332	417		ND	0.50	ND	0.06	9.60	0.79
Lake Whitefish	10	335	427		ND	0.40	ND	0.10	8.10	2.00
Perch	10	267	279		*7.63	*ND	*ND	0.14	*ND	0.24
Largescale Sucker	6	404	750		ND	1.90	ND	0.14	16.60	0.28
Squawfish	2	223	120		ND	3.70	ND	0.15	66.20	0.12

OSOYOOS LAKE

Rainbow Trout	5	385	612	4 - 5	*ND	*ND	*ND	0.05	*3.00	2.56
	2	372	547	4	ND	0.70	ND	0.09	11.10	0.28
	2	289	287	3	*0.41	*ND	*ND	0.01	*33.90	0.37
	2	274	240	3	ND	0.60	ND	0.06	27.00	0.11
Kokanee	10	221	135	2 - 3	*0.94	*ND	*ND	0.04	*ND	2.32
	6	209	117	2 - 3	*2.11	*ND	*ND	0.03	*65.20	2.26
Mountain Whitefish	5	337	448	3 - 6	ND	2.00	ND	0.10	13.70	1.89
Lake Whitefish	10	386	805	5 - 6	ND	0.40	ND	0.05	5.00	0.58
Carp	2	424	1161		ND	0.84	ND	0.09	20.00	0.56
Smallmouth Bass	3	260	289		ND	2.30	ND	0.39	10.20	0.11
	2	87	6.5		ND	18.00	ND	0.20	25.00	0.14
Perch	4	199	109		ND	2.60	ND	0.50	12.10	ND
	3	114	12.3		ND	ND	ND	0.09	29.00	0.27
Largescale Sucker	10	454	1180		ND	1.10	ND	0.10	12.20	0.33
Squawfish	1	389	669		ND	2.10	ND	0.57	6.90	2.62
Chiselmouth	10	252	207		ND	0.60	ND	0.08	27.50	0.44
	1	219	133		ND	7.20	ND	0.13	20.00	0.08

[a] **Some samples of most species from Kalamalka and Okanagan lakes and some species from Wood, Skaha, Vaseux and Osoyoos were analyzed for organo-phosphates (Parathion, Malathion, Diazinon, ethion, dimethoate; Guthion, Sevin, captan) and herbicides (2-4-D, 2, 4, 5-T, Atrazine, tordon). None of these compounds were detected. Results of chlorinated hydrocarbon analyses were inspected for the presence of PCB's; none were detected.**

[b] **Practical limits of detection (parts per million);**

Cadmium	0.003	DDE	0.01	Dieldrin	0.01	Diazinon	0.05	Guthion	1.00	Tordon	0.10
Copper	0.005	DDD	0.01	Heptachlor	0.01	Parathion	0.05	Sevin	1.00	Atrazine	0.10
Lead	0.04	DDT	0.01	Thiodan	0.01	Malathion	0.05	Captan	0.05		
Mercury	0.001	opDDT	0.01	Kelthane	0.05	Dimethoate	0.05	2, 4-D	0.05		
Zinc	0.01	Aldrin	0.01	Perthane	0.05	Ethion	0.05	2, 4, 5-T	0.05		

in Kalamalka in 1956 was smaller than the average of comparable rainbow trout analyzed in 1971, it had higher concentrations of total DDT, zinc, mercury and copper (Table 10). A single carp, caught in Osoyoos Lake 16 years ago, had a higher concentration of total DDT than the average of 2 carp caught in 1971; there was little difference in the concentrations of heavy metals. Three smallmouth bass collected in Osoyoos Lake in 1951 and 1956 had somewhat higher concentrations of total DDT than the average of 2 collected in 1971, however the 1971 fish were considerably smaller. Similarly, perch from Osoyoos showed higher concentrations of total DDT in 1951 than in 1971. There was little difference in concentration of heavy metals between years (Table 10).

Rainbow trout from some headwater lakes were compared with similar sized trout from Wood and Okanagan lakes into which they drain (Table 11). Concentrations of copper and zinc were higher in fish from Wood than the 2 tributary lakes; there was little difference in mercury but, surprisingly, total DDT levels found in Wood Lake fish were lower than concentrations in headwater fish. Levels of copper and mercury in trout from tributary headwater lakes were higher than those of the respective basin lakes but zinc and total DDT residues were lower.

Table 10. Concentration (parts per million wet tissue weight) of heavy metals and chlorinated hydrocarbons in samples of fish musculature in fish from Okanagan Basin lakes. These fish were collected from 1948 to 1956 and were stored in the Museum of Fishes at the University of British Columbia; 1971 data added for comparison. See Table 9 for limits set by Canada Food and Drug Directorate and details regarding analysis.

SPECIES OF FISH	DATE COLLECTED	NUMBER OF INDIVIDUALS IN SAMPLE ANALYZED	MEAN FORK LENGTH (mm)	MEAN WEIGHT (gm)	AGE RANGE IN YEARS	CADMIUM	COPPER	LEAD	MERCURY	ZINC	TOTAL DDT (DDD + DDE + DDT + op DDT)
				KALAMALKA							
Rainbow Trout	1951	1	226	150		ND	5.50	ND	0.10	22.00	2.81
	1971	10	300	259	3 - 5	ND	1.40	ND	0.04	11.00	0.23
				SKAHA							
Chiselmouth	1948	1	223	160		ND	7.60	ND	0.65	12.00	0.43
	1971	10	300	343		ND	0.60	ND	0.08	18.60	0.39
				OKANAGAN RIVER (between Vaseux and Osoyoos lakes)							
Chiselmouth	1951	10	152	36.7		ND	1.70	ND	0.08	22.00	0.47
				OSOYOOS							
Carp	1956	1	380	1065		ND	0.74	ND	0.06	24.00	2.96
	1971	2	424	1161		ND	0.84	ND	0.09	20.00	0.56
Smallmouth Bass	1951	2	139	37		ND	7.50	ND	0.26	25.00	0.80
	1956	1	100	13		NA	NA	NA	NA	NA	0.61
	1971	2	87	6.5		ND	18.00	ND	0.20	25.00	0.14
Perch	1951	2	113	17		NA	NA	NA	NA	NA	0.46
	1971	3	114	12.3		ND	ND	ND	0.09	29.00	0.27
Squawfish	1951	1	146	34		NA	NA	NA	NA	NA	0.92
	1956	3	293	316		ND	0.84	ND	0.21	9.60	4.88

Table 11. A comparison of ranges of heavy metal and total DDT concentrations in rainbow trout from some headwater and main-basin Okanagan lakes, Trout from each system range from about 200 to 400 mm in length. Concentrations in ppm wet tissue weight.

	LAKES		CADMIUM		COPPER		LEAD		MERCURY		ZINC		TOTAL DDT RESIDUE	
	Alex Mountain + Swalwell	Wood	Alex Mountain + Swalwell	Wood	Alex Mountain + Swalwell	Wood	Alex Mountain + Swalwell	Wood	Alex Mountain + Swalwell	Wood	Alex Mountain + Swalwell	Wood	Alex Mountain + Swalwell	Wood
Number of Individuals	26	1	NA	NA	0.30-0.80	2.0	ND	ND	0.05-0.07	0.07	5.0-7.0	43.6	0.06-0.10	0.01
Number of Samples	3	1												
	Jack Pine + Hydraulic + Fish Hawk	Okanagan	Jack Pine + Hydraulic + Fish Hawk	Okanagan	Jack Pine + Hydraulic + Fish Hawk	Okanagan	Jack Pine + Hydraulic + Fish Hawk	Okanagan	Jack Pine + Hydraulic + Fish Hawk	Okanagan	Jack Pine + Hydraulic + Fish Hawk	Okanagan	Jack Pine + Hydraulic + Fish Hawk	Okanagan
Number of Individuals	24	35	NA	ND-0.49	0.70-1.00	0.30-1.30	ND	ND	0.05-0.11	0.06-0.25	6.0-13.7	8.9-30.7	0.02-0.18	0.21-3.11
Number of Samples	5	4												

DISCUSSION

FISH AS INDICES OF EUTROPHICATION

Information on a number of attributes of the fish populations in 6 Okanagan basin lakes has been presented. An attempt will now be made to use these characteristics in assessing the present status of eutrophication in the lakes.

There are marked differences in species composition between the uppermost and lowermost lakes in the drainage basin. Wood Lake has the lowest number of both salmonoids (3) and non-salmonoids (7) whereas Osoyoos has the highest (7 and 15 respectively). Intervening lakes are intermediate. However these differences do not seem related to eutrophication but instead probably result from barriers (both natural and man-made) to upstream movement of fish and from introductions by man. The ictalurid, percid and centrarchids found in Osoyoos Lake could surely thrive in Wood Lake if they had the opportunity of gaining entry. Although there is no clear evidence of a shift in species composition having occurred in the basin lakes as a result of their differential eutrophication, such a change may soon come if present trends go unchecked. The extremely small number of rainbow trout and few kokanee taken by the 1971 extensive netting in Wood Lake as well as the recent reports of kokanee mortalities there during summer undoubtedly are indications of changed lake conditions.

To fairly assess differences in relative abundance, average length, weight-length relationships and growth rates of the fish between lakes, it seemed essential to consider only those species common to all lakes. Furthermore some system, however crude, had to be developed to summarize and summate the considerable body of data presented for each attribute. This has been done in Table 12, where it is possible to compare the relative position of each lake with respect to any other in the system by examining its score in a particular cell of each column of any one matrix. Also one may obtain the general position of each lake for one attribute by summing its score for the 5 lakes with which it is compared in a column. These total scores for each lake are then ranked in order of the most "eutrophic" with respect to the attribute considered.

No attempt will be made to work through each matrix, cell by cell, although the sign and magnitude of the scores often seem reasonable and instructive on that basis. For example, Skaha Lake has a positive eutrophication score for the relative abundance index when compared to Wood (+15), Kalamalka (+50), Okanagan (+51) and Osoyoos (+45), but is negative (-25) in this respect when compared to Vaseux. On the other hand although Skaha shows positive growth rate scores in relation to all other lakes, it is very high (eutrophic) in comparison with Kalamalka (+118) but not so for Vaseux (+46).

Considering the summed (•) relative abundance scores for each lake (Table 12), one sees that Vaseux is by far the most eutrophic in this respect, while Okanagan and Kalamalka are the least. This seems a clear reflection of the large number of non-salmonoids and the few salmonoids taken in Vaseux and of the reverse situation in Okanagan and Kalamalka. Skaha ranks the second most eutrophic in the relative abundance matrix, followed by Wood. Because of the lower number of salmonoids caught in 1971 compared to 1948 in Skaha and the occurrence of carp in net catches there in 1971 but not in 1948, this lake probably would have had a much lower summed relative abundance score in 1948. Although there apparently

Table 12. Matrices of weighted scores developed to compare six Okanagan basin lakes using four attributes of their fish populations in 1971 as indices of eutrophication.

RELATIVE ABUNDANCE[1]

	WD	KL	OK	SK	VA	OS
WD		- 33	- 37	+ 15	+ 40	- 28
KL	+33		- 4	+ 50	+ 70	+ 4
OK	+37	+ 4		+ 51	+ 75	+ 9
SK	-15	- 50	- 51		+ 25	- 45
VA	-40	- 70	- 75	- 25		- 75
OS	+28	- 4	- 9	+ 45	+ 75	
Σ SCORE	+43	-153	-176	+136	+285	-135
RANK	3	5	6	2	1	4

AVERAGE LENGTH[2]

	WD	KL	OK	SK	VA	OS
WD		+ 9	+31	+24	+15	+24
KL	- 9		+19	+16	+ 6	+16
OK	- 31	-19		- 4	-12	- 7
SK	- 24	-16	+ 6		- 9	- 1
VA	- 15	- 6	+12	+ 9		+ 9
OS	- 24	-16	+ 7	+ 1	- 9	
Σ SCORE	-103	-48	+75	+46	- 9	+41
RANK	6	5	1	2	4	3

WEIGHT - LENGTH[3]

	WD	KL	OK	SK	VA	OS
WD		+10	+15	+26	+11	+26
KL	-10		+14	+10	+ 2	+17
OK	-15	-14		+ 4	- 6	- 1
SK	-26	-10	- 4		- 8	+ 2
VA	-11	- 2	+ 6	+ 8		- 1
OS	-26	-17	+ 1	- 2	+ 1	
Σ SCORE	-88	-33	+32	+46	0	+43
RANK	6	5	3	1	4	2

GROWTH RATE[4]

	WD	KL	OK	SK	VA	OS
WD		- 11	+16	+ 65	+12	+47
KL	+ 11		+47	+118	+21	+45
OK	- 16	- 47		+ 93	+ 5	+32
SK	- 65	-118	-93		-46	-65
VA	- 12	- 21	- 5	+ 46		+33
OS	- 47	- 45	-32	+ 65	-33	
Σ SCORE	-129	-242	-67	+387	-41	+92
RANK	5	6	4	1	3	2

[1] Scores equal differences between lakes in total number of the 7 common species of fish caught in standard gill net sets (Fig. 5) weighted so that 1 score unit = 2.5 rainbow trout, 10 kokanee, 5 mountain whitefish, 5 largescale suckers, 50 peamouth chub, 10 squawfish, 2.5 carp; salmonoids given negative score, non-salmonoids positive score, so that score shown in each cell represents their algebraic sum.

[2] Scores equal differences between lakes in average length of the 7 common species of fish caught in standard gill net sets (Fig. 6) weighted so that 1 score unit = 1 cm; score shown in each cell represents algebraic sum of differences for the 7 species.

[3] Scores equal differences between lakes in weight-length regressions (log 10) of the 7 common species of fish; score obtained by adding any statistically significant ($P<0.05$) difference in slope (X100) to a 3 unit index for displacement (+ or -) of the regression line.

[4] Scores equal differences between lakes in "growth rate" (average size attained by each age group) of the 7 common species of fish weighted so that 1 score unit = 1 cm; score shown in each cell represents algebraic sum of differences for age groups of the 7 species.

has been a reduction in total abundance of fish in Wood Lake between 1935 and 1971, the relative abundance of species and hence its position in the present ranking may not have changed markedly.

Average length may not be a particularly good attribute to consider in using fish as indices of eutrophication. It, perhaps more than the others used, may be easily influence by unrelated conditions. Okanagan fish have the highest pooled score for average length (Table 12), followed by Skaha and then Osoyoos. Those in Wood and Kalamalka are lowest. That Wood Lake fish now are so consistently smaller than those from any of the other basin lakes seems most significant, especially since a few decades ago this lake supported a flourishing sport fishery for good sized kokanee.

Skaha Lake has the highest weight-length score followed closely by Osoyoos (Table 12). Scores for Kalamalka are low, and only positive for one comparison (with Wood). Weight-length relationship scores for Wood Lake are negative for all comparisons, giving it a highly negative total score. That the slope of the weight-length regression for carp in Wood has significantly decreased between 1935 and 1971 suggests that conditions for growth of this species may have worsened over this period. In contrast, slopes and/or displacement of the weight-length regression for at least 4 species of fish have increased sharply in Skaha Lake between 1948 and 1971, again suggesting rapid and recent eutrophication there.

Growth rate scores for Skaha Lake fish are highest for all between-lake comparison (Table 12); hence the pooled value is over four times that of the next highest, Osoyoos. Kalamalka shows the lowest score for this attribute, followed by Wood. It was noted previously that there has been a sharp increase in growth rate of all 4 Skaha Lake salmonoids between 1948 and 1971 whereas those in Okanagan have either remained the same or in one case, decreased since 1935.

Low average age of salmonoids taken from Vaseux, Wood and Skaha lakes in comparison with those from Kalamalka and Okanagan may be indicative of advanced eutrophication in the former group. Larkin and Northcote (1969) cite examples from Europe where the average age of coregonids in net catches gradually became lower as eutrophication of the lakes became more severe.

In summary, the four attributes used as eutrophication indices for Okanagan basin fish populations as well as other characteristics or changes presented above, all point towards Skaha Lake as being the most eutrophic followed by Osoyoos and Vaseux. Kalamalka would seem the least eutrophic. Although Wood Lake also ranks very low, several lines of evidence suggest that it has reached this position after passing through a more eutrophic stage, at least with respect to its fish populations. This should not be construed to indicate that Wood Lake today in other features of its limnology, may not be considered highly eutrophic.

For some, it may appear that this whole process has been a long and tedious exercise in proving the obvious; considering the history and success of man's attempts to control eutrophication however, even proving the obvious to many will be just that - a long and tedious process.

STREAM AND SHORE SPAWNING KOKANEE

The number of stream spawning kokanee are probably related to the availability, quality and size of spawning habitat rather than the eutrophic state of the neighbouring region of the lake. For example, 550 kokanee entered Whiteman Creek in 1971 when heavy rains provided a brief flow of water but were unable to use the creek at other times because, the entire flow was diverted. Large populations of spawning kokanee were noted in Coldstream (tributary to Kalamalka) and Mission (tributary to Okanagan) creeks because these streams provide large areas of spawning habitat. It is conceivable that both Kalamalka and Okanagan lakes could support larger numbers of kokanee if there was more spawning habitat in these lakes. There is a suggestion that the few remaining kokanee in Wood Lake spawn in Coldstream because of the lack of spawning habitat in streams tributary to that lake.

The availability of shore-spawning habitat, like that of stream spawning, appears to determine the number of spawners; the largest number (383,000) of shore spawners was observed in the northern section of Okanagan Lake where only 27,000 stream spawners were observed in 3 small streams. The largest number of stream spawners was observed in Mission Creek, a tributary to the central region of Okanagan but compared to the northern area, the shore-spawners were fewer in number; again probably a reflection of available habitat. Good shore-spawning habitat probably is lacking in the southern section of Okanagan Lake, Skaha, Vaseux and Osoyoos because no spawners were seen there; kokanee were observed spawning in tributary streams of these lakes.

PESTICIDES AND HEAVY METALS

This study did not attempt to investigate the effect of pesticides or heavy metals on fish themselves but there is a vast literature dealing with the effect of the former on a variety of fishes and a growing body of information on the effects of heavy metals. Where these documented cases provide comparative information to that of Okanagan fishes, some mention will be made of them and enough data from elsewhere in North America will be given so that the Okanagan Basin case can be put in perspective.

There are two aspects to consider when interpreting the incidence and degree of contamination in fishes: (1) the effect of the compound(s) on the well-being and life cycle of the fish per se, (2) the concentration of the contaminants in fish as it affects the well-being of the consumer of fish - in this instance the angling public.

The DDT group of insecticides has been shown to kill many of the species of salmonoids and cyprinids found in the Okanagan system. In one experiment, the DDT concentration required to kill 50% of the tested individuals in 96 hours was 0.007 for rainbow trout, 0.002 for large-mouth bass, 0.009 for yellow perch and 0.001 for carp (Pimentel, 1971). In addition to acute toxicity there are sub-lethal effects of the DDT group that inhibit reproduction and alter behavior patterns. When levels of DDT and its metabolites were above 0.4 ppm in eggs of hatchery trout, mortality of the resulting fry ranged from 30 to 70 percent. In another study fewer fry survived from lake trout eggs that had 3 ppm DDT and all fry died that hatched from eggs having concentrations of 5 ppm and above - concentrations in eggs ranged from 3 to 335 ppm. It is interesting to note that most mortality occurred in the fry stage at the time of final absorption of the yolk sack rather than in the egg stage (Pimentel, 1971).

Concentrations of chlorinated hydrocarbons are higher in fatty tissue because these compounds are fat-soluble. Concentrations of DDD, which was applied directly to Clear Lake, California, ranged from 5 - 130 ppm in fish of several species but in the fat of those fishes, ranged from 40 to 2,690 ppm or about 20 times the highest concentration (O'Brien, 1967). In 16 species from New York waters, concentrations in flesh ranged from 0.2 to 7 ppm DDT but in other tissues, egg and reproductive organs, up to 40 ppm - about 6 times the highest figure (Pimentel, 1971). If the concentrations of DDT in eggs and reproductive organs of some large rainbow trout from Kalamalka Lake were 6 times the concentration found in flesh there would be as much as 412 ppm or as little as 1.38 ppm. Concentrations in eggs and reproductive organs of larger rainbow trout in Okanagan lakes would probably exceed the 5 ppm level that produced 100 percent mortality in fry of lake trout. The same thing may well apply to some squawfish in Okanagan Lake and some lake whitefish from Skaha Lake. This phenomenon applied particularly to older and therefore usually larger fish because DDT compounds accumulate in tissue with time (Pimentel, 1971). Fish with high concentrations of chlorinated hydrocarbons in their fatty tissues may themselves remain relatively healthy until some stress such as reduced food intake causes the fat in the body to be mobilized. In all probability therefore the larger rainbow trout in Kalamalka and Okanagan lakes are unable to reproduce successfully.

Sub-lethal effects were observed to occur in juvenile Atlantic salmon in streams in areas that had been sprayed with DDT; these fish selected abnormally high water temperatures. Such a physiological change could lead to stress or death in fish that require specific ranges of temperature for survival and/or reproduction. Brook trout fed sub-lethal doses (0.02 ppm) of DDT in the laboratory lost their learned avoidance behavior; doses of 0.02 to 0.06 ppm altered their thermal acclimation mechanism (Pimentel, 1971). Physiological and behavioral changes like these may occur in juvenile salmonoids in Okanagan streams and lakes thus reducing survival.

The allowable limits of DDT for human consumption were exceeded in 14 percent (15 out of 107) of all analyses. It is significant to note that only 2 of the 15 analyses that exceeded the limits were for species (squawfish and lake whitefish) seldom utilized by anglers; nonetheless they are consumed by some anglers. The majority of species containing excessive amounts are those that are given top priority by anglers (Anonymous, 1972). As shown by rainbow trout in Kalamalka and Okanagan lakes, concentrations of total DDT are generally below prohibitive levels in smaller sized fish. These appear safe for human consumption. Similarly, non-piscivorous species such as kokanee, whitefish, suckers and carp are, for the most part, below the 5.0 ppm limit set for chlorinated hydrocarbons.

Average concentrations of total DDT from some species in the Great Lakes are higher than those for the same species in Okanagan basin lakes; lake trout in Michigan and Superior lakes were 6.96 and 7.44 ppm compared to 5.26 and 4.61 ppm in lake trout from Kalamalka. Perch from Vaseux Lake had lower average concentrations (0.24 ppm) than perch from Lake Erie (0.87 ppm) and Lake Ontario (2.10 ppm; Pimentel, 1971). In these lakes, as in Okanagan lakes, the insecticide was applied to the land to control insect pests but found its way into aquatic non-target organisms.

Some heavy metals occur naturally and as pollutants in Okanagan lakes. They may constitute serious forms of pollution because they occur as stable compounds and are therefore persistent. Generally, fish concentrate heavy metals in their tissues where levels may be many times that found in the water or substrate. The amount of accumulation differs for different organs; concentrations in kidney and liver tissue are usually much higher than in muscle.

Heavy metal compounds of copper, lead, mercury and zinc in water, singly or combined, are lethal to fishes (Peterson et al., 1970). Like DDT compounds, sub-lethal concentrations can adversely affect the behavior and physiology of fish.

To date very little investigation has been made of the heavy metal content of fresh water fishes in British Columbia. Peterson, et al., (1970) lists concentrations of copper, lead, mercury and zinc in fish livers and mercury content of livers and muscle. The highest concentration of mercury in rainbow trout muscle elsewhere in the province (1.90 ppm) is about twice as high as the highest concentration (0.89 ppm) found to date in Okanagan rainbow trout. Concentrations of mercury in Okanagan fishes were found to be high (and exceeded limits) in large, old rainbow trout in Okanagan Lake, probably because they live for a long time and commonly prey on other fish which have accumulated lesser concentrations.

Concentrations of mercury above limits have accumulated in some squawfish from Okanagan, Skaha and Osoyoos lakes; like large rainbow trout, this species preys heavily on other fishes. The amount of mercury in one squawfish from Okanagan Lake was as high (1.79 ppm) as the highest concentration (in another predacious species, the lake trout) for the remainder of the province (Peterson, et al., 1970). Mercury concentrations in Lake Erie yellow perch (0.29 to 0.61 ppm) were higher than those found in yellow perch from Vaseux and Osoyoos lakes (0.09 to 0.50 ppm). Lake Erie coho salmon, which are probably much younger but have similar feeding habits to large Okanagan rainbow trout, had mercury concentrations ranging from 0.51 to 0.69 ppm compared to a range of 0.02 to 0.89 ppm for large rainbow trout in Okanagan and Kalamalka lakes. Surprisingly, burbot, also a fish predator, had comparatively low concentrations of heavy metals and pesticides.

Excluding zinc, only 6.5% (7 out of 107) of all analyses showed concentrations of heavy metals in excess of limits for human consumption, based on these data, sports fish are, for the most part, free of serious heavy metal contamination. Because of the difficulties encountered with the analyses of cadmium and zinc, it is not possible to meaningfully interpret the results. It is not surprising to find concentrations of copper in Okanagan fishes as the area has widespread copper mineralization.

Conclusive demonstration of changes in heavy metal content of Okanagan fishes over the years is difficult to make because of lack of an adequate number of museum samples with which comparisons can be made. Similarly, comparisons of analysis from headwater lakes with main basin lakes are based on too few samples to show any definite trends.

A variety of management strategies have been used by fisheries agencies when faced with the problem of contaminated sports fish. In Sweden, about 1 percent of the waters have been "black listed" because of mercury contamination in fishes. Swedish waters are black listed if a sample of 5 pike show residues of 1 ppm or more of mercury in most of the 5. If concentrations are between 0.2 and 1 ppm, Swedes are advised to eat fish from those waters no more often than once a week (Nelson, 1971). The level of 1 ppm chosen by the Swedes is considered too high but if they used the 0.5 ppm level as in Canada and the United States, 5 times as many waters would be black listed and the monitoring costs would be prohibitive (Nelson, 1971). Swedish health authorities sometimes allow species other than pike to be eaten from black listed waters.

In Ontario, sports fishermen have been advised not to eat any fish from some waters and only certain species from others. In British Columbia, a complete ban on fishing was placed on upper Howe Sound because of mercury contamination; later this was lifted but ground fishes and shellfish remained banned. In Okanagan Lake, anglers have been advised to eat rainbow trout only if they are less than 3 pounds (1362 grams).

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APPENDICES

Appendix 1. Length, weight and age (determined from otoliths) for burbot taken from Okanagan and Skaha lakes, 1971.

Station	Date	Length (mm)	Weight (gm)	Age
Okanagan North	Aug 9	451	786	5+
	"	680	1942	9+
	"	759	3300	10+
	Nov 3	570	1045	5+
	"	639	2050	9+
	"	673	2250	9+
	"	700	2250	9+
	Nov 16	85	4	1+
	"	124	13	2+
Okanagan Whiteman	Aug 6	398	464	3+
	Oct 29	524	1125	4+
	"	602	1590	10+ ?
	"	640	2260	5+
	"	650	2171	7+
	"	670	1804	10+ ?
Okanagan Centre	May 16	649	1833	8+
	Aug 4	675	2320	9+
	"	735	2283	9+
	Oct 21	649	1950	7+
Okanagan Kelowna	Aug 3	212	57	2+ ?
	Oct 18	220	63	3+
	May 13	157	30	1+
	"	212	83	1+
Okanagan Peachland	Jul 19	272	127	4+
	"	400	404	4+
	"	518	907	5+
	"	576	1096	7+
	"	648	1895	8+
Okanagan South	May 10	112	10	1+
	"	127	17	1+
	Jun 11	898	5000	14+
	Jul 23	400	416	3+
	"	580	1280	9+
	"	657	1820	11+
	"	672	2285	11+
	Oct 12	505	905	4+
	Nov 21	281	156	1+
Skaha South	Jul 27	682	2355	6+

Appendix 2. Methods of analysis for chlorinated hydrocarbons and heavy metals used for 1971 Okanagan Basin Study.

I Chlorinated Hydrocarbons

Ten grams of tissue, made up of equal portions from each individual fish represented in the sample, were added to 20 ml aceto nitrite in a high speed blender. A double extraction was made for each analysis.

1. Extraction procedure for insecticides, fungicides and herbicides.

   (a) Chlorinated hydrocarbon and organophosphate insecticides, 2,4-D and 2,4,5-T acids and esters.

      (i) McCloud, H. A. (compiled and edited) 1969. Canada Food and Drug Directorate: Analytical methods for pesticide residues in food. Queens Printer, Ottawa. (procedures 5.1 and 5.2).

      (ii) Johnson, L. Y. [ed] 1965. Pesticide analytical manual. United States Department of Health Education and Welfare, Food and Drug Administration, Washington, D. C. (procedure 2.21).

      (iii) Mills, P. A., J. H. Onley and R. A. Gaither. 1963. Rapid method for chlorinated pesticide residues in non-fatty foods. Journal of the Association of Official Agricultural Chemists. 46:186-191.

   (b) Atrazine, Sevin and Captan

      (i) Direct extraction from tissue with chloroform.

(c) Tordon

(i) Saha, J. G. 1967. Determination of the herbicide Tordon (4-amino-3,5,6-trichloropicolinic acid) in soil by electron capture gas chromatography. Journal of the Association of Official Agricultural Chemists. 50:637-641.

2. Partition procedures.

(i) McCloud, H. A. (compiled and edited) 1969. Canada Food and Drug Directorate: Analytical methods for pesticide residues in food. Queens Printer, Ottawa (procedures 6.1 to 6.6).

3. Clean-up and Separation procedures (column chromatography).

(i) McCloud, H. A. (compiled and edited) 1969. Canada Food and Drug Directorate; Analytical methods for pesticide residues in food. Queens Printer, Ottawa (procedures 7.1 and 7.2).

4. Determinative procedure

(i) All analyses were done using a Micro-Tech 220 gas chromatograph with electron capture and flame photometric detector.

II Cadmium, Copper, Lead, Mercury, Zinc.

Atomic absorption measurements were made on a Jarrell Ash 82-500 spectrophotometer.

Reagents:

(1) Mercury Reducing Solution - To a 1-liter volumetric flask add 11g sodium chloride, 50g hydroxylamine sulphate, 140g stannous chloride and 100 ml 18N sulphuric acid. Dilute to volume with deionized water and mix. (Solution will be cloudy but clears with filtration.)

(2) Mercury Standard Solutions

(a) Stock Solution - 1000 ug/ml Dissolve 0.1354g $HgCl_2$ in 5% (v/v) nitric acid in a 100 ml volumetric flask and dilute to the mark.

(b) Intermediate Solution - 10 ug/ml Pipet 1.0 ml of stock solution into a 100 ml volumetric flask and dilute to the mark with 5% nitric acid solution.

(c) Working Solution - 0.1 ug/ml Pipet 2.0 ml of intermediate solution into a 200 ml volumetric flask and dilute to the mark with 5% nitric acid solution.

(3) Copper and Cadmium Solutions

(a) Stock Solution - 1000 ug/ml Dissolve 1.0 g of the cadmium or copper metal in a 1-liter volumetric flask and dilute to the mark with 5% nitric acid.

(b) Intermediate Solution - 100 ug/ml Pipet 10.0 ml of stock solution into a 100 ml volumetric flask and dilute to the mark with 5% nitric acid solution.

(c) Working Solution - 1.0 ug/ml Pipet 1.0 ml of intermediate solution into a 100 ml volumetric flask and dilute to the mark with 5% nitric acid solution.

(4) Lead Standard Solution

(a) Stock Solution - 1000 ug/ml Dissolve 1.5984 g of $Pb(NO_3)_2$ in a small quantity of deionized water and dilute to 1.0 liter volumetrically with 5% nitric acid solution.

(b) Intermediate Solution - 100 ug/ml Pipet 10.0 ml of stock solution into a 100 ml volumetric flask and dilute to the mark with 5% nitric acid solution.

(c) Working Solution - 1.0 ug/ml Pipet 1.0 ml of intermediate solution into a 100 ml volumetric flask and dilute to the mark with 5% nitric acid solution.

Sample Preparation

Ten grams of tissue, made up of equal portions from each individual fish represented in the sample, was weighed out; one half of this amount was used for the determination of cadmium, copper, lead and zinc, the other half for mercury.

The sample for mercury analysis was prepared as follows: Generally a 5 g sample of fish was accurately weighed and placed in a 250 ml erlenmeyer flask having a ground glass ST neck. To the flask was added 0.1 g vanadium pentoxide and a few glass beads. A water-cooled condenser was fitted into the top of the flask and the unit clamped over a hot plate. A 10 ml mixture of conc. H_2SO_4 (3 ml) and conc. HNO_3 (7 ml) was added via the condenser and the top of the condenser closed off with an acetone-dry-ice cold-finger. When all activity ceased in the flask, enough heat to start reflux action was added and refluxing was continued until all solid matter was dissolved and the solution was a clear green The heat source was removed and the flasks allowed to cool. Before being dismantled the cold-finger and condenser were rinsed down with ca. 5-10 ml deionized water, which was allowed to drain into the reaction flask. The contents of each flask were then filtered into separate 25.0 ml volumetric flasks and brought to the mark with deionized water. A blank was also prepared in this manner. Analysis was carried out within 24 hours of preparation.

Fish samples for cadmium, copper, lead and zinc were prepared by dry-ashing as follows: A 35.0 g sample of the fish was accurately weighed and placed in a "Vitreosil" dish. The dish and sample were placed in a muffle furnace. The temperature was raised from ambient to 450°C very slowly and ashing was completed within 24 hours. The dish and contents were allowed to cool down in the oven after which the ash was taken up in a 10% HCl solution. This was diluted to 100 ml making the sample ready for analysis.

Procedure

Lead: Analysis for lead was carried out by the Dithizone method as per 24.045, Official Methods of Analysis of A.O.A.C.

Cadmium, Copper, Zinc: The prepared solutions were selectively analyzed for metal content by atomic absorption. A hydrogen continuum lamp was used to measure and correct for non-atomic absorption.

Element	Fuel/Oxidant	Wavelength	Scale Expansion
Cadmium	C_2H_2 / Air	ca. 2288 A	8.0 X
Copper	C_2H_2 / Air	ca. 3247.5 A	9.0 X
Zinc	C_2H_2 / Air	ca. 2138.5 A	7.0 X
Mercury	Flameless	ca. 2536.5 A	5.0 X

Mercury: The digested solution was analyzed for mercury content by flameless atomic absorption. A 5.0 ml aliquot of diluted sample was pipeted into a 4 oz jar. 15 ml of deionized water were added to the jar and a magnetic stirring bar. The jar was placed on a magnetic stirrer and clamped securely. A rubber stopper was fitted into the jar. The stopper contained three tubes - one directly from a nitrogen cylinder, one leading to the glass flow-through cell, and one from a dropping funnel holding the reducing solution. Once sealed 10 ml of reducing solution is added to the jar and all stopcocks are turned to place the gap and contents in a closed system. The magnetic stirrer is activated and stirring is maintained at a constant rate for a full two minutes. The line running from the nitrogen cylinder through the jar to the cell is then opened allowing the mercury vapour to be carried into the cell for analysis. A strip chart recorder is used in conjunction with the instrument.

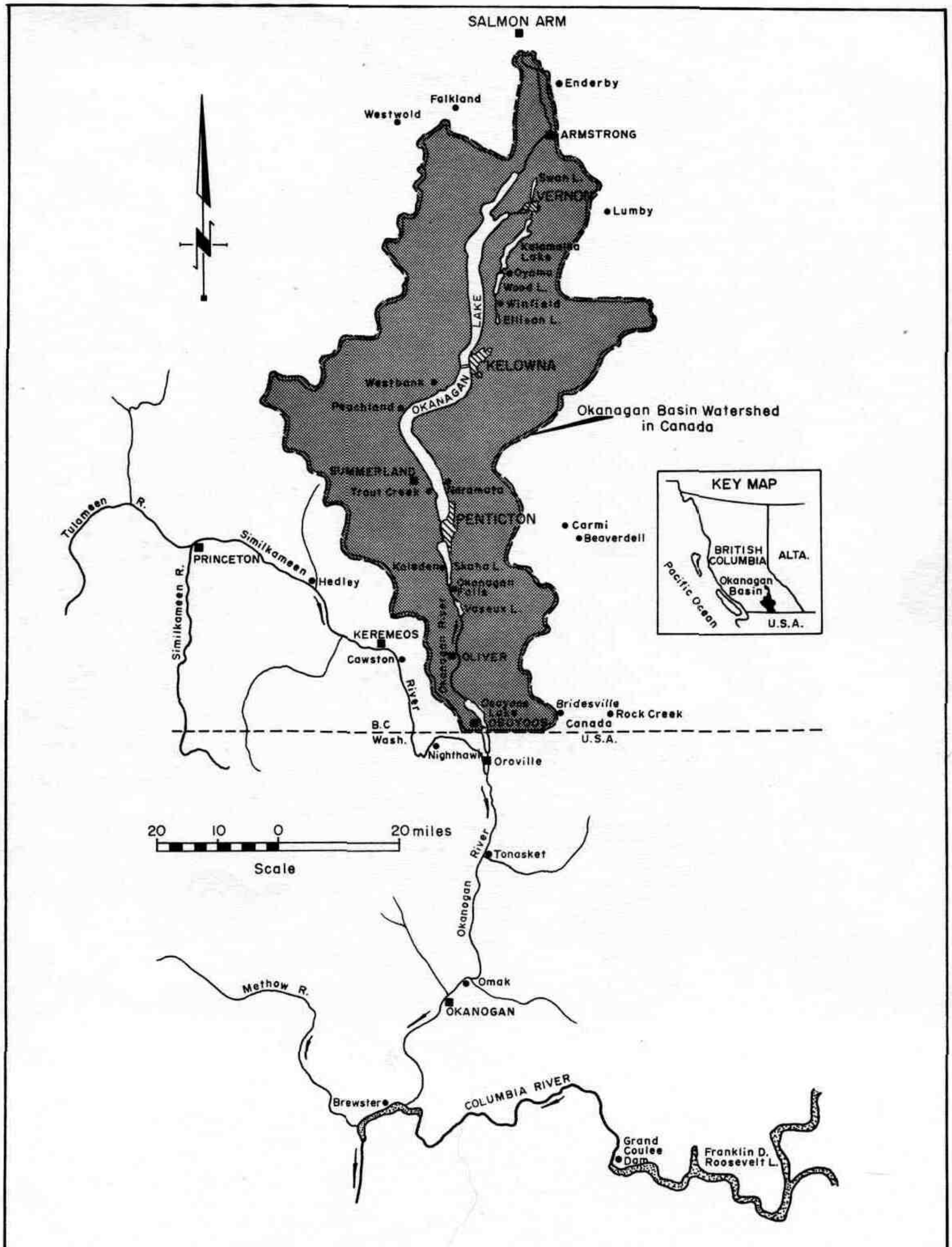
Appendix 3. Daily counts (1971) of spawning kokanee in some streams of the Okanagan basin.

DATE OF COUNT	LAKE: STREAM:	KALAMALKA COLDSTREAM	OKANAGAN VERNON	OKANAGAN EQUESIS	OKANAGAN WHITEMAN	OKANAGAN MISSION[1]	OKANAGAN POWERS	OKANAGAN TREPANIER	OKANAGAN PEACHLAND	SKAHA OKANAGAN RIVER (between Okanaga and Skaha Lake)
Sept. 14						1,156				
15						4,973				
16						4,599				
17						13,819				
18						16,994	28	0	46	
19		0	0			15,635				
20						15,405				
21						44,075				
22						21,500				
23						7,950				
24		0	0			10,925				
25			25			6,470	605	168	1,792	
26						12,730				16,000
27						15,240				
28						17,700				
29						27,030				
30						20,650	2,440	2,011		
Oct. 1						25,350			10,125	
2		0				19,700				
3						24,275	5,090	5,400	11,630	
4						13,250				
5		0	93			8,550				
6						2,500	5,295	5,120	12,500	
7						1,724				
8						2,000				
9		80	340							
10										
11										
12									9,850	
13							4,550	5,005		
14		6,040	635	12,000						
15										
16										
17										
18							2,460	5,800	10,650	
19										
20		20,600								
21			450							
22								5,150	15,100	
23										
24										
25										
26		26,700	350							
27				3,400				1,840	10,850	
28										
29										
30										
31		26,000							11,100	
Nov. 1										
2										
3										
4										
5		26,500							7,000	
6										
7										
8										
9										
10										
11										
12		16,500								
13										
14										
15										
16										
17										
18		8,000								

[1] Numbers passing the fish-counting fence which is shown in Fig. 15.

Appendix 4. Mean lengths and weights based on kokanee males and females of each population. Mean number of eggs per female.

Stream	Mean Length (mm)	Mean Weight (gm)	Mean Number of Eggs per Female
Coldstream	215	100	240
Equesis	254	158	-
Mission	260	183	480
Powers	259	177	530
Trepanier	260	183	490
Peachland	258	178	410
Trout	245	-	-
Okanagan	330	346	990



OKANAGAN DRAINAGE BASIN IN CANADA