CHAPTER 4

Tributary Streams

4.1 BACKGROUND AND RATIONALE

According to local personnel of the B.C. Fish and Wildlife Branch, sections of at least 21 tributary streams of the Okanagan Basin support viable rainbow and/or brook trout populations or did so historically. These fish stocks are currently maintained entirely by natural reproduction, although some stocking was conducted in the past. Most of these tributaries are also utilized for reproduction and rearing by salmonid species from the main valley lakes (see Chapter 5). Two of the streams, Inkaneep and Vaseux, support occasional runs of steelhead trout (S. MacDonald, personal communication).

Two categories of trout harvest capacity estimates were derived for the Okanagan tributary streams, both intended to reflect an annual sustainable harvest equilibrium:

1) Primary potential harvest capacity: the estimated amount of trout which could be harvested annually given a "minimal optimum" discharge regime (see Section 4.3), consistent with the overall average annual discharge volume, and given present physical stream habitat characteristics.

2) Present available' harvest capacity: the primary potential harvest capacity adjusted (downward) to take account of disparities between the present discharge regime and the estimated minimal optimum discharge requirement.

While it is necessary to define both types of harvest capacities here, due to the process used to arrive at results, only the present available capacity is dealt with in detail in this; section. The primary potential harvest capacity, being an alternative, is considered in detail in Chapter 16.

The primary capacities of the Okanagan tributaries to produce trout yields were estimated by reference to published accounts of trout stream yields from other locales, in conjunction with a limited creel census and population sampling program conducted on Trout Creek (tributary to Okanagan Lake) in 1971. Harvest capacity estimates derived for Trout Creek were extrapolated to the other tributaries on the basis of relative lengths of angling reaches and relative natural discharge volumes. Primary potential harvest capacity estimates were adjusted, on the basis of available seasonal discharge estimates as a percent of estimated minimal optimum discharge requirements, to give present available harvest capacity estimates.

Details of location of and access to, those Okanagan tributary streams which provide sport-fishing opportunities are given in Appendix G. These streams are depicted (along with others) on the map, Figure 3.1.

4.2 PRIMARY POTENTIAL HARVEST CAPACITIES

4.2.1 Primary Potential Harvest Capacity of Trout Creek

A limited sampling of the Trout Creek sport fishery between Thirsk Reservoir and Summerland Irrigation District intake in 1971 yielded the following estimates

Length of angling reach sampled	19 miles
Total angling-days	500
Total angling-hours	1202
Total estimated catch -	
Rainbow trout, number	1815
Rainbow trout, pounds	109
Brook trout, number	1130
Brook trout, pounds	90

The average stream width through this reach of Trout Creek is estimated to be about 15 feet. On this basis, the total realized harvest in 1971 was 85 trout weighing 5.7 pounds per acre, or 155 trout weighing 10.5 pounds per mile.

Rotenone samples were obtained through four short reaches of Trout Creek within the overall angling area. These indicated an average abundance of 1285 rainbow trout and 409 brook trout per mile of stream. At the average weight of trout prevailing in these samples (14 grams = 0.0309 pounds), this is equivalent to a standing crop of 52.3 lb/mile, or 28.8 lb/acre. This is considered to be a minimal estimate because very few young-of-the-year trout were held by the retaining net employed in the sampling.

An examination was made of published records pertaining to the fish productivity, standing crop, and yield of salmonid fishes from small streams in temperate zone regions in various parts of the world. These findings are summarized in Table 4.1. While the various trout yields quoted are resultant from a variety of fishing pressures and other conditions, it would appear that annual yields of about 30 pounds per acre may be near the ultimate realistic capacity for small salmonid streams. In this connection the recorded yields from the three Oregon coho salmon streams (30.6 lb/acre) are particularly instructive, since they refer to migrating smolts which may be interpreted as an ultimate form of yield potential. Also relevant is the proposition put forth by Le Cren (1969) that "the rate of salmonid production in normal, natural small streams has a maximum of about 12 $g/m^2/a$ (= 108 pounds per acre per year), even in streams of quite different ecology and natural productivity, and even with populations of trout differing markedly in their growth rates, age structure, and migratory tendencies". Chapman (1967) found that production/yield ratios for salmonid streams typically range from 2.0 to 3.6, corresponding to ultimate yield capacities of 30-54 pounds per acre on the basis of Le Cren's hypothesis.

TABLE 4.1

COMPARATIVE PRODUCTION, STANDING CROP, AND YIELD OF SALMONID FISHES IN SELECTED STREAM HABITATS[a]

Stream	Species	Production lb/acre/yr	Standing Crop lb/acre	Yield lb/acre/yr	Reference
Lawrence Creek Wisconsin	Brook trout	89.9	52.0	11.6	Hunt, 1966
Three streams Oregon	Coho salmon	76.8	30.7	30.6	Chapman, 1965
Horokiwi Stream New Zealand	Brown trout	488.0	244.0	32.5	Allen, 1951
Ten streams Great Britain	Brown trout	26.8-108.0	4.5-115.0	-	Le Cren, 1969
Big Spring Cr. Virginia	Rainbow trout	-	-	30.6	Surber, 1937
Furnace Brook Vermont	Trout	-	-	34.0	Needham, 1969
Seven streams Michigan	Rainbow trout	-	-	15.5	Shetter, 1944
St. Mary River Virginia	Brook and Rainbow trout	-	-	8.6	Shetter, 1944
Trout, Creek B.C.	Brook and Rainbow trout	-	28.8	5.7	Present Study

[a] Includes only streams where artificial stocking has been nil or negligible.

On the basis of the foregoing, and by reference to the standing crop and present (1971) harvest from Trout Creek, it was concluded that 12 pounds per acre is a reasonable (and probably conservative) estimate of the primary annual potential sustainable harvest capacity of Trout Creek under "minimal optimum" discharge conditions and present physical stream habitats. Assuming a mean weight of trout in the angling harvest as was observed in 1971 (0.0676 pounds), this corresponds to 178 trout per acre, or 323 trout per mile, or 6132 trout for the entire reach (b + c) of Trout Creek between Thirsk Reservoir and Summerland Irrigation intake.

4.2.2 Extrapolation to Other Tributaries

It was assumed that the primary potential trout harvest capacity of any Okanagan stream which supports trout could be estimated by reference to the estimate for Trout Creek (6132 fish per year) taking cognizance of:

1) The relative length of stream reach

2) The relative natural discharge volume (from Appendix G).

Stream lengths and discharge volumes are rated separately (relative to Trout Creek, Reach b + c, = 1.000) in Table 4.2. Also given are the products of the

TABLE 4.2

MEAN ANNUAL DISCHARGES, LENGTHS OF ANGLING REACH, AND PRIMARY POTENTIAL TROUT HARVEST CAPACITIES OF OKANAGAN TRIBUTARY STREAMS RELATIVE TO TROUT CREEK. ALSO GIVEN ARE ABSOLUTE PRIMARY POTENTIAL TROUT HARVEST CAPACITIES.

Creek and Reach	Mean Annual Natural Discharge Relative to Trout Creek[b] (Reach b+c)	Length of Angling Reach Relative to Trout Creek (Reach b+c)	Primary Potential Annual Trout Harvest Capacity for "Minimal Optimum" Discharge	
			Relative to Trout Creek (Reach b+c)	Absolute, Number of Trout
B-X, Upper	0.114	0.211	0.024	147
B-X, Lower	0.138	0.158	0.022	135
Coldstream	0.235	0.211	0.050	307
Deep	0.169	0.105	0.018	110
Equesis	0.286	0.421	0.120	736
Ellis	0.2[a]	0.447	0.089	546
Inkaneep	0.2[a]	0.105	0.021	129
Kelowna	0.325	0.105	0.034	208
Lambly	0.713	0.579	0.413	2,533
Mission (a)	1.477	0.211	0.312	1,913
(b)	2.122	0.474	1.006	6,169
(c)	2.523	0.368	0.928	5,690
Peachland	0.290	0.526	0.153	938
Penticton	0.552	0.526	0.290	1,778
Powers	0.276	0.526	0.145	889
Shingle (a)	0.2[a]	0.368	0.074	454
(b)	0.2[a]	0.316	0.063	386
Shorts	0.656	0.632	0.415	2,545
Shuttleworth	0.2[a]	0.158	0.032	196
Trepanier	0.564	0.474	0.267	1,637
Trout (a)	0.201	0.579	0.116	711
(b,c)	1.000	1.000	1.000	6,132
Vaseux	0.3[a]	0.632	0.190	1,165
Vernon (a)	0.190	0.315	0.060	368
(b)	0.744	0.263	0.196	1,202
Whiteman (a)	0.343	0.316	0.108	662
(b)	0.322	0.368	0.118	724
TOTAL				38,410

[a]Rough estimate, from drainage area relative to Trout Creek.
[b]As pertaining to a "dry" year (Smyth MS 1973).

two separate ratings for each stream, these corresponding to the primary potential trout harvest capacities for minimal optimum discharge relative to Trout Creek (reaches b + c). Multiplication of these composite ratings by the independently estimated value for Trout Creek (6,132 fish) produced the absolute estimates; primary potential annual harvest capacities for the separate stream reaches (Table 4.2). The relevant assumptions are apparent from the procedure as outlined. The resultant estimated overall primary potential harvest capacity for all tributaries in the Basin is 38,410 trout, weighing 2,596 pounds.

4.3 DISCHARGE AND OTHER CONSTRAINTS TO TROUT PRODUCTIVITY AND UTILIZATION

Various particular conditions of land ownership and access affect angling utilization of the Okanagan tributaries. Stream channel modifications, and more particularly, water abstraction and flow manipulation, affect the actual production and survival of trout in these streams. The major constraints in these regards are cited in Appendix H.

In the present treatment, specific attention was directed only to discharge constraints. It has been suggested (Elser MS 1972) that adequate reproduction and rearing of resident salmonids is assured in Montana trout streams by minimum flows of 60% of mean annual discharge during April-September; 30% of mean annual discharge during October-March; and absolutely no less than 10% of mean annual discharge for any short time interval. Elser further suggests that "most natural stream flow regimens rarely fall below these levels".

In view of the characteristic "flash-flood" discharge regimes of the Okanagan tributaries, and the apparent basic compatibility of the indigenous trout stocks with such regimes, it seemed reasonable that a less stringent formulation of the "Montana Method" could be adopted for estimating the "minimal optimum" trout stream discharge requirements in the Okanagan. These requirements were accordingly (and arbitrarily) assigned as 30%, 15%, and 10% of mean annual discharge during April-September, October-March, and short-term respectively. This liberalization of minimal optimum requirements, as compared with Elser (MS 1972), is considered consistent with the proposition that primary harvest capacity of trout in Okanagan tributaries is half or less per unit area of the theoretical harvest capacity for small trout streams generally. It is also noted that flows higher than the "minimal optimum", up to approximately flood stage, would promote progressively higher trout productivity.

Suggested minimum discharge requirements for the Okanagan trout streams on the basis of the above criteria are identified in Appendix G. In addition to these criteria, it was arbitrarily assumed that absolute minimum requirements of 3.5, 2.0, and 1.5 cfs during summer, winter and short-term respectively, would apply. These values were also adopted for stream reaches for which actual flow measurements were unavailable.

Present average most critical values of seasonal discharge were identified for each trout stream reach for summer (April-September) and winter (October-March) periods. In general, these were taken from mean monthly discharge data and estimates pertaining to a "dry" year. These were considered to give a more realistic approximation of actual critical flows available to fish in an average year than average annual flows per se. This is because fish are dependent on instantaneous discharges which are necessarily lower than mean monthly flows about half the time. The estimated most critical available flows are given, along with the suggested minimal optimum discharge requirements, in Appendix G. These most critical available discharges are presented as percentages of the estimated corresponding discharge requirements in Table 4.3.

Identification of discharge requirements, and the extent to which they are met, is in itself not an adequate basis for estimating the actual impact on stream fish productivity. This is because the relationship is not linear. Kraft (1972) found that a 90% flow reduction in test sections of a Montana stream resulted in a numerical trout reduction of 62%. Numbers of trout in control sections were reduced 20% concurrently, so that the reduction attributable to de-watering was about 42%. Gradient of the Montana stream was less than is typical of Okanagan tributaries (0.76%, compared with a combined average of 1.61% for three major Okanagan streams - Equesis, Mission and Trout - combined). It is thus anticipated that the effects of de-watering will be proportionately more severe in Okanagan tributaries by virtue of the lesser depths induced by the steeper gradients. From Manning's (1891) hydraulic formula for flow in open channels

$$d_1/d_2 = (s_2/s_1)^{0.3}$$

<u>where:</u>

d_1 = mean depth of Okanagan stream
d_2 = mean depth of Montana stream
s_1 = mean gradient of Okanagan stream
s_2 = mean gradient of Montana stream

We have $d_1/d_2 = (0.76/1.61)^{0.3} = 0.798$.

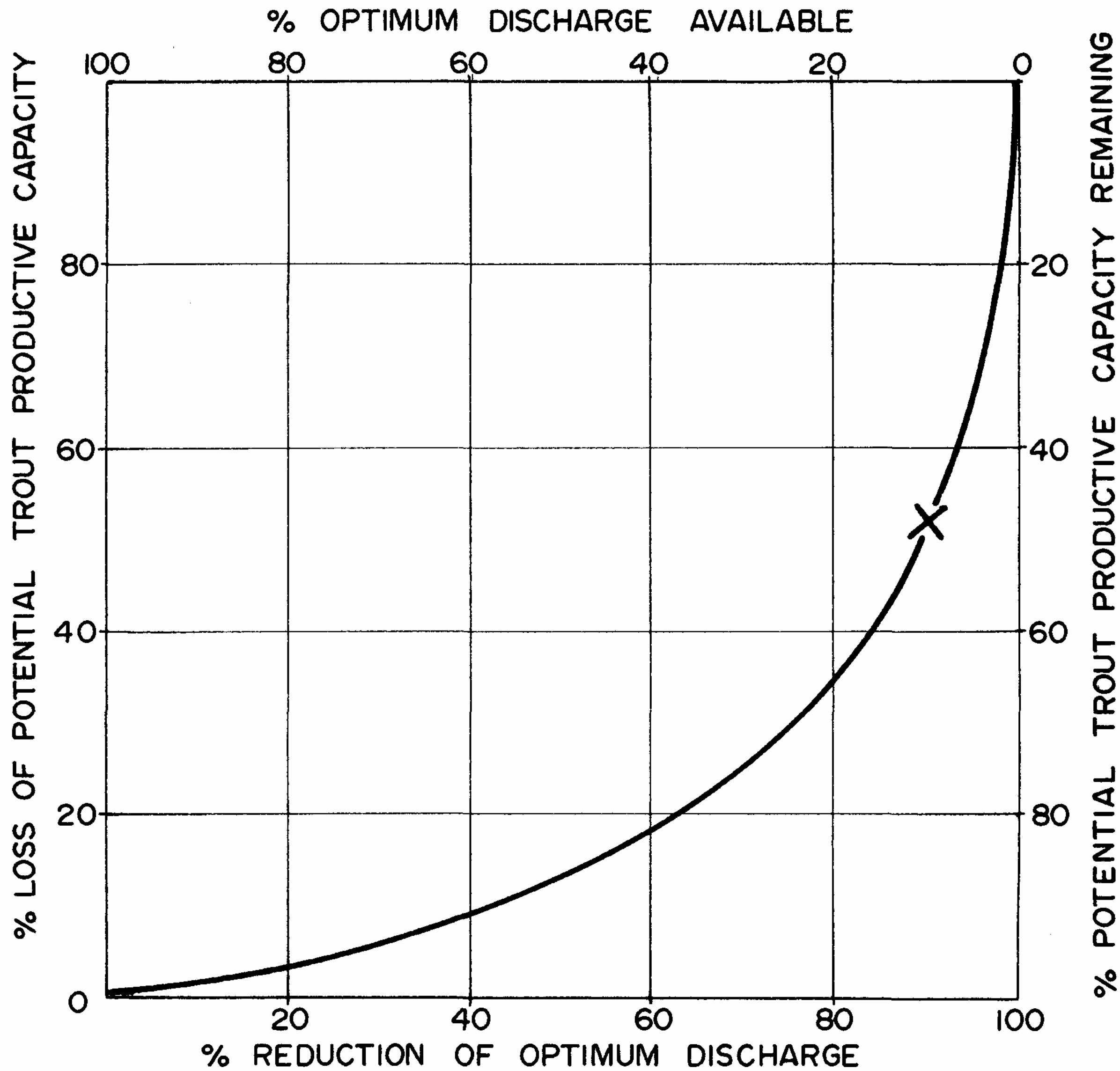
Or, the anticipated effect on resident fish, by virtue of depth reduction, will be 1/0.798 = 1.25 times greater for the average Okanagan stream because of the steeper gradient.

On this basis, it might be expected that a 90% de-watering of a "typical" Okanagan tributary would produce a 42 x 1.25 = 52.5% reduction in trout productive capacity. This was adopted as the pivotal value for a plot of percent loss of trout productive capacity versus percent reduction of normal discharge, (Figure 4.1).

TABLE 4.3

RELATIVE AVAILABLE DISCHARGE UNDER PRESENT OPERATING CONDITIONS, AND PRESENT AVAILABLE TROUT HARVEST CAPACITIES, OKANAGAN TRIBUTARY STREAMS.

Creek and Reach	Most Critical Value of "Present" Available Discharge as a Percent of Estimated "Minimal Optimum" Requirement	Percent of Basic Potential Trout Productivity Remaining	Present Available Annual Harvest Capacity for "Present" Discharge, Number of Trout
B-X, Upper	4	22	32
B-X, Lower	17	61	82
Coldstream	21	67	206
Deep	23	69	76
Equesis	93	99	729
Ellis	60	87	475
Inkaneep	14	57	74
Kelowna	54	88	183
Lambly	17	62	1,570
Mission (a)	66	93	1,779
(b)	57	90	5,552
(c)	48	86	4,893
Peachland	50	87	816
Penticton	35	79	1,405
Powers	36	80	711
Shingle (a)	14	57	259
(b)	34	78	301
Shorts	30	75	1,909
Shuttleworth	25	71	139
Trepanier	39	81	1,326
Trout (a)	48	86	611
(b,c)	55	89	5,457
Vaseux	100	100	1,165
Vernon (a)	51	87	320
(b)	23	69	829
Whiteman (a)	70	95	629
(b)	76	96	695
TOTAL			32,223



RELATION BETWEEN LOSS OF POTENTIAL RESIDENT TROUT PRODUCTIVITY AND REDUCTIONS FROM OPTIMUM DISCHARGE, OKANAGAN TRIBUTARY STREAMS.

Figure 4.1

4.4 PRESENT AVAILABLE TROUT HARVEST CAPACITIES

The most critical values of available discharge under present hydrology and tributary operation (Table 4.3) were referred to the graph of productive capacity vs discharge reduction (Figure 4.1), and the corresponding percentages of trout productivity remaining were estimated. These estimates are given in Table 4.3. For each stream reach they were multiplied by the corresponding estimate of primary potential trout harvest capacity (Table 4.2). The resulting estimates of present available annual trout harvest capacity for present average discharge regimes are included in Table 4.3. The overall present available harvest capacity (all tributaries) is 32,223 trout weighing 2178 pounds. This is only 16% less than the overall primary potential harvest capacity based on minimal optimum discharges.

4.5 DISCUSSION OF PROCEDURES AND RESULTS

This analysis of trout harvest capacities in Okanagan tributaries proceeded from the following important assumptions:

1) That Trout Creek can sustain about twice the present angling harvest of resident trout, viz. about 12 lb/acre
2) That the trout harvest capacity of Okanagan tributary streams is related to the trout harvest capacity of Trout Creek in direct proportion to:
   (a) length of stream
   (b) mean annual discharge.
3) That the size of fish in angler's creels at Trout Creek is representative of the other streams.
4) That sub-optimal discharges and their effects on resident trout production can be identified and quantified according to the models derived.

The relevant data base included the following items:

1) A brief characterization of the 1971 Trout Creek sport fishery, and of the actual catch.
2) An indication of the standing crop of trout in Trout Creek.
3) Published accounts of trout production, standing crop, and yield from other small trout streams elsewhere.
4) Lengths of stream reaches and mean annual discharges (usually) for those Okanagan tributaries with resident trout fishery potentials.
5) Published accounts of reactions of stream trout to discharge reductions below minimal optimum requirements.
6) A reasonable indication of average annual critical (low) discharges in Okanagan tributaries.

It seems probable that the estimate of primary potential harvest capacity for Trout Creek (12 lb/acre) is minimal. Because of access constraints, present harvest (5.7 lb/acre) takes place only very intermittently along the 19-mile reach in question.

It is noted that trout fishing in the Okanagan tributary streams, while providing a different type of angling experience than is offered by the headwater lakes, produces much smaller trout. The average size of fish in creels from Trout Creek (1971) was 0.07 pound; from the headwater lakes it was 0.51 pound. Catch-per-unit-effort however, (in terms of numbers) is over four times as high from streams. Growth of trout in Okanagan streams is much slower than in the lakes.

It is apparent that storage reservoirs on tributary systems expand opportunities to meet resident stream fishery flow requirements. However, these opportunities have not to date received much priority in Okanagan reservoir operations. It is probable that present operations tend to benefit stream trout in summer in those stream reaches situated between reservoirs and diversion points. Unfortunately, gains of this nature achieved in summer tend to be almost cancelled by proportionate losses induced in winter. No specific assessment was made of the absolute water demands implicit in meeting the minimal optimum discharge requirements for resident stream fisheries as estimated. In many cases the actual demands would probably be quite small as deficiencies tend to be short-term. However, in general the resident Okanagan stream fisheries do not appear particularly sensitive to reduced flows, except where such flows virtually cease. Overall, only a 16% enhancement in stream trout productive capacity is predicted from a minimal optimization of discharge regimes for this purpose. Often then, water which might be diverted for the particular benefit of resident stream trout will tend to yield greater fishery benefits if applied to the maintenance of requisite levels for trout in the headwater reservoirs and more particularly, if applied to propagation of salmonids from the main valley lakes in the lower stream reaches.

No attempt was made in the present analysis of resident stream trout production to estimate the particular disbenefits of stream channelization and other cultural modifications to physical stream habitats. Such disbenefits are certainly real, but tend to be confined to the lower stream reaches and accordingly have less wide-spread implications for resident stream fishes than does discharge. Some recognition was given to these disbenefits indirectly, in the adoption of the relatively conservative estimate of 12 lb/acre as the primary potential harvest capacity baseline for present physical habitat and minimal optimum discharge. It is apparent that stream bank preservation measures would significantly enhance resident stream trout productive capacities in these most accessible lower stream reaches.

CHAPTER 5
Main Valley Lakes

5.1 BACKGROUND AND RATIONALE

At least 27 fish species inhabit the main valley lakes of the Okanagan Basin. The known distribution of these species, along with their general ecological and human desirability classification, is given in Table 5.1.

At present these lakes support a substantial sport fishery; about 85,000 angling days annually. Except for a relatively minor subsistence and ceremonial fishery for sockeye salmon conducted by native indians in the lower mainstem area, angling is at present the only legitimate method of exploiting fish stocks in the Okanagan Basin.

Present gross sustainable fish harvest capacities of the main valley lakes were estimated on the basis of morphometric and edaphic parameters according to an existing model developed for exploited north-temperate lakes at comparable latitude (Ryder, 1965). This analysis was applied on the basis of species groups, aggregated according to the general classification noted in Table 5.1.

In view of the particular importance of kokanee and rainbow trout to Okanagan fisheries, and also in consideration of their special habitat requirements and vulnerabilities, more refined estimates were attempted for productive capacities and harvest of these two species. The rationale for these derivations is outlined in Figures 5.1 and 5.2. In summary, estimates were made of the present capacities of each of the lakes to accept the fry of kokanee and rainbow trout. These estimates were accompanied by estimates of present actual (for rainbow trout) or relative (for kokanee) fry production. Degree of utilization of fry carrying capacity was identified and quantified for each lake. Also estimated were the specific sustainable harvest capacities of both species for present conditions of recruitment and lake water quality.

The analysis of kokanee and rainbow trout stocks and harvest capacities as outlined proceeded from the fundamental proposition that present population parameters, spawning escapements, and harvests are representative of long-term conditions. There is in fact some reason to suspect that present (1971) kokanee abundance and harvest were above average. It has also been necessary to assume that present exploitation is at or below productivity equilibrium levels, i.e., that over-exploitation is not occurring. On this basis, minimum estimates of present harvest capacities for both species were equated with present actual harvests. This assumption (that stocks are not being over-exploited at present) may or may not be valid; however adequate assessment is completely beyond the

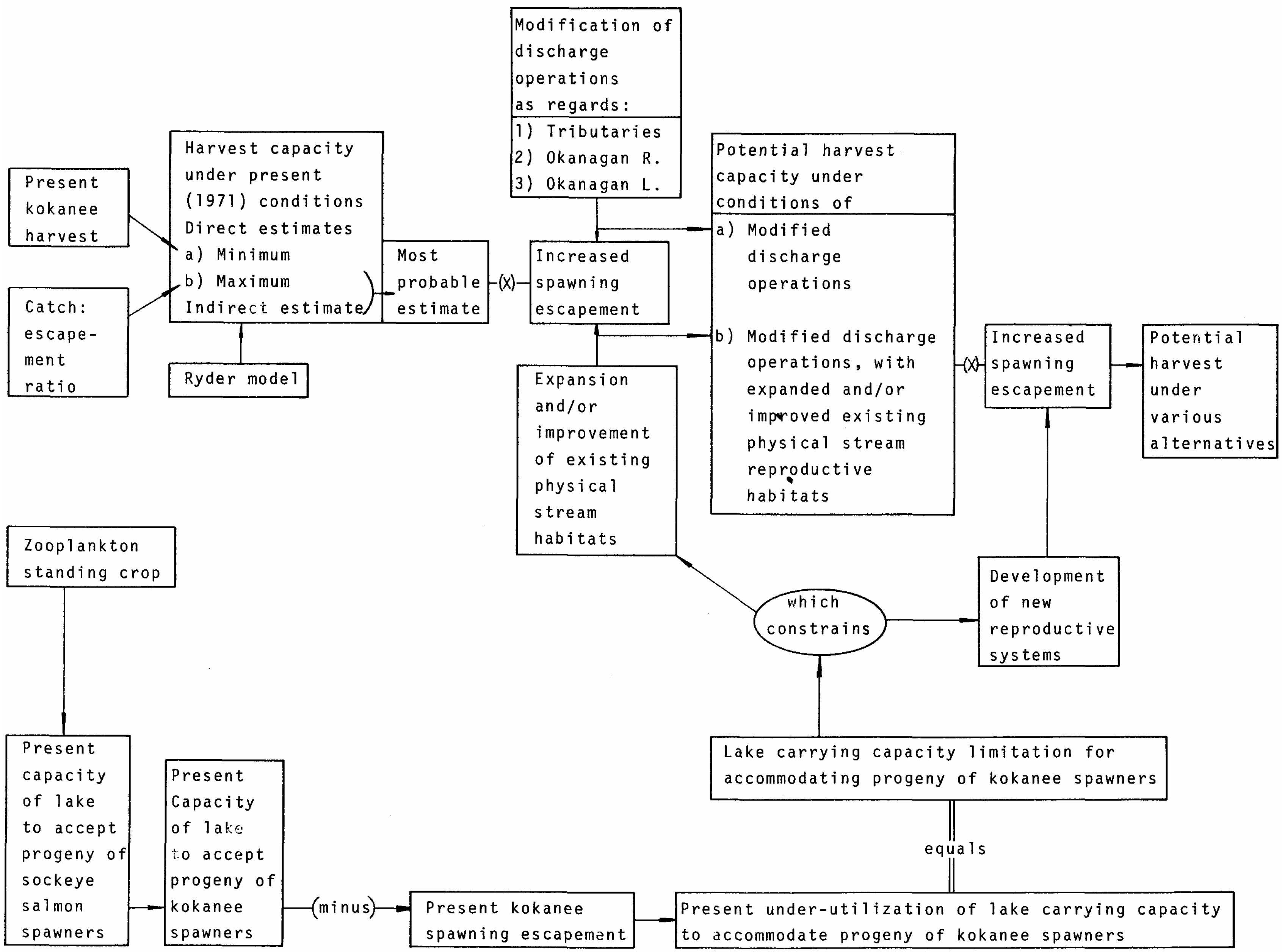
TABLE 5.1

KNOWN OCCURRENCE[a] AND CATEGORIZATION[b] OF FISH SPECIES IN THE OKANAGAN MAIN VALLEY LAKES

Common Name	Scientific Name	Sport Fish		Commercial	Coarse Fish		Forage Fish	Lake Occurrence					
		Preferred	Marginal		Preferred	Marginal		Wood	Kalamalka	Okanagan	Skaha	Vaseux	Osoyoos
Kokanee	*Oncorynchus nerka*	🐟						●	●	●	●	●	●
Rainbow trout	*Salmo gairdneri*	🐟						●	●	●	●	●	●
Steelhead trout	*Salmo gairdneri*	🐟											●
Lake trout	*Salvelinus namaycush*	🐟							●				
Mountain whitefish	*Prosopium williamsoni*	🐟						●	●	●	●	●	●
Smallmouth bass	*Micropterus dolomieui*	🐟										●	●
Largemouth bass	*Micropterus salmoides*	🐟										●	●
Yellow perch	*Perca fluviatilis*		🐟									●	●
Burbot	*Lota lota*		🐟							●	●		
Black bullhead	*Ictalurus melas*		🐟									●	●
Pumpkinseed	*Lepomis gibbosus*		🐟								●	●	●
Black crappie	*Pomoxis nigromaculatus*		🐟										●
Lake whitefish	*Coregonus clupeaformis*			🐟						●	●	●	●
Chinook salmon	*Oncorynchus tshawytscha*			🐟									●
Sockeye salmon	*Oncorynchus nerka*			🐟									●
Largescale sucker	*Catostomus macrocheilus*				🐟			●	●	●	●	●	●
Longnose sucker	*catostomus catostomus*				🐟				●	●	●	●	●
Carp	*Cyprinus carpio*				🐟			●	●	●	●	●	●
Northern squawfish	*Ptychocheilus oregonensis*					🐟		●	●	●	●	●	●
Peamouth chub	*Mylocheilus caurinus*					🐟		●	●	●	●	●	●
Chiselmouth	*Acrocheilus alutaceus*					🐟		●	●	●	●	●	●
Pygmy whitefish	*Prosopium coulteri*						🐟				●		●
Redside shiner	*Richardsonius balteatus*						🐟	●	●	●	●	●	
Leopard dace	*Rhinichthys falcatus*						🐟			●			
Longnose dace	*Rhinichthys cataractae*						🐟		●				
Prickly sculpin	*Cottus asper*						🐟	●	●	●	●	●	●
Slimy sculpin	*Cottus cognatus*						🐟		●	●			

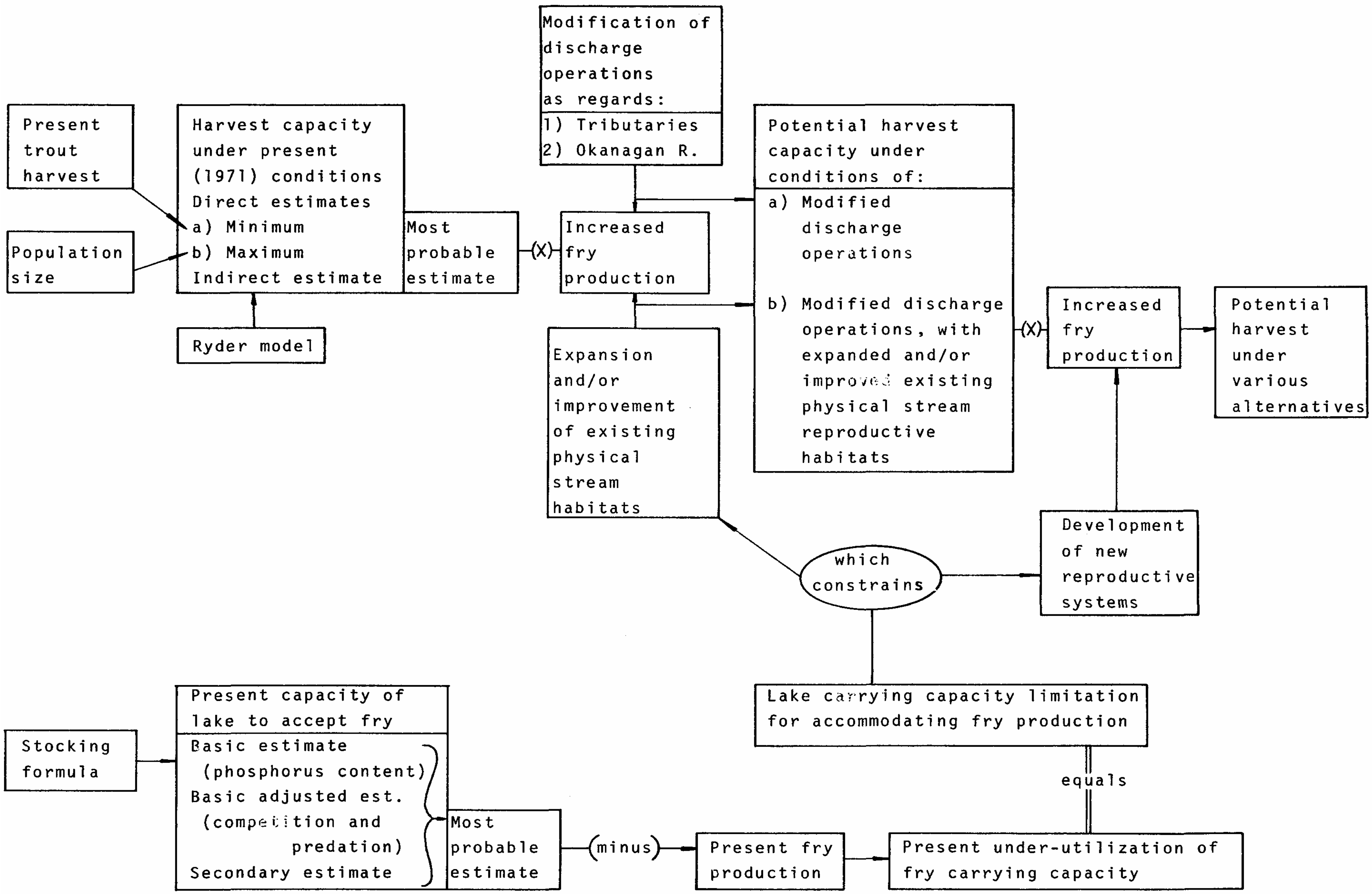
[a] Adapted from Northcote, et al. (MS 1972)

[b] Arbitrary. Some species could fit categories other than those indicated.



CONCEPTUAL MODEL FOR DERIVING POTENTIAL HARVEST CAPACITY ESTIMATES AND LAKE CARRYING CAPACITY CONSTRAINTS FOR KOKANEE IN THE OKANAGAN MAIN VALLEY LAKES.

FIGURE 5.1



CONCEPTUAL MODEL FOR DERIVING POTENTIAL HARVEST CAPACITY ESTIMATES AND LAKE CARRYING CAPACITY CONSTRAINTS FOR RAINBOW TROUT IN THE OKANAGAN MAIN VALLEY LAKES

FIGURE 5.2

scope of the study and of the available data base. Catch:escapement ratios differ markedly among these lakes, but at least for kokanee, they are lower than for certain other British Columbia waters. It also seems relevant that the Okanagan Lakes have provided a long history of generally attractive (but certainly fluctuating) sport-fishing experience.

5.2 OVERALL FISH HARVEST CAPACITIES: ESTIMATES OF GROSS ANNUAL SUSTAINABLE HARVEST

Fish harvest capacity is influenced by three basic groups of factors: morphometric (pertaining to lake dimensions), edaphic (pertaining to nutrient availability), and climatic. Ryder (1965), by selecting lakes so as to exclude most of the variability due to climate, derived a highly significant multiple regression for fish harvest on mean depth (as an index of morphometry) and total dissolved solids (as an index of edaphic conditions). This relation has the form:

$$H = (5.616)\ (TDS^{0.28777})/(\check{z}^{0.50891})$$

Where:
H = observed fish harvest in pounds per acre per year
TDS = total dissolved solids in parts per million
$\check{z}$ = mean depth in feet

Ryder's derivation was on the basis of north-temperate lakes situated below 2000 feet elevation. The relation should accordingly be generally applicable to the Okanagan main valley lakes which also meet these criteria. Expected values of total sustainable fish harvest capacities (all species) on this basis, herein referred to as primary estimates of gross annual harvest capacities, are given for the Okanagan lakes in Table 5.2.

TDS, although useful as a general index of edaphic conditions, is clearly too imprecise and insensitive to reflect such relationships as the cultural eutrophication of the lower Okanagan main valley lakes, or the specialized nutrient chemistry of Kalamalka Lake. A means was therefore sought for adjusting the primary estimates of gross fish harvest capacities according to more critical nutrient relationships. Mean concentrations of total phosphorus in the lake water (Table 5.2), when plotted against chlorophyll concentrations (Figure 5.3), revealed a relationship which, although based on only five data points, is significant at the 95% level. Since chlorophyll is indicative of the basic productivity upon which subsequent aquatic production (including fish) is based, the relative level of phosphorus in the lake water seemed a reasonable (but unproved) criterion for adjusting estimates of fish harvest capacity. The assumption was made that Okanagan Lake phosphorus levels have been least affected by cultural activities (cf. Skaha Lake, etc.), and are not affected by such peculiarities of internal chemistry as are operative for example, in Kalamalka Lake (St. John, personal communication). The adjustment procedure, accordingly, was to revise the primary

TABLE 5.2

CALCULATION OF PRIMARY AND SECONDARY ESTIMATES OF GROSS ANNUAL FISH HARVEST CAPACITIES FOR THE OKANAGAN MAIN VALLEY LAKES UNDER PRESENT (1971) CONDITIONS (ALL SPECIES COMBINED)

Lake	Area,[a] (Acres)	Mean Depth (feet)	Total Dissolved Solids[b], Average Parts per Million	Harvest[c], Pounds/ Acre/Year	Average Concentration of Total Phosphorus[d], (Micrograms per Liter) (1)	(2)	(3)	Mean	Relative[e] Phosphorus Concentration	Adjusted Harvest[f] Pounds per Acre per Year
Wood	2,298	72.2	211	2.968	213	293	150	219	7.30	21.7
Kalamalka	6,400	193.6	252	1.891	14	7	20	14	0.47	0.9
Okanagan	85,990	249.3	164	1.469	29	31	30	30	1.00	1.5
Skaha	4,967	85.3	164	2.536	97	64	70	77	2.57	6.5
Vaseux	680	21.3	164[g]	5.138				77[g]	2.57[g]	13.2
Osoyoos	3,719	56.6	168	3.146	91	62	65	73	2.43	7.6

[a] From Stockner (MS 1973).

[b] From Patalas and Saiki (1973).

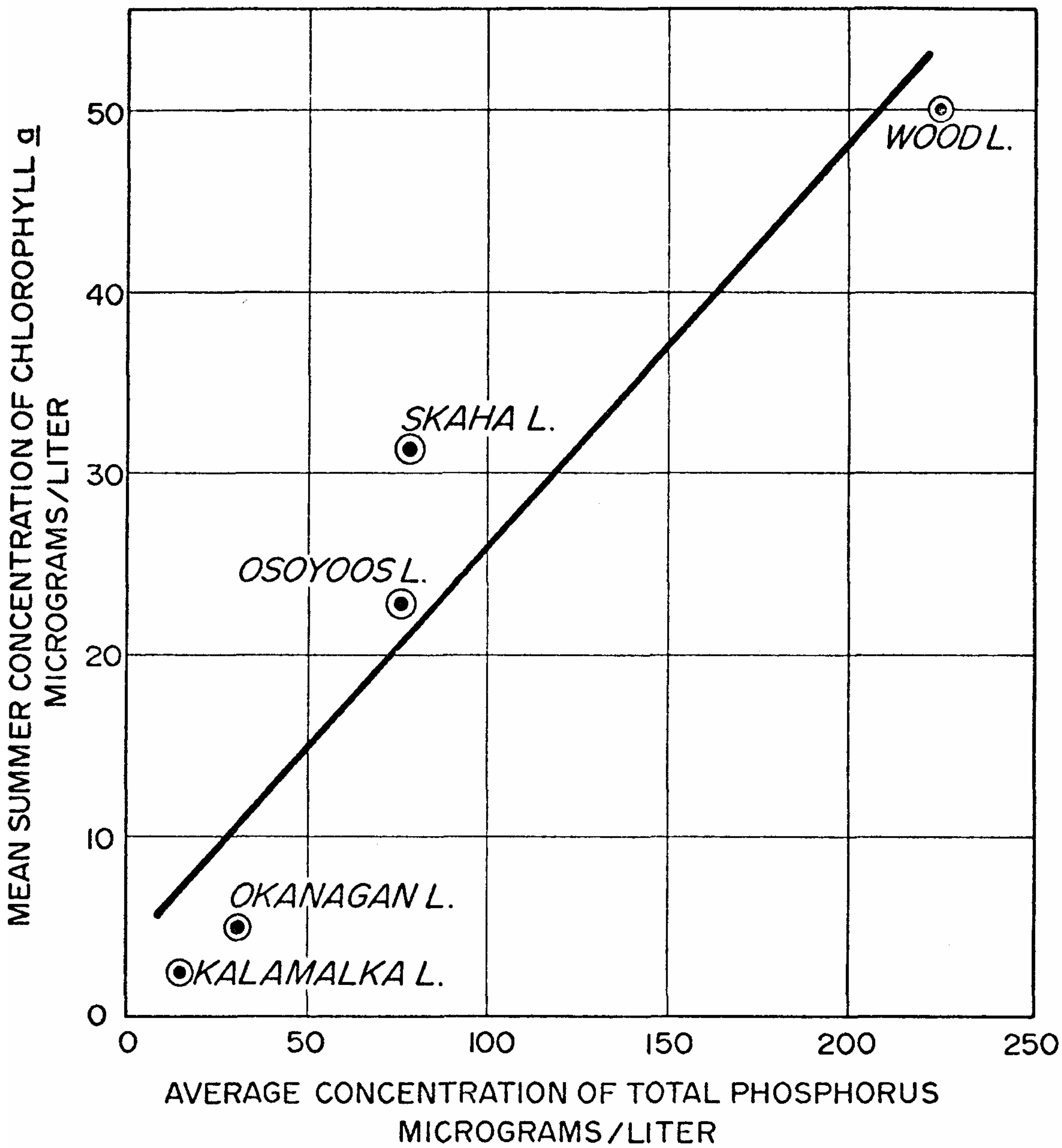
[c] Primary estimates of gross fish harvest capacity (all species) on basis of mean depth and Total Dissolved Solids as per Ryder (equation 6) 1965.

[d] From Stockner (MS 1973). Original sources are: 1) B.C. Research spring overturn studies 1970; 2) Canada Energy Mines and Resources spring overturn samples 1971; 3) Coulthard and Stein average summer values 1969.

[e] Relative to Okanagan Lake

[f] Secondary estimates of gross fish harvest capacity (all species) from primary estimates adjusted for concentration of total phosphorus relative to Okanagan Lake

[g] Estimated by reference to Skaha Lake



RELATION BETWEEN CHLOROPHYLL CONCENTRATION AND TOTAL PHOSPHORUS CONTENT OF WATER FROM THE OKANAGAN MAIN VALLEY LAKES

Figure 5.3

estimates of gross fish harvest capacity for the individual lakes in proportion to the concentration of total phosphorus present relative to the total phosphorus concentration in Okanagan Lake. These adjusted values are given in Table 5.2, and are referred to as secondary estimates of present available gross fish harvest capacities.

Several works (e.g. Schlick MS1972) have refined the Ryder equation in order to predict the harvest capacity of particular fish species or groups of species, the basis for such refinement being the composition by weight of the various species in sampling catches. The composition of gillnet catches along with the gillnetting catch-per-unit-effort for the Okanagan main valley lakes is summarized in Appendix I. Secondary estimates of present available gross harvest capacities on this basis for the species groups categorized in Table 5.1 are given in Table 5.3.

Among "preferred" sport fishes, more refined estimates of harvest capacity have been attempted for the two most prominent species, kokanee and rainbow trout. Independent estimates of harvest capacity were also made for sockeye salmon.

5.3 SPECIAL CONSIDERATIONS PERTAINING TO PRODUCTION OF KOKANEE AND RAINBOW TROUT

5.3.1 Trophic Considerations

Not all the main valley lakes are equally suited to the production of salmonid fishes. Kalamalka Lake at one extreme, appears distinctly too Oligotrophic to promote good sustained production of salmonid (or other) species. Conversly, advanced eutrophication has rendered Wood and Vaseux Lakes decidedly sub-optimal salmonid habitat by virtue of unfavorable temperature, dissolved oxygen levels and presumably other conditions acting in concert. These conditions reflect a deterioration of water quality to which salmonid species are particularly sensitive. It has been suggested (Allen, personal communication), that temperature and oxygen regimes in the American sector of Osoyoos Lake are no longer compatible with a significant salmonid production, and in view of this only the Canadian portion of the lake area has been incorporated in the present derivations of salmonid carrying capacities and harvest potentials.

A preliminary appreciation of the effects of the various water quality limitations (in conjunction with other factors, notably reproductive constraints for salmonids) can be gained from an examination of the species composition, size of fish, angling harvest, and angling catch-per-unit-effort in the different lakes (Appendices Q and S, and Chapter 9). Some correlation was observed between growth of salmonids (as indicated by length-at-age) and the logarithm of total phosphorus concentration (as an index of eutrophication) divided by mean depth (as an index of morphometric amelioration). These values are plotted for kokanee and rainbow trout for each of the main valley lakes in Figure 5.4. The implication seems to be that salmonid growth is hastened by increased nutrient availability

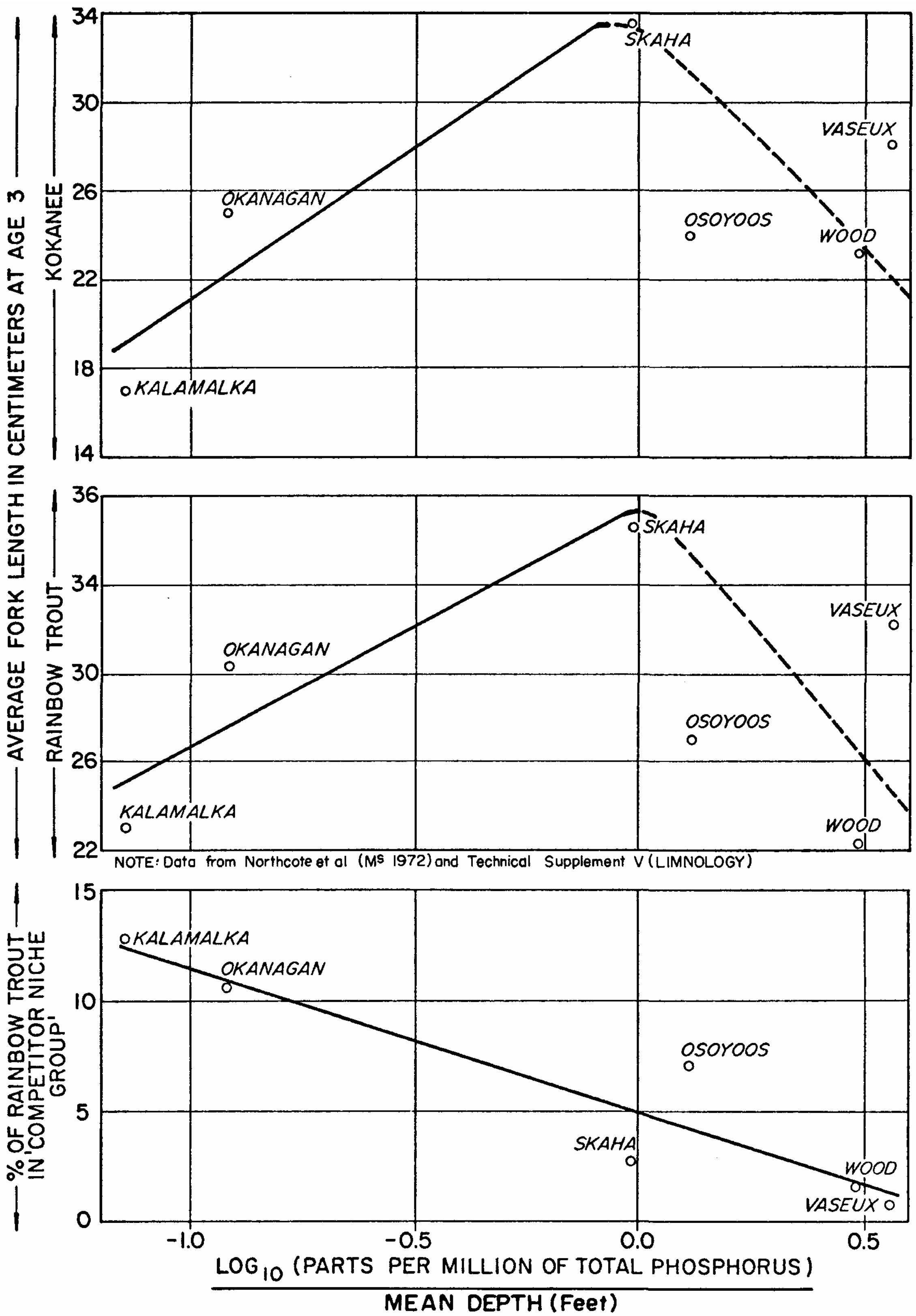
TABLE 5.3

SECONDARY[a] ESTIMATES OF GROSS ANNUAL FISH HARVEST CAPACITIES BY SPECIES GROUPS[b] FOR THE OKANAGAN MAIN VALLEY LAKES UNDER PRESENT (1971) CONDITIONS. BREAKDOWNS ARE ACCORDING TO PROPORTIONS BY WEIGHT OF FISH IN GILLNET (SAMPLING) CATCHES.

	Total[a] All Species	Preferred Sport Fish	Marginal Sport Fish	Lake White-Fish	Preferred Coarse Fish	Marginal Coarse Fish
1. Pounds per acre:						
Wood	21.7	0.93	0.00	0.00	12.59	8.18
Kalamalka	0.9	0.51	0.00	0.00	0.19	0.20
Okanagan	1.5	0.39	0.15	0.22	0.33	0.41
Skaha	6.5	0.76	0.03	2.67	1.40	1.64
Vaseux	13.2	0.34	0.40	4.84	2.02	5.60
Osoyoos	7.6	0.90	0.07	1.05	4.20	1.38
2. Pounds per lake, X 1000:						
Wood	49.0	2.2	0.0	0.0	28.9	18.8
Kalamalka	5.8	3.3	0.0	0.0	1.2	1.3
Okanagan	129.0	33.5	12.9	18.9	28.4	35.3
Skaha	32.3	3.8	0.1	13.3	7.0	8.1
Vaseux	9.0	0.2	0.3	3.3	1.4	3.8
Osoyoos	28.3	3.4	0.3	3.9	15.6	5.1

[a] Derived from primary estimates by adjusting for concentration of total phosphorus relative to Okanagan Lake

[b] For composition of species groups, see Table 5.1.



EFFECT OF TOTAL PHOSPHORUS CONCENTRATION IN CONJUNCTION WITH MEAN DEPTH ON GROWTH OF KOKANEE AND RAINBOW TROUT. AND ON CONTRIBUTION BY RAINBOW TROUT TO ITS COMPETITOR NICHE GROUP IN THE OKANAGAN MAIN VALLEY LAKES. Figure 5.4

up to about the range of conditions (presumably including nutrient loading, morphometry, and perhaps other factors) currently occurring in Skaha Lake. Growth of salmonids in Vaseux and Osoyoos Lakes, which have nutrient levels similar to Skaha, but which are shallower, is distinctly slower. Further growth retardation is evident in Mood Lake which, although nearly as deep as Skaha, has three times the concentration of total phosphorus. On this basis it would appear that the present combination of conditions in Skaha Lake is near optimal for salmonid growth, but that further enrichment (unless perhaps accompanied by equivalent or greater lake depth) results in distinct growth retardation. The bulk of kokanee in these lakes spawn at the same age, so that their fecundity too, is linked to trophic conditions by virtue of the dependence of fecundity on fish size.

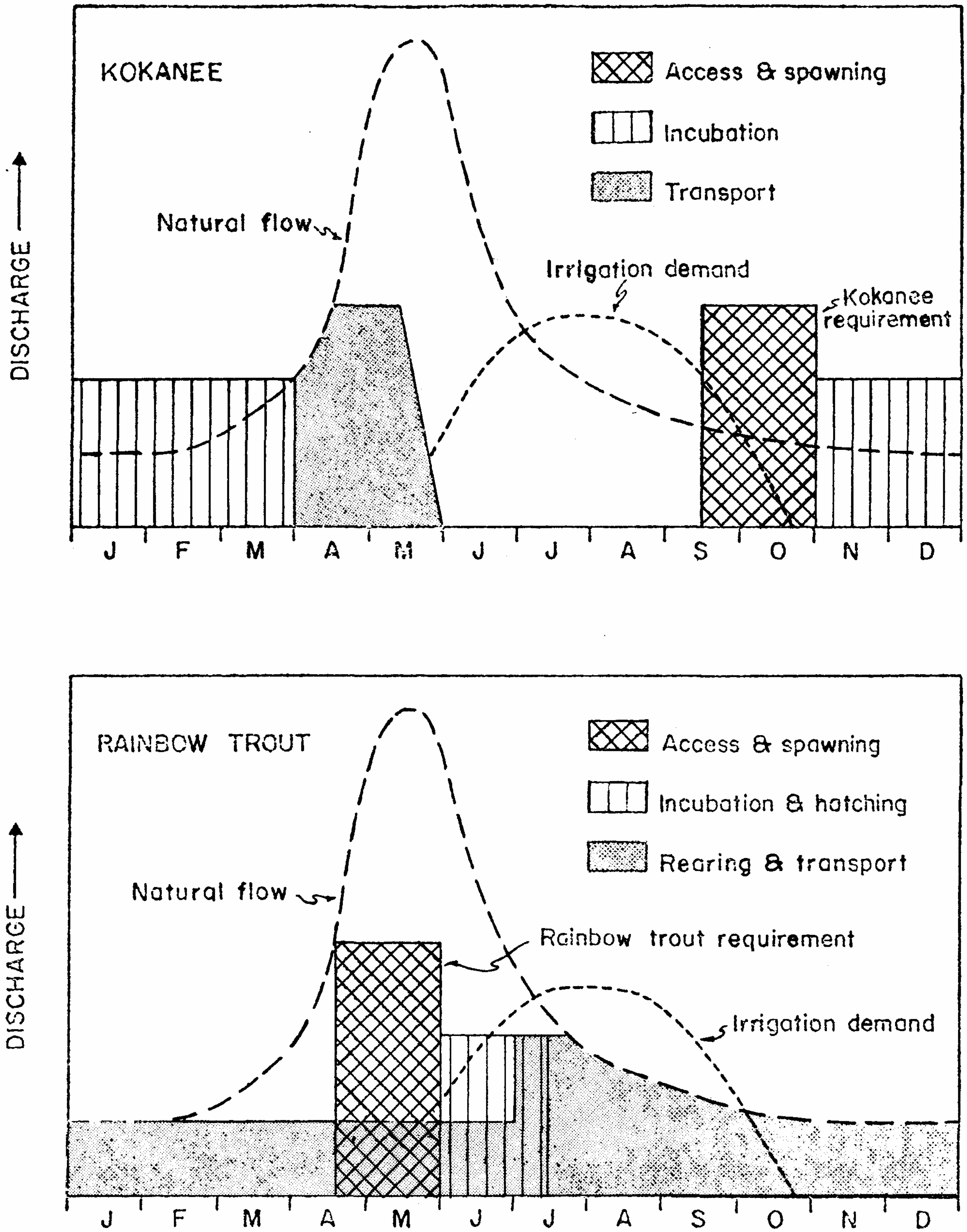
It is postulated that enrichment (beyond some critical level) may also disbenefit salmonids indirectly, by enhancing populations of competitor and predator species. Northcote *et al* (MS 1972) noted that the contribution by salmonid species to the fish fauna of the Okanagan main valley lakes was inversely related to the degree of eutrophication. On the assumption that lake trout, mountain whitefish, bass, yellow perch, burbot, bullheads, pumpkinseeds, squawfish, and peamouth chub are direct competitors with rainbow trout, the contribution by rainbow trout to its "competitor niche group" was derived from the weight of fish in gillnet catches (Appendix I). Plotting this percentage against log (total phosphorus/mean depth) for each lake (Figure 5.4), produced a highly significant regression (r = 0.94). It thus appears that interspecific interactions may contribute substantially to reduced growth and population density of salmonids in the most enriched of the Okanagan main valley lakes.

5.3.2 Discharge and Related Requirements and Constraints for Reproduction

Salmonid species are unique among the Okanagan fish fauna in that they are heavily dependent on the in-flowing streams for reproduction. Recently kokanee have also been found to spawn extensively along the shores of at least some of the main valley lakes; however no such behaviour has ever been ascribed to rainbow trout.

(a) Tributary Stream-spawning Kokanee and Rainbow Trout

Discharge requirements for reproduction of kokanee and rainbow trout in streams differ in seasonal timing, but are generally the same as to location. The timing aspect of these requirements is indicated schematically in Figure 5.5. Okanagan Basin kokanee ascend the tributaries to spawn from mid-September through October, generally in response to a drop in maximum daily stream temperatures below 10°C. The eggs incubate through the winter and the fry descend to the lake during the spring freshet. Lakeshore spawning takes place from mid-October through November, and the fry emerge from mid-March through April.



SCHEMATIC REPRESENTATION OF NATURAL HYPOTHETICAL DISCHARGE REGIME, IRRIGATION DEMAND AND FISH REPRODUCTIVE REQUIREMENTS IN OKANAGAN STREAMS

Figure 5.5

Rainbow trout ascend the streams and spawn during the spring freshet. The incubation period is relatively short and the resultant fry may begin downstream migration during June. However, it has been determined that at least half the rainbow trout in the main valley lakes maintain a stream residence period of at least one year before entering the lake. This implies significant year-round stream discharge requirements for rainbow trout rearing and emigration.

A specific attempt was made to estimate actual minimum flow requirements for propagation of kokanee and rainbow trout in those Okanagan tributaries which appeared to have sufficient water yield potential to consistently meet fishery requirements, if so directed. A general characterization of these tributaries along with a summary of prescribed minimum flows is given in Table 5.4. Discharge requirements are outlined in more detail for kokanee and rainbow trout separately in Tables 5.5a and 5.5b. These estimates were made empirically in consultation with B.C. Fish and Wildlife personnel, from consideration of stream channel and substrate characteristics along with the observed effects of measured flows on kokanee spawning migrations in 1971.

While the flows recommended are those considered minimal to be consistent with present channel configurations and substrates, somewhat higher guaranteed flows would, in most cases, further enhance fish propagation capacities. It is axiomatic that stream flows, to be useful for fish propagation, must be without interruption in space and time during migration of adults and descent of fry, and without interruption in time during incubation of eggs.

Reservoirs on streams tributary to the Okanagan main valley lakes are presently operated without particular regard for the migration, spawning, incubation, or rearing requirements of stream spawning salmonids. Significant loss of reproductive capacity occurs as a result, and an assessment was made of the extent to which such losses might be lessened by a pattern of "modified" reservoir operations. It would appear that certain such modifications are operationally practical, as well as feasible for at least those tributary systems with significant storage development. Smyth (MS 1973) modelled discharge at the mouths of eight of the Okanagan tributaries, for various levels of Okanagan Basin Development, for both historic and "modified" reservoir operating sequences. Of the tributaries so modelled, six still support reproduction of salmonids from the main valley lakes. From Smyth's projections for present (1970) development, discharge deficiencies in these six streams were identified with respect to present salmonid propagation, necessitating revision of scores on this basis. These are presented in Table 5.6.

(b) Shore-Spawning Kokanee

Kokanee are known to spawn along the shores of at least three of the Okanagan lakes (Wood, Kalamalka, and Okanagan). Estimates of abundance are given in Table 5.9. Shore-spawners accounted for an estimated 57% of the total kokanee spawning population for Okanagan Lake in 1971 (Northcote *et al*, MS 1972).

TABLE 5.4

GENERAL CHARACTERIZATION OF PRESENT SALMONID REPRODUCTIVE OPPORTUNITIES. AND SUGGESTED ACCOMPANYING MINIMUM DISCHARGE REQUIREMENTS, IN MAJOR OKANAGAN TRIBUTARY STREAMS

STREAM	ESTIMATED KOKANEE SPAWNING ESCAPEMENT 1971	RANGE OF OBSERVED DISCHARGE, CFS, DURING 1971 KOKANEE SPAWNING PERIOD	RECOMMENDED MINIMUM DISCHARGE, CFS		WHERE DISCHARGE PRESENTLY REQUIRED, MOUTH TO -
			SPAWNING RUN	INCUBATION, REARING, ETC.	
Trout Cr.	+	6.6-51.0	15	10	Mile 1.3 (start of canyon)
Peachland Cr.	36,000	2.5-11.8	4.5-5	2.5-3	Mile 0.8 (impassible falls)
Trepanier Cr.	10,000	1.8- 5.2	8-10	6-8	Mile 0.8 (natural obstruction)
Powers Cr.	7,000	2.4- 5.7	5	4	Mile 0.4 (small falls)
Shorts Cr.	+	0.7- 1.6	8-10	6-8	Mile 0.8 (impassible falls)
Whiteman Cr.	1,000	3.2- 5.3	5	3-4	Mile 3.0 (falls?)
Equesis Cr.	28,000	8.2-12.4	8-10	6-8	Mile 8
Deep Cr.	-	5.5- 8.1	7-8	6	Mile 15?
B-X, Upper	-	0.9- 5.3	4	2.5	Mile 6
Vernon Cr., Upper	+	4.3- 6.0	8-10	7-8	Mile 3 (Ellison Lake)
Vernon Cr., Lower	1,000+	7.3-10.3	10	8	Mile 6 (Kalamalka Lake)
Coldstream Cr.	60,000	7.8-10.5	8	6-7	Mile 3.2 (Coldstream Ranch)
Kelowna Cr.	0	8.3-10.2	5	4	Mile 10
Mission Cr.	380,000	13.7-62.2	40-45	30-35	Mile 11.8 (falls)
Penticton Cr.	+	2.4-14.0	-	-	-
Shingle Cr.	0	0.0- 3.9	7-8	4	Mile 7

TABLE 5.5a

SUMMARY OF ESTIMATED MINIMUM DISCHARGE REQUIREMENTS,[a] ACRE-FEET BY WHOLE MONTHS. TO SUPPORT REPRODUCTION BY KOKANEE FROM THE MAIN VALLEY LAKES IN MAJOR OKANAGAN TRIBUTARY STREAMS

	TROUT	PEACH-LAND	TREP-ANIER	POWERS	SHORTS	WHITE-MAN	EQUESIS	DEEP
Jan.	600	150	360	240	360	180	360	360
Feb.	600	150	360	240	360	180	360	360
Mar.	600	150	360	240	360	180	360	360
Apr.	600	150	360	240	360	180	360	360
May	600+	150+	360+	240+	360+	180+	360+	360+
Sept.	500	270	300	300	300	240	300	300
Oct.	900	270	480	300	480	300	480	420
Nov.	600	150	360	240	360	180	360	360
Dec.	600	150	360	240	360	180	360	360
TOTAL	5600	1590	3300	2280	3300	1800	3300	3240

	B-X, UPPER	VERNON		COLD-STREAM	KELOWNA	MISSION	SHINGLE
		UPPER	LOWER				
Jan.	150	420	480	360	240	1800	240
Feb.	150	420	480	360	240	1800	240
Mar.	150	420	480	360	240	1800	240
Apr.	150	420	480	360	240	1800	240
May	150+	420+	480+	360+	240+	1800+	240+
Sept.	150	300	480	-	240	2400	300
Oct.	240	480	600	480	300	2400	420
Nov.	150	420	480	360	240	1800	240
Dec.	150	420	480	360	240	1800	240
TOTAL	1440	3720	4400	3000	2220	17,400	2400

[a] Based on minimum ranges of recommended discharge from Appendix G.

TABLE 5.5b

SUMMARY OF ESTIMATED MINIMUM DISCHARGE REQUIREMENTS,[a] ACRE-FEET BY WHOLE MONTHS, TO SUPPORT REPRODUCTION BY RAINBOW TROUT FROM THE MAIN VALLEY LAKES IN MAJOR OKANAGAN TRIBUTARY STREAMS

	TROUT	PEACH-LAND	TREP-ANIER	POWERS	SHORTS	WHITE-MAN	EQUESIS	DEEP
Jan.	600	150	360	240	360	180	360	360
Feb.	600	150	360	240	360	180	360	360
Mar.	600	150	360	240	360	180	360	360
Apr.	600	150	360	240	360	180	360	360
May	900+	300+	600+	300+	600+	300+	600+	480+
June	600	150	360	240	360	180	360	360
July	600	150	360	240	360	180	360	360
Aug.	600	150	360	240	360	180	360	360
Sept.	600	150	360	240	360	180	360	360
Oct.	600	150	360	240	360	180	360	360
Nov.	600	150	360	240	360	180	360	360
Dec.	600	150	360	240	360	180	360	360
TOTAL	7500	1950	4560	2940	4560	2280	4560	4440

	B-X, UPPER	VERNON		COLD-STREAM	KELOWNA	MISSION	SHINGLE
		UPPER	LOWER				
Jan.	150	420	480	360	240	1800	240
Feb.	150	420	480	360	240	1800	240
Mar.	150	420	480	360	240	1800	240
Apr.	150	420	480	360	240	1800	240
May	240+	600+	600+	480+	300+	2700+	480+
June	150	420	480	360	240	1800	240
July	150	420	480	360	240	1800	240
Aug.	150	420	480	360	240	1800	240
Sept.	150	420	480	360	240	1800	240
Oct.	150	420	480	360	240	1800	240
Nov.	150	420	480	360	240	1800	240
Dec.	150	420	480	360	240	1800	240
TOTAL	1890	5220	5880	4440	2940	22,500	3120

[a] Based on minimum ranges of recommended discharge from Appendix G.

TABLE 5.6

RELATIVE AVAILABLE DISCHARGE UNDER HISTORIC AND MODIFIED RESERVOIR OPERATIONS FOR REPRODUCTION OF KOKANEE AND RAINBOW TROUT IN SIX SELECTED STREAMS TRIBUTARY TO OKANAGAN LAKE FOR PRESENT (1970) LEVEL OF OKANAGAN BASIN DEVELOPMENT

Stream	KOKANEE			RAINBOW TROUT		
	Most Critical[a] Value of Available Discharge, as a Percent of Estimated Requirements		Improvement Factor for Reproduction Based on Modified Discharge	Most Critical[a] Value of Available Discharge, as a Percent of Estimated Requirements		Improvement Factor for Reproduction Based on Modified Discharge
	Historic Discharges	Modified Discharges		Historic Discharges	Modified Discharges	
Trout Creek	51.5	72.5	1.41	25.0	70.2	2.81
Peachland Creek	39.5	100.0	2.53	25.0	100.0	4.00
Powers Creek	59.0	60.5	1.03	25.0	68.5	2.74
Equesis Creek	65.5	100.0	1.53	82.5	100.0	1.21
Vernon Creek, Lower	70.2	100.0	1.42	70.0	100.0	1.43
Mission Creek	26.7	26.7	1.00	38.0	66.8	1.76
AVERAGE			1.49			2.33

[a] Most Critical Value was that determined to be most limiting to the reproductive requirements for kokanee or rainbow trout.

TABLE 5.7a

ESTIMATED PRESENT SPAWNING AREAS FOR KOKANEE AND RAINBOW TROUT IN STREAMS OF THE OKANAGAN BASIN[a]

STREAM	PRESENT GROSS SPAWNING AREA[b] (SQUARE YARDS X 1000)	PRESENT HABITAT QUALITY FACTOR,[b,c] BASED ON SELECTED NON-HYDROLOGICAL PARAMETERS
Vernon Creek, Upper (= Wood Lake total)	7.0	0.05
Coldstream Creek (= Kalamalka Lake total)	17.2	0.15
Trout Creek	15.4	0.01
Eneas Creek	0.1	0.40
Peachland Creek	1.3	0.30
Trepanier Creek	7.0	0.05
Powers Creek	11.0	0.20
McDougall Creek	0.9	0.05
Lambly Creek	4.0	0.05
Shorts Creek	2.6	0.20
Whiteman Creek	13.2	0.15
Naswhito Creek	4.0	0.05
Equesis Creek	18.5	0.35
Deep Creek	3.1	0.05
B-X Creek	22.2	0.05
Vernon Creek, Lower	1.4	0.05
Mission Creek[d]	146.1	0.05
Bellevue Creek	4.4	0.01
Penticton Creek	0.1	0.01
Okanagan Lake total	255.3	
Ellis Creek	0.1	0.01
McLean Creek	0.4	0.05
Shingle Creek	0.0	0.15
Okanagan River	31.7	0.20
Skaha Lake total	32.2	
Okanagan River (= Vaseux Lake total)	9.3	0.20
Inkaneep Creek	3.0	0.05
Okanagan River	185.3	0.20
Osoyoos Lake total	188.3	

[a] Re-interpreted, on the basis of more recent information and development, from Galbraith and Taylor (MS 1970)
[b] Referable to present average reservoir operations
[c] Weighted average for entire gross spawning area
[d] Based in part on Hinton (MS 1972a)

It has been found that about half the spawning area utilized is less than 1.5 feet deep, and that virtually all spawning occurs in the upper 5 feet. The implications of drawdown of Okanagan Lake on kokanee egg mortality are discussed in Chapter 17. These implications were assessed on the basis of average drawdown during the period October through February. While actual fry emergence may take place somewhat later, it is likely that the alevins are sufficiently mobile to avoid dessication after February.

5.3.3 Physical Habitat Requirements and Constraints for Reproduction

A survey of natural reproductive habitat available to salmonids in the accessible lower reaches of streams tributary to Wood, Kalamalka, Okanagan and Skaha Lakes was compiled by Galbraith and Taylor (MS 1970) and summarized by Study personnel. It was determined that over 80% of the reproductive capacity of Okanagan streams has been lost to cultural manipulation and modifications. This reduction has been brought about by alterations to access, substrates, configuration, silt load, stream bank cover, pollution and discharge regimes.

A tabulation of present gross stream spawning areas and associated habitat quality factors for those streams which provide at least some present (or potential) reproductive opportunities is given in Table 5.7. Gross spawning area is simply the length of accessible stream reach multiplied by the average width. The habitat quality factor as here defined, is a subjective attempt to represent certain influences including specifically, stream gradient, substrate, configuration, and screening of irrigation intakes. In this connection, a quality factor of 1.00 would indicate silt-free gravel with ideal distribution of 1/4 inch to 3-inch components, situated in a system with good gradient and configuration characteristics and with proper screening of intakes. Specifically omitted from this quality factor are discharge considerations (dealt with in the previous section), stream bank developments (such as would be integral to a leave-strip program), and such socio-economic considerations as urban development, land ownership and pollution.

5.4 KOKANEE: PRESENT PRODUCTIVE CAPACITIES AND HARVESTS

5.4.1 Capacities of Lakes to Accept Kokanee

The carrying capacities of the Okanagan main valley lakes for kokanee were estimated by reference to a method developed by the International Pacific Salmon Fisheries Commission for estimating lake. carrying capacities for the progeny of sockeye salmon spawners. The steps in this procedure are outlined in the following sections.

(a) Lake Carrying Capacity for Sockeye Spawners

In the experience of the I.P.S.F.C., the rearing capacity of a lake for sockeye salmon can be estimated from the lake surface area in conjunction with

TABLE 5.7b

ESTIMATED PRESENT (1971) RAINBOW TROUT AND KOKANEE SPAWNING ESCAPEMENTS AND RAINBOW TROUT FRY PRODUCTION IN SPECIFIC REPRODUCTIVE HABITATS

STREAM	TOTAL EFFECTIVE PRESENT RAINBOW SPAWNING ESCAPEMENT [c]	PRESENT RAINBOW TROUT FRY PRODUCTION x 1000 [d]	PRESENT KOKANEE (1971) SPAWNING ESCAPEMENT [a,b] X 100
Vernon Cr., Upper	119	3.6	5
Shore-spawners			33
(= Wood Lake total)			33+
Coldstream Cr.	10,558	297.9	597
Shore-spawners			55
(= Kalamalka Lake Total)			652
Trout Cr.	45	1.6	5
Eneas Cr.	45	1.6	5
Peachland Cr.	418	15.3	47 (362)
Trepanier Cr.	927	33.8	104
Powers Cr.	651	23.8	73
McDougall Cr.	44	1.6	0
Lambly Cr.	45	1.6	5
Shorts Cr.	45	1.6	5
Whiteman Cr.	53	1.9	6
Naswhito Cr.	45	1.6	5
Equesis Cr.	2,460	89.7	276
Deep Cr.	45	1.6	5
B-X Cr.	44	1.6	0
Vernon Cr.	89	3.3	10
Mission Cr.	27,819	1,014.1	3121
Bellevue Cr.	44	1.6	0
Penticton	45	1.6	5
Total stream spawners			3637+
Shore spawners			5180
Okanagan Lake totals	32,864	1,197.9	8817+
Ellis Cr.	18	0.7	5
McLean Cr.	19	0.8	5
Shingle Cr.	19	0.8	5
Okanagan R.	1,495	60.0	401
Skaha Lake totals	1,551	62.3	401+
Okanagan R.	49	1.9	4
(= Vaseux Lake total)			
Inkaneep Cr.	4	0.2	5
Okanagan R.	294	10.9	369
Osoyoos Lake total	299	11.1	369+

[a] Where estimated escapement exceeded the gross spawning habitat capacity (see text), the latter was assumed to be limiting and was the value adopted. In these instances the first estimates of actual escapement are given in brackets.

[b] Present escapements of fewer than 500 kokanee were not incorporated in the present escapement totals. However they were considered as 500 kokanee for subsequent calculations.

[c] Apportioned among individual streams in proportion to kokanee escapements, based on present'(1971) physical habitat.

[d] Incorporating particular fecundity estimates and assumed egg to fry survival of 5%.

an index of Zooplankton abundance (I.P.S.F.C. 1970). Ideally, the plankton abundance index (P.A.I.) is represented by the average centrifuged volume, as cubic centimeters, of Zooplankton in at least six replicate 100-foot vertical hauls. Samples are taken with a 25-cm. net of No. 10 bolting silk, preferably in the middle of the successive months of August, September and October (Gjerness, personal communication). The plankton abundance index multiplied by ten times the lake surface area in acres was taken to be indicative of the number of "effective" female sockeye spawners the progeny of which can be supported by Okanagan Lake (Andrew, personal communication). An effective female sockeye spawner, in this interpretation, represents a capacity for successful deposition of 3,500 eggs.

Zooplankton samples for derivation of a plankton abundance index were obtained for Okanagan Lake on 29 August 1972. Samples were taken offshore at three locations: Lambly Creek, Okanagan Centre, and Squally Point. From these, an average P.A.I. value of 1.66 was derived. This value was multiplied by the ratios of Zooplankton abundance as determined by the program of Patatas and Saiki (1973) to give estimates of P.A.I. values for the other main valley lakes relative to Okanagan. From these estimated P.A.I. values, in conjunction with lake areas, estimates were made of the number of sockeye spawners whose progeny could be accommodated by the rearing capacity of each of the main valley lakes. These estimates are given in Appendix J.

(b) Lake Carrying Capacities for Kokanee Spawners

The lake carrying capacities for sockeye salmon (in terms of numbers of spawners accommodable) were transposed to "equivalent" numbers of kokanee for each lake on the basis of the comparative fecundity of the two species and their comparative periods of lake residence. Kokanee carrying capacity estimates for each lake are detailed in Appendix J and are summarized in Table 5.8. An example calculation (for Osoyoos Lake) is given in Appendix K. Derivations of kokanee fecundity for each lake are given in Appendix L.

For Osoyoos Lake, the estimated carrying capacity for kokanee incorporated a reduction to accommodate the progeny of sockeye salmon which spawn in Okanagan River and rear in Osoyoos Lake. This adjustment was made on the basis of an average (19,000) sockeye escapement. It was assumed (Major and Craddock, 1962) that the sex ratio of sockeye salmon spawning in Okanagan River is 1:1, that the females carry an average of 2,500 eggs, and that the average residence period of the progeny in Osoyoos Lake is one year. Details of this adjustment are given in Appendix K.

It has been observed that kokanee spawning within specific regions of Kootenay Lake exhibit much greater homogeneity than do kokanee in the lake as a whole (Vernon, 1957). Okanagan and Kootenay Lakes are of similar size, and it is accordingly not unreasonable to suppose that regional differences also exist among kokanee in Okanagan. Such heterogeneity is in fact implied by the different regional angling success rates and harvest (Chapter 9). The carrying capacity of Okanagan Lake for kokanee, as supportable spawners, was accordingly differentiated among three arbitrary lake regions on the basis of relative regional area (Table 5.8).

The principal assumptions embodied in the estimates of lake carrying capacities for kokanee are as follows:

1) That the standing crop of Zooplankton is a reliable index of the carrying capacity of a lake for juvenile sockeye salmon.
2) That the sex ratio for both spawning sockeye and kokanee is 1:1.
3) That salmon juveniles have an average lake residence period of about 1.25 years (Foerster, 1968).
4) That most kokanee mature and die after about 3.5 years of lake residence in the Okanagan lakes (Northcote _et al_ MS 1972).
5) That egg-to-fry survival of sockeye salmon and kokanee is the same
6) That diet of sockeye and kokanee during lake residence is identical
7) That competition and predation interactions in the Okanagan main valley lakes are comparable (as regards sockeye salmon/kokanee) to those in the lakes from which the I.P.S.C.F. carrying capacity model was derived.
8) That competition and predation affect kokanee and sockeye salmon equally during lake residence. This will be in error to the extent that the lake residence periods of the two species are unequal, subjecting kokanee to a longer period of predation, etc. This will accordingly lead to under-estimation of lake carrying capacity for kokanee.
9) That food consumption by kokanee is equivalent for all individual age classes. This will be in error to the extent that older kokanee eat more food, and will accordingly lead to over-estimation of lake carrying capacity for kokanee.
10) That the implications of assumptions 8) and 9) above, tend to cancel. In fact, the overall error is probably toward some under-estimation of carrying capacities.

5.4.2 Present Kokanee Spawning Escapements

The present kokanee spawning escapements for the individual Okanagan main valley lakes were first estimated from field sampling of tributary streams (and Okanagan River) in 1971 as reported by Northcote _et al_, (MS 1972). Also estimated in 1971 were the numbers of kokanee shore-spawners in Okanagan Lake, and subsequently the number of shore-spawners in Wood and Kalamalka Lakes. These various direct estimates of "present actual" kokanee spawning escapements are summarized in Table 5.9.

There are several, reasons to suspect that only for Okanagan Lake, and probably for Kalamalka Lake, are these direct estimates relatively reliable (Table 5.9).

TABLE 5.8

ESTIMATES OF TOTAL KOKANEE SPAWNING ESCAPEMENTS SUPPORTABLE ANNUALLY BY OKANAGAN MAIN VALLEY LAKES ON THE BASIS OF LAKE CARRYING CAPACITIES; AND BEST ESTIMATES OF "PRESENT" ANNUAL ESCAPEMENTS ON THE BASIS OF DATA OBTAINED IN 1971 and 1972.

LAKE	Estimated Number of Spawners, X 1000			
	Supportable by Present Lake Carrying Capacity	Best Estimates of Present Escapement		
		Stream	Shore	Total
Wood	802	0	3.3	3.3
Kalamalka	1,140	597	5.5	65.2
Okanagan, Total	7,529	364	518	882
North	2,033[a]	29	259[b]	288
Central	3,584[a]	335	254[b]	588
South	1,912[a]	+	5[b]	5
Skaha	567	40	0	40
Vaseux	97	0.4	0	0.4
Osoyoos	636	37	0	37

[a] Differentiated according to surface areas of regions arbitrarily, assigned as follows :

North	27.0%
Central	47.6%
South	25.4%

[b] Interpolated from Northcote et al. (MS 1972, Fig. 15).

TABLE 5.9

DERIVATION OF BEST ESTIMATES OF "PRESENT" TOTAL KOKANEE SPAWNING ESCAPEMENTS IN THE OKANAGAN MAIN VALLEY LAKES

	Wood	Kalamalka	Okanagan North	Okanagan Central	Okanagan South	Okanagan Total	Skaha	Vaseux	Osoyoos
Surface Area, Acres	2298	6400	23200	40950	21840	85990	4967	680	3719
Direct Estimate of Total Actual Escapement, X 100									
Stream-spawners	5	597	292	3660	+	3952	368	20	200
Shore-spawners	90	55	2590[a]	2538[a]	52[a]	5180	0	0	0
TOTAL SPAWNERS	90	652	2882	6198	52	9132	368	20	200
Direct Estimate of Total Escapement, per Acre	3.916	10.188	12.422	15.136	0.238	10.620	7.409	2.941	5.378
Kokanee gilnetted, per gang-hour	0.130	0.592	1.163	1.010	0.583	0.964	0.735	0.060	0.900
Kokanee per gang-hour, Relative to Okanagan Lake (Total)	0.135	0.614	1.206	1.605	1.048	0.605	1.000	0.062	0.934
Indirect Estimate of Total Kokanee Spawning Escapement, per Acre[b]	1.434	6.521	12.808	11.130	6.425	10.620	8.092	0.658	9.919
Indirect Estimate of Total Kokanee Spawning Escapement, per Lake, X 100	33	417	2971	4558	1403	8932	401	4	369
BEST ESTIMATE OF TOTAL ESCAPEMENT, X 100	33	652	2882	5883[c]	52	8817[c]	401	4	369

[a] Interpolated from Northcote et al. (MS 1972, Fig. 15).

[b] Based on direct estimate of total escapement for Okanagan Lake.

[c] Incorporates an adjustment for present "over-spawning" in Peachland Creek (see Text).

On this assumption, "best" estimates of present numbers of kokanee spawners in each of the other lakes (Wood, Skaha, Vaseux and Osoyoos) were derived by adjusting the estimate for Okanagan Lake (total) according to the relative catch-per-unit-effort of kokanee in gillnets (data of Northcote et al, MS 1972), taking account of relative lake surface areas. All kokanee captured in the 1971 gillnet sampling program were used in these calculations. As was done for the kokanee carrying capacity estimates, the kokanee spawning escapement within Okanagan Lake was apportioned according to north, central and south regions. It is noted that even for Okanagan Lake, the enumeration procedure probably produced a somewhat conservative estimate of escapement (Northcote et al, MS 1972). Thus, all estimates derived on this basis are probably low, perhaps by as much as 25%.

Experience at Meadow Creek, British Columbia (Vernon, personal communication) suggests that kokanee in the 10 inch range require about 0.5 square yards of gravel per spawning pair. According to the fecundity: length relation among Okanagan kokanee (Appendix L), this would indicate a potential egg deposition of about 850 eggs per square yard. On this basis, and from the gross area of spawning habitat, it was possible to estimate the gross number of kokanee spawners physically accommodable by reference to the average kokanee fecundity in the particular lake. In situations where the estimated spawning escapement exceeded the estimated gross capacity of the reproductive habitat to accommodate spawners, the latter was adopted as the best working estimate of escapement. In the case of present escapements outlined in Table 5.9 the direct estimate of 36,200 spawners in Peachland Creek was reduced to 4,700 effective spawners on this basis. It is appreciated that this represents a rather crude correction, since differences in substrate and in discharge velocities will influence the actual disposition of spawning kokanee and of eggs in streams.

5.4.3 Utilization of Lake Carrying Capacity by Kokanee Spawners

The logical application of the results of the previous sections is to use them to determine if:
1) the carrying capacity of the lakes is presently or potentially limiting with regard to the kokanee fishery, or
2) the capacity of the stream and lake-spawning areas is presently limiting the production of kokanee. The relevant data are presented in Table 5.10.

It is apparent that the carrying capacities of the main valley lakes for kokanee are presently being considerably under-utilized. There is a large "reservoir" for accepting increased kokanee production in all the lakes examined. The highest utilization of available lake capacity is 16.4% in the central portion of Okanagan Lake. The indication then, is that available spawning habitat is presently the principal limiting factor for kokanee populations in the main valley lakes.

TABLE 5.10

ESTIMATED UTILIZATION OF LAKE CARRYING CAPACITIES BY KOKANEE SPAWNING ESCAPEMENTS IN THE OKANAGAN MAIN VALLEY LAKES

Lake	Carrying Capacity (Spawners X 1000)	Escapement (Spawners X 1000)	Utilization of Carrying Capacity (Percent)
Wood	802	3.3	0.4
Kalamalka	1139.6	65.0	5.7
Okanagan - North	2033	288	14.2
- Central	3584	588	16.4
- South	1912	5.2	0.3
Skaha	467	40	8.6
Vaseux	97	0.4	0.4
Osoyoos	636	37	5.8

TABLE 5.11

ESTIMATED PRESENT ANNUAL SUSTAINABLE KOKANEE HARVEST CAPAICITES, OKANAGAN MAIN VALLEY LAKES

Lake	Number of Kokanee Harvestable Annually (X 1000)				Pounds of Kokanee Harvestable Annually (per Acre[d])
	Direct Minimum[a]	Direct Maximum[b]	Indirect[c]	Most Probable	Most Probable
Wood	1.82	5.47	8.78	7.12	0.49
Kalamalka	1.24	73.02	2.97	25.74	0.75
Okanagan	237.50	2019.90	82.20	1128.70	3.65
Skaha	5.91	185.66	5.56	95.78	10.12
Vaseux	0.01	1.36	0.20	0.52	0.23
Osoyoos	0.99	69.13	6.28	25.46	1.79
TOTAL	247.47	2354.54	105.99	1283.32	

[a] Equated to present (1971) realized annual harvest (Chapter 9).
[b] Based on kokanee population and exploitation parameters for Kootenay Lake (Chapter 9).
[c] Based on Ryder (1965), in conjunction with mean weight in angling catch.
[d] Based on mean weight of kokanee in present (1971) angling catch (Chapter 9).

5.4.4 Present Available Harvest Capacities

Direct estimates of the range of present available kokanee harvest capacities for the Okanagan main valley lakes, reflecting present discharge regimes and present conditions of gross spawning habitat availability and quality, were derived by reference to:

(a) the present (1971) realized kokanee harvests, and

(b) the population and exploitation parameters for kokanee in the West Arm of Kootenay Lake, B.C.

An estimated 247,500 kokanee were taken by angling from the Okanagan main valley lakes during the 12 months June 1971-May 1972, with the majority (96%) being taken from Okanagan Lake (Chapter 9). The 12-month catch was interpreted as a direct minimum estimate of the present available sustainable kokanee harvest capacity over a 1-year period (Table 5.11).

Kokanee in the West Arm of Kootenay Lake support a substantial sport fishery and are considered (Andrusak, personal communication) to be exploited at or near the "sustainable yield", i.e. it is considered that natural reproduction provides sufficient fry (and larger fish) to meet natural and fishing mortality with little surplus. This population then, was adopted as a basis for estimating present maximum sustainable potential harvest capacities for kokanee among the Okanagan main valley lakes. The ratio of kokanee caught by angling to kokanee spawning escapement in the Kootenay Lake West Arm is about 3.5:1, and the average fecundity is about 750 eggs per female. On the assumption that natural mortality rates for kokanee in Kootenay and Okanagan Lakes are similar through all life history stages, and that the Kootenay Lake West Arm population is being exploited to near capacity, corresponding allowable catch-to-escapement ratios for each Okanagan main valley lake under present conditions were derived by direct application of fecundity ratios to the estimated total escapement of kokanee spawners. This is assumed to give a direct maximum estimate of available sustainable kokanee harvest capacity over a 1-year period under present habitat conditions and operations affecting reproduction. An example calculation (for Okanagan Lake) is as follows:

Fecundity of Okanagan Lake kokanee = 474 eggs
Fecundity of Kootenay Lake kokanee = 750 eggs

To maintain a sustained yield it is assumed that the catch-to-escapement ratio must not rise above the present observed ratio (Kootenay Lake) of

3.5 : 1

Then, corresponding allowable catch-to-escapement ratio for Okanagan Lake = (474/750) (3.5) : 1 = 2.212 : 1.

But, total Okanagan Lake kokanee escapement (1971) = 913,150. Therefore direct maximum estimate of present available sustainable kokanee harvest capacity over a 1-year period = 2.212 x 913,150 = 2,019,888 kokanee.

Indirect estimates of. present available kokanee harvest capacities in the main valley lakes were derived from the gross estimates of overall harvest capacities determined from Ryder's (1965) morphoedaphic index. The procedure was to multiply the overall estimates from Ryder's formula by the percent contribution by weight of kokanee to gillnet catches in the individual lakes (Appendix I), and then divide the result by the mean weight of kokanee in angling catches. These indirect estimates of kokanee harvest capacities appear with the direct estimates in Table 5.11. Assumptions pertinent to the derivation of "Ryder estimates" were outlined earlier. (Section 5.2)

From the three independent estimates as outlined above, estimates of "most probable" present available kokanee harvest capacities in the Okanagan main valley lakes were deduced. This involved an averaging of all three estimates for lakes where the Ryder estimate fell between the other two, and an averaging of the two highest estimates when the Ryder estimate fell outside. These estimates of most-probable available kokanee harvest capacities sustainable under present stream habitat conditions and operations are given in Table 5.11.

5.4.5 Discussion

No attempt will be made at this point to review and evaluate all the procedures and assumptions leading to the various derivations above, except to emphasize that most of these derivations were indirect. The actual relevant data base included:

1) An existing model (International Pacific Salmon Fisheries Commission 1970) for predicting the carrying capacity of a lake for the progeny of sockeye salmon spawners on the basis of Zooplankton standing crop.
2) An estimate of Zooplankton standing crop in each of the main valley lakes.
3) An estimate of kokanee spawning escapement according to particular reproductive habitat for each of the lakes.
4) Estimates of kokanee size-at-age and fecundity in each of the lakes.
5) An estimate of the present average sockeye escapement to Okanagan River, and associated sockeye habits and population parameters.
6) A survey of stream reproductive habitat characteristics and constraints.
7) An estimate of the angling catch, and catch characteristics of kokanee from each of the lakes.
8) An estimate of a sustainable catch : escapement ratio as regards the Kootenay Lake West Arm.
9) The relative proportion of kokanee in gillnet catches for each of the lakes.
10) An existing model (Ryder 1965) for predicting sustainable harvest on the basis of mean depth, total dissolved solids, and species composition in sampling catches.

The rationale for deploying this data base was set out in Figure 5.1. The various procedures and assumptions are detailed in the text above.

Present utilization of the carrying capacities of the Okanagan main valley lakes to accept the progeny of kokanee spawners ranges from less than 1% in Wood and Vaseux Lakes and in the southern part of Okanagan Lake, to 16% in the central part of Okanagan Lake (Table 5.10). This utilization reflects the present distribution of reproductive opportunities.

Sustainable harvest estimates derived for kokanee are not considered to be highly reliable. However, it is noted that catch : escapement ratios implied by these estimates range from a low of 0.4 : 1 for Kalamalka Lake, to a high of 2.4 : 1 for Skaha Lake, and do not appear unrealistic. The most probable estimates of present sustainable harvest capacities total 1,283,000 kokanee, or about five times the present (1971) estimated annual catch. This would appear to indicate a considerable reservoir for additional exploitation. However, it is uncertain to what extent present (1971) recorded catch and escapements are representative of the long-term average situation in these lakes.

It should also be noted that increased exploitation, while biologically feasible, would result in less satisfaction to anglers due to a decrease in catch success. The degree to which this would take place is unknown.

5.5 RAINBOW TROUT: PRODUCTIVE CAPACITY AND HARVEST

5.5.1 Present Capacities of Lakes to Accept Rainbow Trout Fry

Numbers of trout fry which can be accommodated by the main valley lakes were estimated on the basis of morphometry and total dissolved solids according to the stocking formula utilized for the same purpose for the Okanagan headwater lakes. These estimates are detailed in Appendix M and are summarized in Table 5.12. An example calculation (for Okanagan Lake) is given in Appendix N. The basic assumption made is that the influence of morphometric factors on rainbow trout productivity can be extrapolated in linear fashion from the small to medium-sized British Columbia trout lakes for which the stocking formula has proved effective, to the generally much larger and deeper Okanagan main valley lakes. In this connection it seems probable that for particularly deep lakes with low littoral development (e.g. Kalamalka, Okanagan) the stocking formula may under-estimate fry carrying capacity somewhat.

The basic fry carrying capacities derived according to the stocking formula were adjusted for each lake according to the proportionate total phosphorus concentration of the lake water relative to Okanagan Lake. The rationale parallels that developed for adjusting the estimates of gross fish yield capacities on the basis of total phosphorus concentrations.

The primary assumption is that the basic carrying capacity for rainbow trout increases in direct proportion to the concentration of total phosphorus in the lake water. This is probably an over-simplistic assumption and one that appears to fail entirely at the highest phosphorus concentrations encountered (i.e. Wood Lake). On the other hand, the elements of this apparent failure may be adequately accounted for by means of the adjustment for interspecific competition as undertaken below.

Basic adjusted carrying capacity estimates for rainbow trout fry in these lakes are derived in Appendix M and are summarized in Table 5.12.

The basic stocking formula was developed from the premise that competitor and predator fish species are absent or negligible. Since this is definitely not the case in the Okanagan main valley lakes, it seemed prudent to attempt to refine the basic adjusted carrying capacity estimates on this account. Secondary estimates of fry carrying capacities were accordingly derived, incorporating adjustment for competition and predation.

It seems reasonable that, in the presence of competitor species, the carrying capacity for trout fry would be reduced. The adjustment procedure adopted was to multiply the basic adjusted carrying capacity for each lake by the proportion of rainbow trout (by weight) in its "competitor niche group" as estimated from gillnet catches (see Appendices M and I). The detailed weight composition of these catches is given in Appendix I.

The following assumptions were made in respect to the competition adjustment model:

1) That lake trout, mountain whitefish, bass, yellow perch, burbot, bullheads, pumpkinseeds, squawfish and peamouth chub (along with rainbow trout themselves) are in direct competition for food and habitat among the Okanagan main valley lakes. This assumption is based on food studies from other sources. The feeding habits of rainbow trout and kokanee were assumed to be complementary for this analysis; however, older kokanee have been shown (e.g. Ricker 1938) to feed to some extent on food items typically utilized by rainbow trout. The same is probably also true to some degree for most of the other species (e.g. lake whitefish). Balancing this error is the probability that none of the species assigned to the "rainbow trout competitor niche group" do in fact have feeding habits identical to those of rainbow trout.

2) That all species in the "rainbow trout competitor niche group" are equally effective as competitors with rainbow trout, and that this effectiveness is proportional to their contribution by weight to gillnet catches.

Since rainbow trout in the Okanagan main valley lakes are subjected to predation as well as to competition, it seems reasonable that to achieve the maximum abundance of catchable-size trout consistent with the productive potential (as reflected by the stocking formula), more fry would have to be stocked than predicted by the basic formula in order to compensate for predation losses. In other words, the "apparent" carrying capacity for fry would be increased. The amount of this increase, relative to "carrying capacity adjusted for competition" (Appendix M), was estimated for each of the Okanagan main valley lakes according to the following assumptions:

1) That lake trout, bass, yellow perch, burbot, bullheads, pumpkinseeds and squawfish (along with rainbow trout themselves) are predatory on rainbow trout in the Okanagan main valley lakes.
2) That these species are equally effective as predators on rainbow trout,
and that this effectiveness is proportional to their contribution by weight to gillnet catches.
3) That each predatory species consumes three times its own body weight of fish annually. Johnson (1966), by way of indirect supporting evidence, deduced that northern pike consumed from 2.70 to 3.81 units of food biomass annually per unit of their own body weight.
4) That the impact of predation on rainbow trout is directly proportional to the numerical contribution by rainbow trout to the total fish population.
5) That the proportion of rainbow trout (by number) in the total fish population (and hence available to predation) is reflected by the proportion (by number) in gillnet catches. In other words, it was assumed that predation is not selective, at least not as regards rainbow trout specifically, within the total prey species complex.

Application of these predation adjustments to fry carrying capacities is shown in Appendix M. The secondary (fully adjusted for competition and predation) carrying capacity estimates are included in Table 5.12 and a sample calculation (for Okanagan Lake) is given in Appendix N.

As noted above, the adjustments incorporated in the basic adjusted and in the secondary estimates of rainbow trout fry carrying capacities, while attempting to take account of actual phenomena, are completely artibrary and unproved. Since the three procedures produced vastly different carrying capacity estimates, it seemed appropriate to interpret these not as definitive estimates, but rather as indicative of the probable range within which the true carrying capacities occur. To this effect, the two lowest of the three estimates derived for each lake were averaged to produce "most probable" estimates of rainbow trout fry carrying capacity. These most-probable estimates are included in Table 5.12.

TABLE 5.12

ESTIMATES OF ANNUAL CARRYING CAPACITIES OF OKANAGAN MAIN VALLEY LAKES FOR RAINBOW TROUT FRY ESTIMATED "PRESENT" FRY PRODUCTION

LAKE	Basic Estimate	Basic Adjusted Estimate	Secondary Estimate	Best Estimate	Estimated Present (1971) Fry Production X 1000
Wood	1,297	9,468	216	756	3.6
Kalamalka	3,390	1,593	319	956	297.9
Okanagan	40,844	40,844	5,910	23,377	1,197.9
Skaha	3,174	8,157	290	1,732	62.3
Vaseux	978	2,513	23	501	1.9
Osoyoos	3,078	7,480	636	1,857	11.1

5.5.2 Present Rainbow Trout Fry Production

An indirect estimate of the number of effective rainbow trout spawners in each of the main valley lakes was derived by extrapolation from the relative proportions of rainbow trout and kokanee in gillnet catches, in conjunction with the kokanee spawning population estimates derived earlier, and incorporating assumed survival and other parameters. The estimated number of effective rainbow trout spawners was then multiplied by the estimated mean fecundity to give estimates of present (1971) egg production. On the basis of an assumed 5% survival of eggs to fry, the estimated resulting fry production was calculated for each lake. These derivations are summarized in Table 5.13. The relevant assumptions may be summarized as follows:

1) That the (1971) kokanee spawning escapement estimates are reliable. It was noted earlier that the enumeration procedure for Okanagan Lake kokanee, especially as applied to shore-spawners, may have resulted in considerable under-estimation of this particular spawning population. Such error would have been transmitted to estimates for those lakes (Wood, Skaha, Vaseux and Osoyoos) for which kokanee escapements were estimated indirectly, and would result in proportionate under-estimation of rainbow trout spawners.

2) That the relative abundance of kokanee spawners (generally aged ±3.5 years) is reflected by the gillnet catches to the same extent that those catches reflect the relative abundance of rainbow trout of the same age (3.5 years) and older (combined). This can only be true to the extent that:
   (a) Rainbow trout and kokanee, of corresponding ages and proportionately in all lakes, were equally vulnerable to the gillnetting program as conducted. This is probably false to some extent but there is no available basis for evaluating the assumption, and the bias is hopefully not serious.
   (b) Survival rates of rainbow trout and of kokanee, up to the kokanee spawning age, are comparable within the particular lakes. There is no

a priori reason why this should necessarily be so; however, it seems a not unreasonable assumption. It could not be tested without very major and specific study effort. On this basis, and if assumption (a) above is near correct, the proportion of gillnetted kokanee in any of these lakes should be approximately equal to the proportion of gillnetted rainbow trout to rainbow trout aged 3.5 and over during the autumn period.

3) That survival rates for rainbow trout consistently approximate those estimated for trout in the Okanagan headwater lakes. This seems a rather tenuous assumption on first consideration; however, it is probably not seriously in error in view of the fact that the maximum age of trout encountered in sampling both lake categories was the same. Also on this basis, if assumptions under 2) above are near correct, the ratio between numbers of rainbow trout in particular age classes at particular seasons should be approximately as follows:

(a) Age 3.5 in autumn to age 3 and over combined in spring = 1:1.2395
(b) Age 3.5 in autumn to age 4 and over combined in spring = 1:0.8077
(c) Age 3 in spring to age 3 and over combined in spring = 1:0.3484
(d) Age 4 in spring to age 4 and over combined in spring = 1:0.4011

4) That the number of effective rainbow trout spawners in Wood, Kalamalka, Okanagan and Osoyoos Lakes is approximated by the number of trout aged 4, and that the number of effective spawners in Skaha and Vaseux Lakes is approximated by trout aged 3. This is considered reasonable because:

(a) As a general rule female rainbow trout in these lakes are mature at age 4, with some mature at age 3, particularly in Skaha (and presumably in Vaseux) Lakes (Halsey, personal communication).

(b) It is probable that little successful reproduction results in these lakes from rainbow trout older than 4 years because of pesticide (primarily DDT) accumulations in the flesh and hence in the eggs (Northcote *et al*, MS 1972).

(c) The implications of items (a) and (b) should be internally compensatory.

5) That the mean fecundity of effective spawners is represented by trout of the mean effective spawning age. The rationale for this is that:

(a) Some reproductive success is probably generated by trout older than 4 years despite pesticide accumulations.

(b) This would tend to be compensated by presumed reproduction by a certain proportion of the trout at age 3 in Wood, Kalamalka, Okanagan and Osoyoos Lakes.

(c) In Skaha Lake, only one 4-year old rainbow trout was encountered in the 1971 gillnetting program. It therefore seems defensible to assume that for this lake (and also for Vaseux) that the mean fecundity of effective spawners is reasonably approximated by trout aged 3 years.

6) That the sex ratio among effective spawners is 1:1 in all cases.

7) That egg-to-fry survival averages 5% for these rainbow trout spawning populations. Survival is, of course, correlated with water flow and dissolved

oxygen through gravel (Coble 1971), and on factors such as density, shading and predation. It can accordingly vary from zero to near 100%. The value adopted is quite arbitrary, but it seems to approximate the general average experience in British Columbia, particularly at Loon Lake (based on Halsey, personal communication). Also relevant is an Idaho experiment (Bjorn MS1966) where 4% to 10% of eggs planted in gravel survived to downstream migration. Experimental procedure such as this of course, would exclude losses normally incurred during ascent of the adults and in conjunction with natural spawning and egg deposition.

The estimated present (1971) fry production for each of the main valley lakes (Table 5.13) was apportioned to individual streams in proportion to the present (1971) kokanee spawning escapements. The assumption is of course inherent that rainbow trout and kokanee utilize particular streams in the same proportions relative to their own densities. This is probably a gross over-simplification but the implications of error do not appear serious for the present analysis.

In contrast to kokanee, the estimated gross capacities of all reproductive habitats appear adequate to accommodate all present and predicted trout spawning escapements, at least on the basis of effective spawners only. Consequently there was no necessity to develop adjustment procedures on this account. It might be noted in this regard that observations at Loon Lake, B.C., as well as at other locations (Vernon, personal communication) suggests that rainbow trout of the size of the effective spawners in the Okanagan main valley lakes (average 12-15 inches) require about 2 square yards of area per spawning pair.

TABLE 5.13

SUMMARY OF ESTIMATED EFFECTIVE RAINBOW TROUT ESCAPEMENT AND FRY PRODUCTION IN THE OKANAGAN MAIN VALLEY LAKES

LAKE	NUMBER OF EFFECTIVE SPAWNERS	FRY PRODUCTION (X 1000)
Wood	119	3.6
Kalamalka	10,558	297.9
Okanagan	32,864	1,197.9
Skaha	1,551	62.3
Vaseux	49	1.9
Osoyoos	299	11.1

5.5.3 Utilization of Lake Carrying Capacities for Rainbow Trout Fry

Estimated rainbow trout fry production under present (1971) conditions, is compared with the estimated present fry carrying capacities of the main valley lakes (Tables 5.12 and 5.13). These two sets of data are presented and compared in Table 5.14. It is noted that, as with kokanee, the limitation imposed by the deficiencies of spawning habitat results in very limited utilization of the capacities of the lakes to accept rainbow trout fry.

5.5.4 Present Available Harvest Capacities

Direct estimates of the range of present available rainbow trout harvest capacities for each of the Okanagan main valley lakes for present tributary and mainstem discharge regimes and for present conditions of gross spawning habitat availability and quality were derived (Table 5.15) by reference to:

(a) the present (1971) realized rainbow trout harvest, and
(b) the estimated rainbow trout populations.

Some 12,800 rainbow trout were taken from the Okanagan main valley lakes during the twelve month period June 1971 to May 1972. The majority of these (98%) were taken from Okanagan Lake. No rainbow trout were encountered in creels at Wood or Vaseux Lakes. The twelve-month (1971-72) angling catches were interpreted as direct minimum estimates of the present available sustainable rainbow trout harvest capacity over a one-year period (Table 5.15).

Direct maximum estimates of available sustainable rainbow trout harvest capacities (Table 5.15) were derived as follows:

1) The number of trout in the age class corresponding to the average age in the angling catch was assumed to represent an approximation of the present maximum sustainable harvest capacity.
2) The average age-at-catching of rainbow trout was deduced from the mean size of trout in creels (Chapter 4) in conjunction with size-at-age characteristics given by Northcote *et al*.(MS 1972), and was estimated to be three years for Skaha and Vaseux Lakes and five years for the other lakes.
3) By reference to the estimated number of rainbow trout in spring at the mean effective spawning age in conjunction with the estimated survival rates for rainbow trout in the Okanagan headwater lakes, estimates were made of the trout population size at the mean age-at-catching in each of the main valley lakes. These derivations are detailed in Appendix 0 and the resulting estimates are summarized in Table 5.15.

Indirect estimates of present available rainbow trout harvest capacities in the main valley lakes were derived from the gross estimates of overall harvest capacities on the basis of Ryder's (1965) morphoedaphic index approach as was done for kokanee. Also paralleling the kokanee derivations, estimates of "most-probable" average present available rainbow trout harvest capacities were deduced for each of the main valley lakes. This involved averaging all three estimates where the Ryder estimate fell between the other two, and averaging the two highest estimates when the Ryder estimate fell outside. Alt estimates of rainbow trout harvest capacities for these lakes are given in Table 5.15.

TABLE 5.14

ESTIMATED UTILIZATION OF LAKE CARRYING CAPACITIES FOR RAINBOW TROUT FRY IN THE OKANAGAN MAIN VALLEY LAKES.

LAKE	Carrying Capacity (X 1000)	Fry Production (X 1000)	Utilization of Fry Carrying Capacity (Percent)
Wood	756	3.6	0.5
Kalamalka	956	297.9	32.1
Okanagan	23,377	1,197.9	5.1
Skaha	1,732	62.3	3.6
Vaseux	501	1.9	0.4
Osoyoos		-	

TABLE 5.15

ESTIMATED PRESENT ANNUAL SUSTAINABLE RAINBOW TROUT HARVEST CAPACITIES OKANAGAN MAIN VALLEY LAKES

LAKE	Number of Rainbow Trout Harvestable Annually, (X 1000)				Pounds of Rainbow Trout Harvestable Annually (per Acre[e])
	Direct Minimum[a]	Direct Maximum[b]	Indirect[c]	Most Probable	Most Probable
Wood	0.00	0.09	0.21	0.15	0.09
Kalamalka	0.10	7.92	0.36	2.79	0.60
Okanagan	11.08	24.65	4.95	17.86	0.26
Skaha	1.35	1.55	0.32	1.45	0.20
Vaseux[d]	0.00	0.05	0.05	0.05	0.05
Osoyoos	0.25	0.22	0.22	0.23	0.10
TOTAL	12.78	34.48	6.12	22.53	

[a] Equated to present (1971) realized annual harvest.

[b] Based on analysis of present (1971) population.

[c] Based on Ryder (1965), in conjunction with mean weight in angling catch.

[d] Size of rainbow trout estimated by reference to Skaha Lake.

[e] Based on mean weight of rainbow trout in present (1971) angling catch.

5.5.5 Discussion

The above analysis of rainbow trout productive capacities and harvest potentials proceeded according to the rationale depicted in Figure 5.2. As was the case for kokanee, the bulk of the derivations proceeded on an indirect basis and from generally unproved relationships. The actual relevant data base included:

1) A stocking formula which has generally proven a reasonable basis for estimating the carrying capacity of small-to-medium sized British Columbia lakes for trout fry.
2) Estimated relative abundance of rainbow trout with respect to kokanee and other species on the basis of comparative gillnet catches.
3) Size-at-age characteristics of rainbow trout in each lake.
4) Estimated trout mortality rates and fecundity on the basis of headwater lakes.
5) A survey of stream reproductive habitat characteristics.
6) An estimate of the angling catch and catch characteristics of rainbow trout from most of the lakes.
7) An existing model (Ryder 1965) for predicting sustainable harvest on the basis of mean depth, total dissolved solics and species composition in sampling catches.

Present utilization of the estimated carrying capacities of the Okanagan main valley lakes to accept rainbow trout fry is 5% or less in all except Kalamalka Lake, where it is 32%. The general pattern of utilization of carrying capacity is similar to that of kokanee. Present sustainable rainbow trout harvest capacity probably totals about 22,500 fish annually for all the lakes (Table 5.15), or about double the present (1971-72) actual annual harvest. Comparison with the much lower overall (1:5) catch to availability ratio which was deduced for kokanee suggests the basis for the generally much lower catch-per-unit-effort of rainbow trout in the angling fishery. It also suggests that rainbow trout stocks, under the present conditions of recruitment, are in more imminent danger of over-exploitation. In fact, it seems probable that only Kalamalka and Okanagan Lakes are at present producing a "comfortable" excess of rainbow trout production over harvest.

CHAPTER 6

Okanagan River

6.1 BACKGROUND AND RATIONALE

The Okanagan River provides limited angling opportunities throughout most of its length. Fishing is not good, but at times a moderately successful fishery for large rainbow trout and some warm species is enjoyed.

That part of Okanagan River between Vaseux and Osoyoos Lakes, serves as the major reproductive habitat for sockeye salmon ascending the Columbia River. The total Columbia sockeye escapement has averaged about 95,000 fish annually since 1961, of which an average of about 19,000 have spawned in the Okanagan River section. The actual Okanagan River escapement has varied from 2,000 to 45,000 fish, depending on the particular management of the commercial fishery, and in response to the Okanagan River discharge regime and other factors.

Commercial fishermen operating in the lower Columbia River take an average of about 21,600 sockeye annually, of which an estimated 70% (15,120 fish) are of Canadian origin. An additional 3,100 sockeye (annual average) are caught by Canadian and American Indians for subsistence and ceremonial purposes.

6.2 SPORT FISHERY

Because of its use as a flood control channel, the Okanagan River cannot be managed optimally for its indigenous fish fauna. The river is channelized through much of its length and consequently lacks the meanders, pool-and-riffle development, and shading characteristics of un-engineered streams. High temperatures coincident with these modifications and also attributable to the epilimnetic water sources in the mainstem lakes may drive salmonid fishes out of the river during the summer period.

The availability of fish in the river, particularly in the channelized reaches appears to be heavily dependent on migration from the main valley lakes. Thus, the status of populations in the latter will, to a large degree, determine fishery opportunities in the river.

It was estimated, in the course of derivations concerning Okanagan tributary streams (Chapter 4), that these waters could probably sustain annual trout harvests of at least 12 lb/acre under "minimum optimum" discharge conditions and present physical habitat situations. It seems reasonable to project the productive potential of Okanagan River on the same basis. However, it was considered that inherent trout productivity could reasonably be ascribed only to the "unimproved" river section.

The surface area of the Okanagan River channel in the un-improved section, based on an estimated length of three miles and a mean width of 88 feet, is 32 acres. A present potential trout harvest capacity of about 384 lb/year, exclusive of migratory contributions, is thus indicated. At the average weight (0.772 lb) prevailing in the 1971-72 angling catch, this is equivalent to about 497 fish, or about 87% of the present realized harvest. Rather than over-exploitation, these values are taken as a reflection of the role played by sport fishes migrating into the river from the main valley lakes.

6.3 SOCKEYE SALMON

It has been estimated that the reproductive habitat in the available section of the Okanagan River can successfully accommodate a minimum of 38,900 sockeye spawners, and that it might accommodate as many as 50,000 spawners under a more optimal discharge regime. The preferred discharge regime, incorporating "revised" sockeye salmon requirements, may be summarized as follows:

Upstream migration	August 1 - September 15	300-450 cfs with removal of stop logs as necessary
Spawning	September 15 - October 31	350-550 cfs.
Incubation	November 1 - February 15	175-1000cfs
Fry and migration	February 16 - April 30	175-1000cfs
Rearing (Osoyoos Lake)	12 months	Not sensitive under realistic alternatives

The basic carrying capacity of Osoyoos Lake for the progeny of sockeye salmon was estimated (Appendix K), by reference to the plankton abundance index to be 107,500 "effective" female spawners. An effective spawner in this context represents a capacity for successful deposition of 3500 eggs (Andrew, personal communication). Since the average fecundity of sockeye salmon spawning in the Okanagan is only about 2500 eggs (Major and Craddock, 1962), it may be assumed that basic rearing capacity exists in Osoyoos Lake to accommodate the progeny of (3500/2500) x (107,500) = 150,500 female sockeye spawners. At a sex ratio of 1:1 (Major and Craddock, 1962) this equates to 301,000 total spawning sockeye.

Since kokanee are direct competitors with sockeye for lake rearing capacity, it is reasonable to attempt some adjustment on this account. The "present" kokanee spawning escapement from Osoyoos Lake was estimated (Table 5.8) to be 37,000 total spawners. This, according to the assumptions set forth in Section 5.4, is equivalent (in terms of rearing capacity requirements) to 20,700 spawning sockeye. Thus, it is apparent that lake rearing capacity is not a limiting factor for Okanagan River sockeye at the abundance levels displayed by this run since 1961.

6.4 DISCUSSION

This analysis of fish harvest potentials for Okanagan River, and of sockeye salmon productive capacity in Okanagan River and Osoyoos Lake, proceeded from the following data base and associated inferences:

1) The present (1971) angling participation and catch for those reaches of Okanagan River below Skaha Lake.
2) An inferred present available trout harvest capacity estimate for Okanagan River based on estimates for Okanagan tributary streams and on recorded harvests from trout streams in other temperate locales.
3) An indirect estimate of the rearing capacity of Osoyoos Lake for sockeye salmon/kokanee.
4) Historic records of the annual sockeye salmon escapement to the mouth of the Columbia River, and to the Okanagan spawning location.
5) Historic records of the annual sockeye salmon harvest.