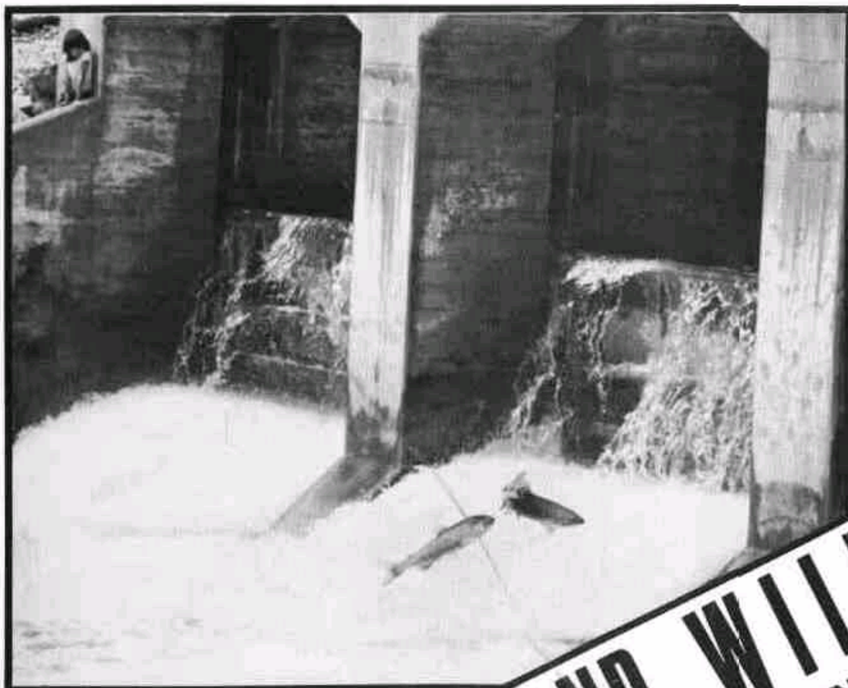
CANADA-BRITISH COLUMBIA OKANAGAN BASIN AGREEMENT



FISHERIES AND WILDLIFE IN THE OKANAGAN BASIN

"To be valuable does not necessarily mean to be manufactured"

MARCH 1974

TECHNICAL SUPPLEMENT IX

FINAL PUBLICATIONS IN THIS SERIES

1. SUMMARY REPORT OF THE CONSULTATIVE BOARD
2. THE MAIN REPORT OF THE CONSULTATIVE BOARD
3. TECHNICAL SUPPLEMENTS TO THE MAIN REPORT
   - I Water Quantity in the Okanagan Basin
   - II Water Quantity Computer Models
   - III Water Quantity Alternatives and Supporting Water Quantity Data
   - IV Water Quality and Waste Loadings in the Okanagan Basin
   - V The Limnology of the Major Okanagan Basin Lakes
   - VI Review and Evaluation of Wastewater Treatment in the Okanagan Basin
   - VII Value and Demand for Water in the Okanagan Basin
   - VIII Water-Based Recreation in the Okanagan Basin
   - IX Fisheries and Wildlife in the Okanagan Basin
   - X Economic Growth Projections
   - XI Public Involvement
   - XII Planning, Administration and Institutional Considerations

Cover Photos by Tom W. Hall

Top Left - 'Salmon below S.O.L.I.D. Dam on Okanagan River'
Bottom Right -'Canada Geese on Okanagan Lake'

Enquiries for copies of these publications should be directed to --

B.C. Water Resources Service,
Parliament Buildings,
VICTORIA, B.C.

FOREWORD

This Technical Supplement describes and presents the results of fishery resource studies (Technical Supplement IX(A), and water dependent Wildlife studies (Technical Supplement IX(B), as carried out under the Canada-British Columbia Okanagan Basin Agreement. The results of other water resource studies may be found in the publications listed on the inside front cover of this report.

The material presented in this supplement supersedes that of all earlier preliminary reports or publications prepared under the terms of reference of this Agreement.

A. Murray Thomson
Study Director

CANADA-BRITISH COLUMBIA OKANAGAN BASIN AGREEMENT

TECHNICAL SUPPLEMENT IX(A)

TO THE

FINAL REPORT

FISHERIES AND SPORT FISH POTENTIALS

OF THE

OKANAGAN BASIN

PUBLISHED BY
OFFICE OF THE STUDY DIRECTOR
Box 458, PENTICTON, B.C.
MARCH, 1974

THE CONSULTATIVE BOARD WISH TO ACKNOWLEDGE THE CONTRIBUTION OF THE FOLLOWING PEOPLE IN THE PREPARATION OF THIS TECHNICAL SUPPLEMENT

COMPILATION

MORLEY E. PINSENT
B. C. FISH & WILDLIFE BRANCH
DEPARTMENT OF RECREATION & CONSERVATION
VICTORIA, B.C.

CONTRIBUTING AUTHORS

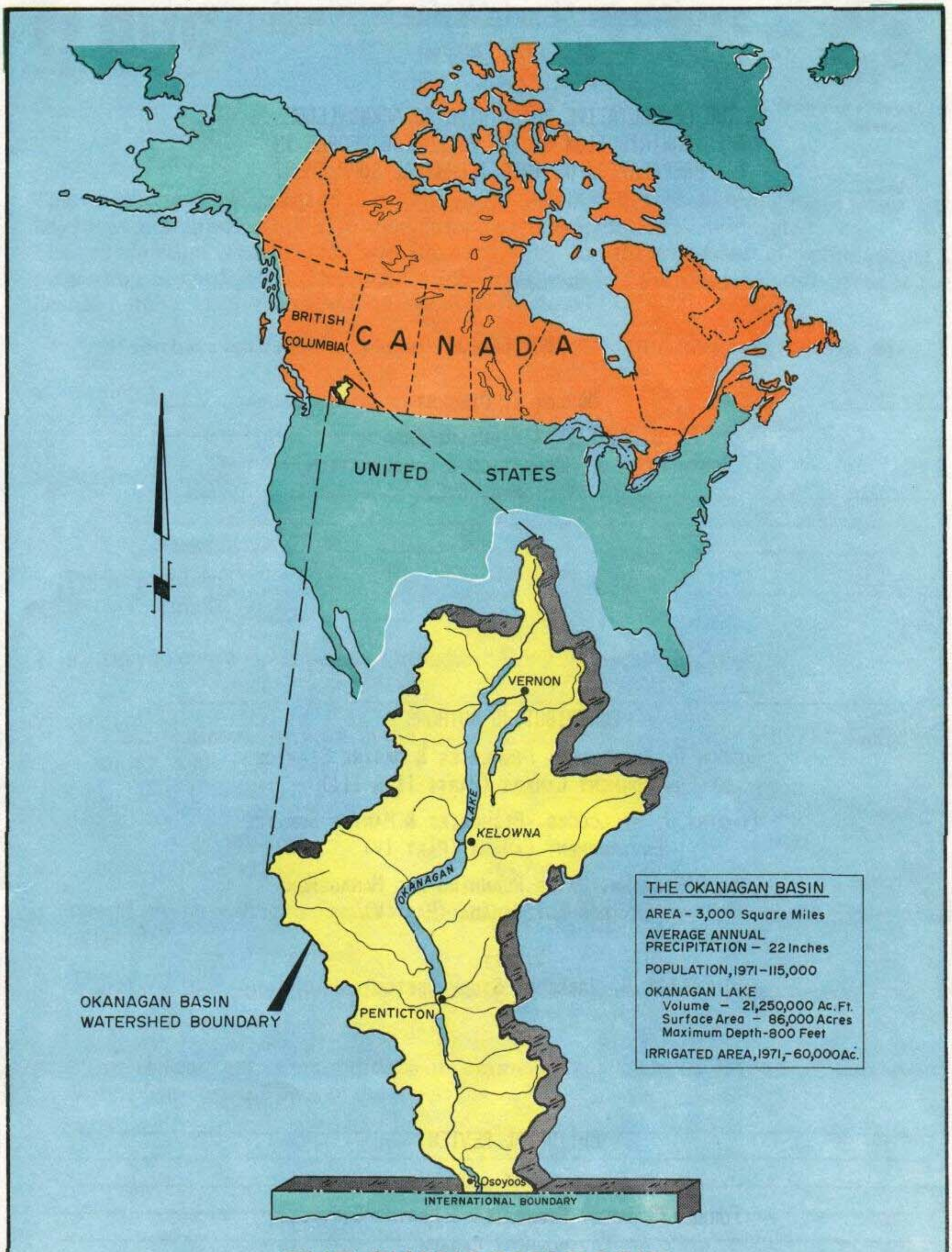
GORDON D. KOSHINSKY, FISHERIES & MARINE SERVICE
ENVIRONMENT CANADA (PARTS II & III)
TIMOTHY J. WILLCOCKS, FISHERIES & MARINE SERVICE
ENVIRONMENT CANADA (PART IV)
JON O'RIORDAN, WATER PLANNING AND MANAGEMENT
ENVIRONMENT CANADA (PART V)

TYPIST
L.W. JACKSON, STUDY OFFICE

EDITORIAL REVIEW

BY

FORBES C. BOYD, FISHERIES & MARINE SERVICE,
ENVIRONMENT CANADA
GORDON D. KOSHINSKY, FISHERIES & MARINE SERVICE
ENVIRONMENT CANADA



THE OKANAGAN BASIN
IN
BRITISH COLUMBIA — CANADA

Figure A

SYNOPSIS

The potentials of the Okanagan headwater lakes, the tributary streams, the main valley lakes and the Okanagan River are assessed in terms of the sustainable fish harvest they are capable of providing to various exploitation interests. These potentials are estimated according to various definitions, taking into account (insofar as possible) various recruitment and productivity requirements and constraints. The analysis provides a basis for evaluating, in terms of fish harvest capacities, the cost and effects of ameliorating these constraints. Present productivity of the fisheries is compared with potential productivity under both present and ameliorated conditions. This allows assessment of residual capacity of the various fisheries, under various broad management options, to meet fishery demands.

PART I: GENERAL

1. The objectives of the fisheries program and its role in water management planning were defined and explained.

2. Four basic Okanagan Basin fishery components were identified:
   a) Headwater lakes
   b) Tributary streams
   c) Main valley lakes
   d) Okanagan River

   and the discreteness and interfaces defined and discussed. The general methodology and approach involving these four fishery components was discussed.

3. Excess capacity for rearing salmonid fishes exists in all the Okanagan lake categories, and provides a strong basis upon which enhancement of stocks may be undertaken. Stock enhancement is necessary to accommodate increased future angling demand and/or to improve angling quality.

4. The Okanagan streams (including Okanagan River) provide relatively little

   inherent salmonid producing capability. However, they are extremely import-and for the reproduction of salmonids from the main valley lakes, and also for the reproduction of the Columbia River run of sockeye salmon.

PART II: PRESENT RESOURCE BASE

5. In the Okanagan Basin, 137 headwater lakes and reservoirs have been identified. They have a combined surface area of 10,904 acres and appear to provide present or potential sport-fishing opportunities. These lakes accommodated an estimated 65,900 angling-days of sport-fishing activity

in the 12 month period of June 1971 to May 1972 and yielded an estimated 125,500 fish. These headwater lake fisheries are primarily based on rain bow trout, although brook trout and/or a few other species occur in some of them. Elevation plays the predominant role in delimiting headwater lake fish productivity.

6. Recent (1967-71) annual stocking among all Okanagan headwater lakes has averaged 2,068,000 trout at 2500/lb or equivalent size. Stocking has utilized only about 18% of the estimated carrying capacity among those 57 lakes (comprising 67% of the surface area) where significant angling is presently conducted. Some additional utilization of carrying capacity occurs due to natural reproduction, particularly at the higher elevations. Annual sustain- able harvest capacity based on this recent stocking record and on its disposition according to elevation is 139,000 adult trout. In those 57 lakes actually fished to any significant extent, the estimated annual harvest capacity based on stocking, is 119,400 trout. This is slightly less than the present realized annual harvest (125,500 trout) and is accordingly indicative of a measure of natural reproduction. It also suggests that the present stocking program, although not quite ideally distributed, is about the minimum program which could maintain present angling quality for present angling effort.

7. Present potential trout harvest capacity in the 137 headwater lakes, based on saturation recruitment with under-yearling trout (by stocking or otherwise), is estimated to total 474,600 adult trout annually. This takes account of such present negative influences as excessive drawdown, winter kill and mixed species populations which occur to some extent among many of the lakes. It also implies stocking to capacity of four particular lakes (Swan, Ellison, Tugulnuit and Hydraulic), wherein conditions for trout are so unsuitable that specific management for trout appears unrealistic. Excluding these four lakes from consideration, reduces the estimated overall headwater lakes present potential annual trout harvest capacity to 453,000 fish.

8. The estimated present available annual trout harvest capacity from Okanagan tributary streams is 32,200 trout.

9. The sport-fishing effort on the Okanagan main valley lakes totalled 84,000 angling-days during June 1971 to May 1972. 83% of this effort transpired on Okanagan Lake. The resultant sport-harvest totalled 262,000 fish, of which 94% was kokanee and 5% was rainbow trout.

10. Present utilization of lake carrying capacities for kokanee ranges from 0.4% to 16.4% among the Okanagan main valley lakes, being lowest in Wood and Vaseux Lakes and highest in the northern and central regions of Okanagan Lake. Present available harvest capacity is estimated to be 1,283,000 kokanee (annual average), 88% of it from Okanagan Lake. This is 5.2 times the estimated present harvest.

11. Present utilization of carrying capacities for rainbow trout is 32.1% in Kalamalka Lake, but 5% or less in the other main valley lakes. Present available harvest capacity is estimated to be 22,500 rainbow trout (annual average) or 1.8 times the estimated present harvest.

12. The present run of sockeye salmon to Okanagan River averages 19,000 fish. The escapement contributes about 15,120 salmon annually to commercial fishing in the lower Columbia, and an additional 3,100 (estimated annual average) are caught by Canadian and American Indians. Modification of Okanagan main-stem operation could expand the strength of this sockeye escapement by as much as 2.3 times, as well as promoting its long-term survival. These modifications would also benefit kokanee. However, there would appear to be little or no opportunity to benefit rainbow trout through modified mainstem operation. Rainbow trout stocks in Osoyoos Lake could presumably be most readily enhanced through artificial reproductive facilities. If a spawning channel were built for the maintenance and enhancement of the sockeye salmon run, it might be possible to adapt it to accommodate rainbow trout as well.

PART III: PRESENT ANGLER USE

13. Angler interviews on 57 headwater lakes and the six main valley lakes, as well as an aerial boating use and ice-fishermen survey, were conducted in the Okanagan from June 1971 to May 1972.

14. An artificially stocked rainbow trout fishery in 57 utilized headwater lakes supported an estimated 65,900 angler-days. Average number of anglers per boat was 2.0. The average angling-day was 4.06 hours long.

15. Catch per angler-hour in the headwater lakes varied from 0 to 3.25 among lakes. Altitude is the primary factor affecting angler success, but it is also heavily influenced by access, geographic location, water level manipulation and stocking practices.

16. A direct relationship exists between "access factors" and lake usage by anglers. Success however, varied inversely with access factor. Those with an access factor less than 2.0 have an average C/UE of 0.66. Those with an access factor of 2.0 or greater, yielded 1.1 fish per angler-hour.

17. Twenty-one tributary streams do, or did support a sport fishery. It is estimated that about 2,300 angler-days are spent annually on tributary streams. Fish are small, averaging only 0.07 pounds each.

18. Boat fishermen in the main basin lakes spent 70,150 angling days harvesting 87,000 pounds of game fish (260,000 fish). The catch was 80% kokanee and 18% rainbow trout by weight.

19. Numerically, kokanee were the dominant sport fish in all main valley lakes, except Wood and Osoyoos. Rainbow trout harvest follows the same trend as kokanee harvest.

20. Sport fishing catch per unit-effort generally parallels available sport fish fauna. Harvest on a per-acre basis suggests some fish populations are being under- or over-harvested relative to others.

21. An estimated 4,900 angling days on the Okanagan River below Skaha Lake yielded 2,600 fish, 40% of which were preferred sport fish, 4% were marginal sport fish and 56% were coarse fish. Peak participation in this fishery occurs in June and September.

PART IV: PRESENT FISHERY VALUES

22. Resident anglers fished for an average of about 21 days in 1971 - usually at locations close to their homes. Non-residents fished for an average of 7 days per season and came mainly from the Lower Mainland (42%), Alberta (20%) or Western U.S.A. (17%). Only about one-third came for the primary purpose of fishing. Over 40% of non-residents were fishing in the Okanagan for the first time in 1971.

23. Non-resident anglers tended to fish more in family groups, were younger, better educated and had higher household incomes than resident anglers. Resident anglers had considerably more fishing experience in the valley than their non-resident counterparts.

24. Good access and proximity to place of residence were stated as primary reasons for choice of angling site. By far the majority of anglers (84%) preferred catching rainbow trout to kokanee. Most (70%) were satisfied with the range of sport fishing species available in the Okanagan.

25. The majority of anglers who stated preference for fishing experiences in the Okanagan, chose headwater lake fishing, and a significant minority (23%) desired more tributary stream fishing in the Okanagan.

26. Most anglers (70%) were satisfied with the quality of facilities offered in the basin, but many main valley lake fishermen would prefer more improved boat launching facilities.

27. Sport fishermen spent a total of $1.6 million attributed to angling recreation in the Okanagan in 1971, $1.1 million by residents and $0.5 million by non-residents. The net economic benefit of these expenditures to the Okanagan was estimated at about $446,000. In addition, anglers valued their recreational expenditures at almost $1.9 million over and above those expenditures. This value is estimated recreational value of sport fishing to anglers and although it does not accrue as actual dollars, its significance should not be ignored.

PART V: FISHERY USE PROJECTIONS AND EVALUATIONS

28. Angler-day demands could increase almost three-fold to 2020, given the conditions outlined.

29. Meeting projected demands in the headwater lakes fishery will require stocking of 5.2 million rainbow trout fry at 2500/lb annually by 2020.

30. The 137 headwater lakes have the productive capacity to rear the equivalent of 5.4 million fry annually.

31. Consideration will have to be given to angler distribution and/or stocking of catchable-size fish in heavily fished headwater lakes by 1980.

32. Tributary stream fisheries, although of very limited potential in the basin, do provide a different recreational experience. Optimization of stream flows could account for a 16% increase in annual catch, making a total catch of 38,400 trout possible annually.

33. The factor limiting salmonid sport fish production in the main valley lakes is tributary spawning area. Okanagan Lake salmonid populations are expected to be little affected by nutrient loading alternatives. A high nutrient input into Skaha Lake will result in a declining salmonid population after 1980.

34. Projected angler demands to 2000 in Okanagan Lake can be met by carrying out a program involving sequentially;
    a) Modified discharge operation, Mission Creek
    b) Development of 4,000 acre-feet of storage on Mission Creek
    c) Pumping and stream bed improvement, Trepanier Creek
    d) Incubation channel, Trout Creek
    e) Stream improvement, Mission Creek
    f) Rehabilitation and storage, Equesis Creek

    Beyond this date (2000), artificial reproductive facilities will be required to meet projected demands.

35. A hatchery facility is suggested on Skaha Lake to meet projected angler demands.

36. By the inception of Okanagan mainstem flow alternatives 1(d), 2(b), 3(a) and 3(b), the commercial harvest of the Okanagan River sockeye salmon population could be approximately doubled, given it is assumed to be stable under present flow conditions.

37. Construction of a spawning channel for sockeye salmon would result in an annual saving of 19,825 acre-feet of water. Annual costs in excess of $50,000 make the scheme unfeasible within the Study projection period.

38. Total costs for the proposed sport fish management program in the Okanagan Basin could exceed four million dollars over the next fifty years.

39. It is concluded that a broad productivity base exists in the Okanagan Basin lakes upon which the enhancement of salmonid stocks may be undertaken in an attempt to satisfy anticipated angler demands. This may be accomplished by improvement of water regimes and habitat, water storage and/or by use of artificial reproductive facilities.

It will be apparent throughout, that the various steps and conclusions have proceeded from a data base which, in most cases, was adequate only to establish the tone and direction of the assumptions which were necessary for the analyses. An attempt has been made to list these assumptions as they were incorporated, but in most cases there was no good basis for estimating the magnitude of the various biases which might have been introduced. The analyses, therefore involved a considerable measure of intuition. However, this was the only means by which this evaluation of the Okanagan fishery resource(s) could be completed within the terms of reference of the Study. Existing information, or at least available interpretation of such information prior to the Study, did not allow definition of a program which would have provided all the required data. Such a program would imply a vast and specific study effort, and one spanning a considerable time frame. This report does identify where such effort might profitably be applied. Certain more detailed assessments would clearly be in order before any large-scale fishery enhancement measures were undertaken, other than in an experimental setting. It is accordingly emphasized that the present assessment, and the evaluations arising from it, cannot at this stage be regarded as a complete and reliable blueprint for future Okanagan fishery management. Indeed, the present exercise is primarily demonstrative rather than definitive, and it is anticipated that actual management will proceed in a cautious and incremental manner. However, it is considered that the fundamental conclusions and recomm-endations presented here are valid in principle if not in detail.

TABLE OF CONTENTS

	PAGE
FOREWORD	i
TECHNICAL SUPPLEMENT IX(A)	ii
SYNOPSIS	v
TABLE OF CONTENTS	xi
LIST OF TABLES	xv
LIST OF FIGURES	xx
LIST OF APPENDICES	xxii
PART I INTRODUCTION	1
CHAPTER	
1. BACKGROUND	3
1.1 Objectives	3
1.2 Role in Comprehensive Planning	3
1.3 Problems Encountered	3
2. GENERAL METHODOLOGY AND APPROACH	5
PART II THE PRESENT FISHERY RESOURCE BASE	9
CHAPTER	
3. HEADWATER LAKES	11
3.1 Background and Rationale	11
3.2 Capacities of Lakes to Accept Trout Fry	14
3.3 Present Stocking and Utilization of Fry Carrying Capacities	15
3.4 Present Available Trout Harvest Capacities	16
3.4.1 Rationale and Methodology	16
3.4.2 Present Available Harvest Capacities	22
3.5 Discussion of Procedures and Results	22
4. TRIBUTARY STREAMS	25
4.1 Background and Rationale	25
4.2 Primary Potential Harvest Capacities	26
4.2.1 Primary Potential Harvest Capacity of Trout Creek	26
4.2.2 Extrapolation to other Tributaries	27
4.3 Discharge and Other Constraints to Trout Productivity and Utilization	29
4.4 Present Available Trout Harvest Capacities	33
4.5 Discussion of Procedures and Results	33

CHAPTER PAGE
5. MAIN VALLEY LAKES 35
5.1 Background and Rationale 35
5.2 Overall Fish Harvest Capacities: Estimated Gross Annual Sustainable Harvest 39
5.3 Special Considerations Pertaining to Production of Kokanee and Rainbow Trout 42
5.3.1 Trophic Considerations 42
5.3.2 Discharge and Related Requirements and Constraints for Reproduction 45
5.3.3 Physical Habitat Requirements and Constraints for Reproduction 52
5.4 KOKANEE: Present Productive Capacities and Harvests 52
5.4.1 Capacities of Lakes to Accept Kokanee 52
5.4.2 Present Kokanee Spawning Escapements 55
5.4.3 Utilization of Lake Carrying Capacity by Kokanee Spawners 58
5.4.4 Present Available Harvest Capacities 60
5.4.5 Discussion 61
5.5 RAINBOW TROUT: Productive Capacity and Harvest 62
5.5.1 Present Capacities of Lakes to Accept Rainbow Trout Fry 62
5.5.2 Present Rainbow Trout Fry Production 65
5.5.3 Utilization of Lake Carrying Capacities by Rainbow Trout Fry 67
5.5.4 Present Available Harvest Capacities 68
5.5.5 Discussion 70

6. OKANAGAN RIVER 71
6.1 Background and Rationale 71
6.2 Sport Fishery 71
6.3 Sockeye Salmon 72
6.4 Discussion 73
PART III PRESENT UTILIZATION 75
CHAPTER
7. HEADWATER LAKES 77
7.1 Methods 77
7.2 Angler Use and Catch 77

8. TRIBUTARY STREAMS 83

9. MAIN VALLEY LAKES 85
9.1 Methods 85
9.2 Fishing Effort, Catch and Harvest 87
9.2.1 Harvest by Boat-Fishermen 87
9.2.2 Shore-Fishing and Ice-Fishing 90
9.3 Discussion 92

10. OKANAGAN RIVER FISHERY 93
10.1 Methods 93
10.2 Results and Discussion 93

PART IV PRESENT FISHERY VALUES 97
CHAPTER PAGE
11. INTRODUCTION 99
12. METHODS 101
13. RESULTS 105
13.1 General 105
13.2 Background of Fishermen 106
13.3 Socio-Economic Characteristics of Fishermen 109
13.4 Behaviour and Preferences 113
13.5 Economic Evaluation of Sport Fishing 118
13.5.1 Non-resident fishing values 118
13.5.2 Resident fishing values 119
13.5.3 Non-resident angler expenditures 120
13.5.4 Resident angler expenditures 121
13.5.5 Costs of managing the Okanagan fishery 122
13.5.6 Non-economic values 123
PART V SPORT FISHERY EVALUATION AND ALTERNATIVES 125
CHAPTER
14. BACKGROUND RATIONALE FOR FISHERIES EVALUATION 127
14.1 Future Angling Demands 128
14.1.1 High growth (Projection I) 128
14.1.2 Low growth (Projection III) 129
15. HEADWATER LAKES FISHERY MANAGEMENT 131
15.1 Background and Rationale for Evaluations 131
15.2 Resource Capability 131
15.3 Projected Angling Demands and Future Success Rate 133
15.4 Future Management Alternatives 134
15.5 Detailed Projections of Angling Demand by Lake in 1980 136
15.5.1 Access factors 137
15.5.2 Projected demand 137
15.5.3 Conclusions and Discussion 141
16. TRIBUTARY STREAMS FISHERY MANAGEMENT 143
16.1 Rationale 143
16.2 Present Productivity and Utilization 143
16.3 Harvest Capacities and Characteristics of Stream Fisheries 143
16.4 Future Fishery Management Alternatives 145
17. MAIN VALLEY LAKES FISHERY MANAGEMENT 147
17.1 Background and Rationale 147
17.2 Estimates of Annual Fish Harvest Capacities and Projections of Angling Demand 147
17.3 Management Alternatives: Wood, Kalamalka, Vaseux and Osoyoos Lakes. 149
17.4 Okanagan and Skaha Lakes: Evaluation 149
17.4.1 General estimates of supply of and demand for kokanee and rainbow trout. 149
17.4.2 Specific enhancement measures for kokanee and rainbow trout 150

CHAPTER	PAGE
18. OKANAGAN RIVER FISHERY MANAGEMENT	175
18.1 Sport Fishery Management Alternatives	175
18.1.1 Future angling demand and fishery potentials	175
18.2 Sockeye Salmon Fishery Alternatives	176
18.2.1 Present status	176
18.2.2 Effects of mainstem flow on reproductive habitat	176
18.2.3 Construction of artificial reproductive habitat	176
18.2.4 Osoyoos Lake constraints	178
19. GENERAL DISCUSSION AND CONCLUSIONS	179
20. ACKNOWLEDGEMENTS	187
REFERENCES	189
PERSONAL COMMUNICATIONS CITED	191
MANUSCRIPT REPORTS	192
LITERATURE CITED	193
APPENDICES	195
TECHNICAL SUPPLEMENT IX(B)	227

LIST OF TABLES

TABLE NUMBER	TITLE	PAGE
3.1	Distribution by Elevation of 137 Okanagan Headwater Lakes with Present or Potential Sport-Fishing Opportunities	11
	A. Numbers of Lakes	11
	B. Water areas of lakes at fully supply level, acres	13
3.2	Distribution by Elevation of Basic Carrying Capacity for Trout Fry, Recent (1967-71) Average Trout Introductions, And Percent Utilization of Fry Carrying Capacity by Stocking, 57 “Key” Okanagan Headwater Lakes.	15
3.3	“Most Probable” Average Survival Rates for Stocked Rainbow Trout Starting from Fry at 2500/lb, in the Okanagan Head-Water Lakes	20
3.4	Average Size and Age-at-Catching, and Corresponding Cumul-ative Survival of Rainbow Trout among 33 Okanagan Headwater Lakes According to Elevation, 1971.	21
3.5a	Distribution by Elevation of “Present” Available Trout Harvest Capacities, 19 “Additional” Okanagan Headwater Lakes	23
3.5b	Distribution by Elevation of “Present” Available Trout Harvest Capacities, 19 “Additional” Okanagan Headwater Lakes	23
3.5c	Distribution by Elevation of “Present” Available Trout Harvest Capacities, 76 Okanagan Headwater Lakes Stocked During 1967-1971.	23
4.1	Comparative Production, Standing Crop, and Yield of Salmon-id Fishes in Selected Stream Habitats.	27
4.2	Mean Annual Discharges, Lengths of Angling Reach, and Prim-ary Potential Trout Harvest Capacities of Okanagan Tribut-ary Streams Relative to Trout Creek.	28
4.3	Relative Available Discharge under Present Operating Cond-itions, and Present Available Trout Harvest Capacities, Okanagan Tributary Streams.	31
5.1	Known Occurrence and Categorization of Fish Species in the Okanagan Main Valley Lakes	36
5.2	Calculation of Primary and Secondary Estimates of Gross Annual Fish Harvest Capacities for the Okanagan Main Valley Lakes under Present (1971) Conditions.	40
5.3	Secondary Estimates of Gross Annual Fish Harvest Capacities by Species Groups for the Okanagan Main Valley Lakes under Present (1971) Conditions.	43
5.4	General Characterization of Present Salmonid Reproductive Opportunities and Suggested Accompanying Minimum Discharge Requirements, in Major Okanagan Tributary Streams	48
5.5a	Summary of Estimated Minimum Discharge Requirements, Acre-feet by Whole Months, to Support Reproduction of Kokanee from the Main Valley Lakes in Major Okanagan Tributary Streams	49

TABLE NUMBER	TITLE	PAGE
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	50
5.7a	Estimated Present Spawning Areas for Kokanee and Rainbow Trout in Streams of the Okanagan Basin	51
5.7b	Estimated Present (1971) Rainbow Trout and Kokanee Spawning Escapements and Rainbow Trout Fry Production in Specific Reproductive Habitats	53
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.	56
5.9	Derivation of Best Estimates of “Present” Total Kokanee Spawning Escapements in the Okanagan Main Valley Lakes.	57
5.10	Estimated Utilization of Lake Carrying Capacities by Kokanee Spawning Escapements in the Okanagan Main Valley Lakes.	59
5.11	Estimated Present Annual Sustainable Kokanee Harvest Capacities, Okanagan Main Valley Lakes	59
5.12	Estimates of Annual Carrying Capacities of Okanagan Main Valley Lakes for Rainbow Trout Fry Estimated “Present” Fry Production.	65
5.13	Summary of Estimated Effective Rainbow Trout Escapement and Fry Production in the Okanagan Main Valley Lakes.	67
5.14	Estimated Utilization of Lake Carrying Capacities for Rainbow Trout Fry in the Okanagan Main Valley Lakes	69
5.15	Estimated Present Annual Sustainable Rainbow Trout Harvest Capacities, Okanagan Main Valley Lakes.	69
7.1	Summary of Lake Characteristics and Annual Trout-Fishing Effort, Catch and Harvest Estimated by Boat-Fishermen and Ice-Fishermen combined, Okanagan Headwater Lakes, 1971-72.	80
7.2	Grouping of 57 Okanagan Headwater Lakes According to Estimated Annual Sport-Fish Harvest, 1971-72.	81
9.1	Summary of Annual Angling Effort, Catch by Boat Fishermen, Okanagan Main Valley Lakes, 1971-72.	86
9.2	Estimated Total Seasonal Boat-Fisherman Catch from Okanagan Main Valley Lakes, 1971-72.	89
9.3	Summary of Annual Angling Catch-per-Unit-Effort Estimates for Shore-Fishing and Ice-Fishing, Okanagan Main Valley Lakes, 1971-1972.	91
9.4	Effort, Catch and Harvest Estimates for Shore-Anglers Fishing the Okanagan Main Valley Lakes and Okanagan River during November, 1971.	91
10.1	Summary of Annual Angling Effort, Catch and Harvest in Three Sections of Okanagan River, 1971-1972.	94
13.1	Summary of Angler-Days in the Okanagan Valley, May 1971 to June 1972.	105
13.2	Seasonal Proportion of Resident and Non-Resident Fishing Effort in the Okanagan Valley in 1971.	106
13.3	Residence of Valley Fishermen in the Okanagan in 1971	108
13.4	Location of Non-Resident Anglers Fishing in the Okanagan Basin, June 1971 to May 1972.	108
13.5	Frequency of Resident Participation in Fishing in the Okanagan Basin in 1971.	109

TABLE NUMBER	TITLE	PAGE
13.6	Age Distribution of Resident and Non-Resident Anglers in the Okanagan Basin in 1971.	111
13.7	Occupations of Residents and Non-Resident Okanagan Basin Fishermen in 1971.	111

13.8	Household Income Distribution of Resident and Non-Resident Anglers in 1971.	112
13.9	Education of Resident and Non-Resident Anglers in the Okanagan, 1971.	113
13.10	Time Required to Reach Fishing Site of Interviewed Resident Okanagan Basin Anglers in 1971.	115
13.11	Stated Preferences for Fishing of Okanagan Basin Anglers	116
13.12	Non-Resident Anglers' Expenditures in the Okanagan in 1971	120
13.13	Net Benefits from Non-Resident Anglers Spending in 1971.	121
13.14	Net Benefits from Resident Angler Spending in 1971.	122
14.1	Projections of Angling-Day Demands a) Residents and Non-Residents b) Main Valley and Headwater Lakes c) Main Valley Lakes	130
15.1	Distribution by Elevation of Potential Increases of Available Trout Harvest from 1971 Levels, and Consequent Increases Necessary in Introductions, 57 "Key" Okanagan Headwater Lakes.	132
15.2	Distribution by Elevation of Potential Increases of Available Trout Harvest from 1971, and Levels and Consequent Increases Necessary in Introductions, 80 "Additional" Okanagan Headwater Lakes	132
15.3	Present Potential Annual Trout Harvest Capacities, and Corresponding Introductions Necessary for their Realization at the Equivalent Size of 2500/lb., for 137 Okanagan Headwater Lakes, for all Elevations Combined.	133
15.4	Expected Angler Success Rates in Headwater Lakes Assuming no Change in Average Annual Stocking Rates.	134
15.5	Projected Headwater Angling Demand under Projection II 1970-2020, with Corresponding Trout Harvests Necessary to Maintain 1971 Success Rates.	135
15.6	Estimated Benefits and Costs of a Headwater Lakes Stocking Program to Meet Projected Angling Demands, 1970-2020.	135
15.7	Estimated 1971 and 1980 Access Factors and Angling Pressures at 57 "Key" Headwater Lakes, for High and Low Projections of Angling Demand.	138-9
15.8	1980 Projected Demand – Angling Days (By Region).	137
16.1	Primary Potential and Present Available Trout Harvest Capacities of Okanagan Tributary Streams.	144
17.1	Projections of Angling Day Demands in Okanagan Main Valley Lakes, for Projections I – 1970 to 2020.	148
17.2	Estimated Present and Potential Annual Sustainable Kokanee Harvest Capacities, Okanagan Main Valley Lakes, 1970 Level Of Basin Development.	148
17.3	Estimated Present and Potential Annual Sustainable Rainbow Trout Harvest Capacities, Okanagan Main Valley Lakes, 1970 Level of Basin Development.	148

TABLE NUMBER	TITLE	PAGE
17.4	Estimated “Most Probable” Annual Sustainable Kokanee Harvest Capacities, Okanagan and Skaha Lakes for 1970, 1980, 2000 and 2020 Levels of Basin Development	151
17.5	Estimated “Most Probable” Annual Sustainable Rainbow Trout Harvest Capacities, Okanagan and Skaha Lakes for 1970, 1980, 2000 and 2020 Levels of Basin Development	151
17.6	Comparison Between Production of, and Demand for, Kokanee in Okanagan Lake from 1970 to 2020 under Alternative Conditions of Angling Success Rate, Discharge Management and Status of Reproductive Habitat.	156
17.7	Comparison Between Production of, and Demand for, Kokanee in Skaha Lake from 1970 to 2020 under Alternative Conditions of Angling Success Rate, Lake Water Quality, Discharge Management and Status of Reproductive Habitat.	156
17.8	Comparison Between Production of, and Demand for, Rain-Trout in Okanagan Lake from 1970 to 2020 under Alt-Ernative Conditions of Angling Success Rate, Lake Water Quality, Discharge Management and Status of Reproductive Habitat.	157
17.9	Comparison Between Production of, and Demand for, Rainbow Trout in Skaha Lake from 1970 to 2020 under Alternative Conditions of Angling Success Rate, Lake Water Quality, Dischare Management and Status of Reproductive Habitat.	157
17.10	Pumping from Okanagan Lake Versus Upland Storage, Viewed as Possible Sources of Supplemental Water Required to Meet “Fisheries Deficiencies” under “Average Year Flow Conditions” and “1980” Level of Development	159
17.11	Increments in Kokanee and Rainbow Trout Harvests made Available by Enhancement of Spawning Area and by Modif-Ications of Stream Discharges.	160
17.12	Approximate Costs of Enhancement of Natural Reproductive Habitat for Kokanee and Rainbow Trout in 13 Streams Trib-Utary to Okanagan and Skaha Lakes	162
17.13	Production and Costs of Kokanee and Rainbow Trout from Artificial Reproductive Habitat Considered for Okanagan And Skaha Lakes.	162
17.14	Approximate Costs and Benefits of Hatchery Raised Kokanee and Rainbow Trout for the Satisfaction of Angling Demand in Skaha Lake, 1980 to 2020.	164
17.15	Expected Decline in Fishing Success in Okanagan and Skaha Lakes, Assuming No Enhancement of Kokanee and Rainbow Trout Stocks.	164
17.16	Kokanee Harvests in Okanagan Lake, 1970-2020, under Various Fishery Management Alternatives	166
17.17	Rainbow Trout Harvests in Okanagan Lake, 1970-2020, under Various Fishery Management Alternatives	166
17.18	Water Deficits for Fisheries in Mission Creek by 2020, Assuming Existing Storage and Alternative Operating Rules.	167
17.19	Okanagan Sport Fishery Management Evaluation Matrix in Mission, Trepanier and Equesis Creeks.	169
17.20	Evaluation of an Incubation Channel Proposal on Trout Creek	170
17.21	Sport Fishery Management Program for Kokanee and Rainbow Trout in Okanagan Lake, 1970-2020.	173
18.1	Relative Effect on Okanagan River Sockeye Salmon of Various Mainstem Operating Alternatives	177

TABLE NUMBER	TITLE	PAGE
18.2	Okanagan River Discharge Requirements for Sockeye Salmon in Natural River Channel, and with Spawning Channel Construction.	178

19.1 Total Salmonid Fishes Available to Present Sustained Annual Harvest in Lakes of the Okanagan Basin 179

19.2 Total Surface Area of all Lakes in the Okanagan Basin Harboring Sport-Fishing Opportunities. 179

19.3 Summary of Estimated Present (and Realistic Potential) Mean Annual Sustainable Fish Harvest Capacities for the Basic Okanagan Basin Fishery Components, 1970 Level of Development 180

19.4 Total Annual (1971-72) Angling Participation on all Lakes in the Okanagan Basin Harboring Sport-Fishing Opportun-ities. 181

19.5 Total Annual (1971-72) Sport-Fish Catch from All Lakes in the Okanagan Basin Harboring Sport-Fishing Opportun-ities. 181

19.6 Total Fish Kept per Angling-Hour from All Lakes in the Okanagan Basin Harboring Sport-Fishing Opportunities. 182

LIST OF FIGURES

FIGURE NUMBER	TITLE	PAGE
A	The Okanagan Basin in British Columbia-Canada	iv
2.1	Basic Factors and Inter-Relationships Controlling Fish Productivity in the Okanagan Basin	6
3.1	Location of Headwater Lakes and Streams in the Okanagan Drainage Basin	12
3.2	Measured and Empirical Smoothed Average Length-at-Age of Rainbow Trout in Okanagan Headwater Lakes, According to Elevation.	17
3.3	Empirical Smooth Average Weight-at-Age of Rainbow Trout in Okanagan Headwater Lakes According to Elevation	18
3.4	Distribution by Elevation of Present Trout Harvest Capacity and Present (1971) Realized Harvest, Okanagan Headwater Lakes.	18
4.1	Relation Between Loss of Potential Resident Trout Productiv-ity and Reductions from Optimum Discharge, Okanagan Tributary Streams.	32
5.1	Conceptual Model for Deriving Potential Harvest Capacity Est-imates and Lake Carrying Capacity Constraints for Kokanee in the Okanagan Main Valley Lkes.	37
5.2	Conceptual Model for Deriving Potential Harvest Capacity Estimates and Lake Carrying Capacity Constraints for Rainbow Trout in the Okanagan Main Valley Lakes.	38
5.3	Relation Between Chlorophyll Concentration and Total Phosphorus Content of Water from the Okanagan Main Valley Lakes.	41
5.4	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.	44
5.5	Schematic Representation of Natural Hypothetical Discharge Regime, Irrigation Demand and Fish Reproductive Require-Ments in Okanagan Streams.	46
7.1	Seasonal Variation in Length of Angling-Days Among Okan-agan Headwater Lakes, 1971 Data from All Key Lakes Combined.	79
9.1	Fish Catch by Boat-Fishermen, Okanagan Main Valley Lakes, June 1971 – May 1972.	88
10.1	Smoothed Curves of Seasonal Sport-Fishing Participation (angling-days per calendar day) in Three Sections (accumul-ated) of the Okanagan River Between Vaseux and Osoyoos Lakes, 1971-72.	95
13.1	Seasonal Patterns of Boat Angling Effort in the Okanagan.	107
13.2	Length of Fishing Experience of Residents and Non-Residents in the Okanagan Basin	110
13.3	Types of Group Fishing in the Okanagan Basin Lakes	110
13.4	Factors Taken into Consideration by Resident Anglers when Choosing a Fishing Location in the Okanagan Basin	114
13.5	Residence of Okanagan Fishermen and Location of Fishing in 1971.	114

TABLE NUMBER	TITLE	PAGE
13.6	Angler Evaluation of Quality of Facilities in the Okan-agan Basin	117
13.7	Resident Fishermen: Annual Aesthetic Values Associated with Angling in the Okanagan Basin.	124
13.8	Non-Resident Fishermen: Annual Aesthetic Values Assoc-iated with Angling in the Okanagan Basin.	124
15.1	Okanagan Headwater Lakes: Angling Pressure as a Function of Access Factor	140
17.1	Comparisons between Available Harvest of, and Demand for, Kokanee in Okanagan Lake, 1970-2020, under Specified Cond-Itions of Management.	152
17.2	Comparisons between Available Harvest of, and Demand for, Rainbow Trout in Okanagan Lake, 1970-2020, under Specified Conditions of Management.	153
17.3	Comparison between Available Harvest of, and Demand for, Kokanee in Skaha Lake, 1970-2020, under Specified Cond-Itions of Management.	154
17.4	Comparison Between Available Harvest of, and Demand for, Rainbow Trout in Skaha Lake, 1970-2020, under Specified Conditions of Management.	155

LIST OF APPENDICES

APPENDIX NUMBER	TITLE	PAGE
A_1	Elevation and Surface Areas at Full Supply Level of 75 "Additional" (Non-Key) Okanagan Headwater Lakes Known to Harbor Sport-Fishing Opportunities	197
A_2	Elevation, Total Dissolved Solids, and Surface Areas Of 57 "Key" Headwater Lakes	198
B.	Summary of Trout Carrying Capacities and Actual Trout Introductions to 57 "Key" Okanagan Headwater Lakes, 1967-1971.	199
C.	Summary of Trout Introductions to "Additional" (Non-Key) Okanagan Headwater Lakes, 1967-1971	200
D.	Size Distribution of Trout Stocked in Okanagan Head-Water Lakes, 1967-1971.	200
E.	Comparison of Rainbow Trout Harvest and Virtual Popul-Ations Estimated from "Most Probable" Average Annual Survival Rates, 12 Okanagan Headwater Lakes, 1971.	201
F.	Estimated "Present" Available and Present (1971) Real-ized Annual Trout Harvest for 57 "Key" Okanagan Headwater Lakes.	202
G.	Suggested Minimum Discharge Requirements, and Present Average Most Critical Seasonal Discharges Available for Resident Trout Production in Okanagan Tributary Streams.	203
H.	Predominant Constraints to Resident Fish Production and Angling Utilization of Tributary Streams in the Okanagan Basin.	204
I_1	Summary of Gillnet Catches from Wood Lake, 1971.	204
I_2	" " " Kalamalka Lake, 1971	205
I_3	" " " Okanagan Lake, (All Regions Combined), 1971	205
I_4	" " " Skaha Lake, 1971	206
I_5	" " " Vaseux Lake, 1971	206
I_6	" " " Osoyoos Lake, 1971	207
I_7	Synopsis of Gillnet Catches by Species Groups, Okanagan Main Valley Lakes, 1971.	207
J.	Derivation of Present Annual Carrying Capacity Estimates For Kokanee Fry, Referable to Numbers of Kokanee Spawners Supportable, Okanagan Main Valley Lakes.	208
K.	Sample Calculations of Present Carrying Capacity (of Osoyoos Lake) for Kokanee Spawners.	209
L.	Derivation of Average Kokanee Fecundity, Okanagan Main Valley Lakes, 1971	210
M.	Derivation of Present Annual Carrying Capacity Estimates For Rainbow Trout Fry (at 2500/lb), Okanagan Main Valley Lakes.	210
N.	Sample Calculation of Basic, Basic Adjusted, Secondary and Most Probable Estimates of Present Carrying Capacity (of Okanagan Lake) for Rainbow Trout Fry.	211

APPENDIX NUMBER	TITLE	PAGE
O	Derivation of Pertinent Rainbow Trout Population Para-Meters at Mean Age-at-Catching, Okanagan Main Valley Lakes, 1971.	213
P_1	Sport Fishing Effort Statistics by Boat-Fishermen, 1971-1972: Wood Lake.	214
P_2	Kalamalka Lake	214
P_3	North Okanagan Lake	214
P_4	South Okanagan Lake	214
P_5	Skaha Lake	215
P_6	Vaseux Lake	215
P_7	Osoyoos Lake	215
Q_1	Average Size of Fishes Taken by Angling, Okanagan Main Valley Lakes and Okanagan River, 1971-72. Wood Lake	216
Q_2	Kalamalka Lake	216
Q_3	North Okanagan Lake	216
Q_4	South Okanagan Lake	216
Q_5	Skaha Lake	217
Q_6	Vaseux Lake	217
Q_7	Osoyoos Lake	217
Q_8	Okanagan River	217
R.	Inventory of Present Angling Opportunities and Angling Utilization of Tributary Streams in the Okanagan Basin	218
S.	Sport-Fishing Effort, Catch and Harvest Statistics.	219
T.	Interview Form for Okanagan Valley Fishermen	220-22
U.	Relative Contribution of Tributary and Shore Spawning Kokanee to Increase Harvest Availability in Okanagan And Skaha Lakes, with 1970 Water Quality Conditions, Mod-Ified Discharge Regimes and Reproductive Habitat enhanced To Realistic Potential.	223
V.	Annual and Maximum Monthly Discharge Deficiencies in an Average Year for the Accommodation of Full fishery Require-Ments in Six Tributaries to Okanagan Lake, 1970, 1980 and 2020 for Historic and Modified Discharge Management.	224
W.	Derivation of Natural and Artificial Productivity Factors For Okanagan and Skaha Lakes, 1970-2020. Indicating the Incremental Harvests of Kokanee and Rainbow Trout made Available per Unit Area of Reproductive Habitat.	225

PART I

INTRODUCTION

CHAPTER 1

Background

1.1 OBJECTIVES

The objectives of the fisheries program in the Okanagan Basin Study were: to identify the current fishery resources within the basin, to estimate present and potential harvest capacities of the various resource components with reference to water quantity and quality, to estimate current sport and commercial fishery use, to identify the socio-economic aspects of the fishery and to project and present alternatives for water and fisheries management conducive to meeting anticipated angling and water demands in the Basin over the next fifty years.

1.2 ROLE IN COMPREHENSIVE PLANNING

As a major, but non-consumptive user of water within the Okanagan Basin, it was deemed that the requirements and future planning for fisheries should be considered a part of the Okanagan Basin water management study. The sport fisheries of the Okanagan Basin support an industry of considerable real value as well as presenting residents of the Okanagan with a recreational pursuit of considerable non-monetary significance. The fish populations also provide a valuable indication of the ecological well-being of the Basin. The sockeye salmon run into the Okanagan River provides a considerable portion of the sockeye catch in the lower Columbia River and is the subject of international agreement-thus Canada has the responsibility of maintaining the spawning segment of the life cycle.

If fishes were to be considered as rightful users of the water resource in the Basin within the time horizons outlined in the study, it was essential that this case be adequately presented. This document forms a basis for that inclusion.

1.3 PROBLEMS ENCOUNTERED

The ever-present problems of any investigational study with the need for relatively quick results, namely lack of adequate time, money and resources were of course present. As a result many conclusions are based on a number of untested or very inadequately tested assumptions. Due to lack of data, many of of the estimates, expansions and conclusions drawn there from are not adequate for rigorous statistical analysis. In many instances local knowledge and biological intuition played a major role in determinations.

In spite of the problems and limitations mentioned above, it is felt that in general, adequate data are presented to make decisions and recommendations within the framework and terms of reference; namely, a planning exercise to encompass the coming fifty years. The examination in detail of many aspects touched on by this investigation remains in the realm of the resource managers as they implement various aspects of the Study.

CHAPTER 2

General Methodology and Approach

Four basic Okanagan Basin fishery components may be identified:

1) Headwater lakes
2) Tributary streams
3) Main Valley lakes
4) Okanagan River
   (a) Sport fishes
   (b) Sockeye salmon

These components are to some extent discrete within the overall Okanagan fishery system. However there are certain vital interfaces, including the following:

(a) Rainbow trout and kokanee from the main valley lakes utilize tributary stream habitats for reproduction.

(b) Streamflows, generated in part by discharge from headwater lakes and reservoirs, are vital to the production of in-channel stream fisheries, and to reproduction by rainbow trout and kokanee from the main valley lakes.

(c) Many of the headwater lake fisheries are vulnerable to lake drawdown for meeting discharge requirements (including in-channel fishery needs) in the tributaries.

(d) The Okanagan River sport fishery is heavily dependent on the influx of fishes from the main valley lakes, especially Skaha, Vaseux and Osoyoos.

(e) Propagation of sockeye salmon (and other species) in Okanagan River is dependent on water releases from Okanagan Lake. Such releases affect shore-spawners and other factors in the lake.

(f) Sockeye salmon propagated in Okanagan River rear in Osoyoos Lake in association with the non-andromous fish species.

These inter-relationships, and other general factors influencing the inherent fish productivity of the Okanagan systems are diagrammed in Figure 2.1.

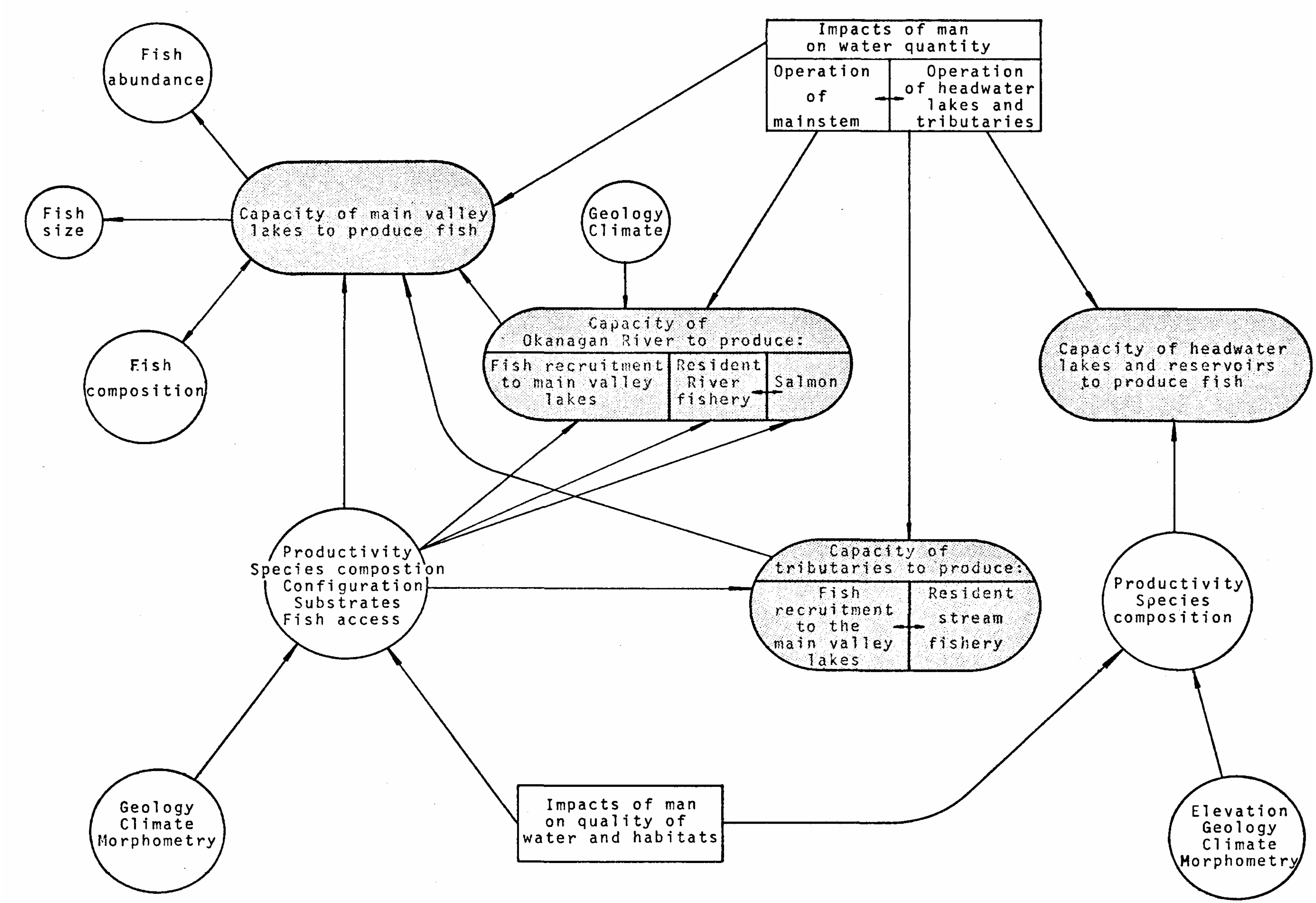
With the above mentioned points in mind, the general approach to the investigation was:

1) to determine the basic resource capabilities of the Basin in each of the four segments, i.e. what the system can produce?

2) to what extent is the fishery capacity of the Basin being utilized in each of its four segments?

3) what are the present economic and social values attached to the use of the sport fishery resource by man?

4) what might be expected to happen to the basic fishery resource capacity of



BASIC FACTORS AND INTER-RELATIONSHIP CONTROLLING FISH PRODUCTIVITY IN THE OKANAGAN BASIN

FIGURE 2.1

the Basin given a series of alternative development patterns for the human activities in the Basin up to the year 2020?

5) to provide a plan for provision of an adequate sport fishery resource in view of the increased angling demands and increased water demands in the Basin to 2020.

An attempt was made throughout the study to incorporate all the basic factors and inter-relationships contributing to fish productivity denoted in Figure 2.1. This was the general approach to both the investigational and planning aspects of the fisheries portion of the Okanagan Basin Study.

In view of time limitations almost all investigational work was carried on concurrently. A Basin-wide creel census and socio-economic angler survey, a limnological investigation of headwater lakes, analysis of tributary stream characteristics, kokanee spawning escapement documentations and many other fishery investigations were undertaken.

These fisheries investigations were carried out in a series of assigned tasks. As these data became available they were incorporated for use in the planning function. The logical end-product of the field investigations - fishery task reports - which were used extensively in preparation of this technical supplement are listed in the reference section.

Data from other aspects of the Okanagan Basin Study, in particular the limnological studies and tributary and mainstem water quantity studies were also used extensively.

PART II

THE PRESENT FISHERY RESOURSE BASE

CHAPTER 3

Headwater Lakes

3.1 BACKGROUND AND RATIONALE

Headwater lakes, for purposes of the present analysis, have been arbitrarily defined as any lakes or reservoirs within the Okanagan Basin exclusive of the six "main valley Lakes" (see Chapter 5). These definitions involve a few artificial distinctions at lower elevations. Lakes such as ElIison, Swan, and Tugulnuit have been included with the headwater lakes (basically by default) even though they lie on the main valley floor. Wood and Kalamalka, on the other hand, have been included with the main valley lakes even though they are part of a system which is tributary to the Okanagan mainstem. Locations of the Okanagan headwater lakes are indicated in Figure 3.1 and listed in Appendix A.

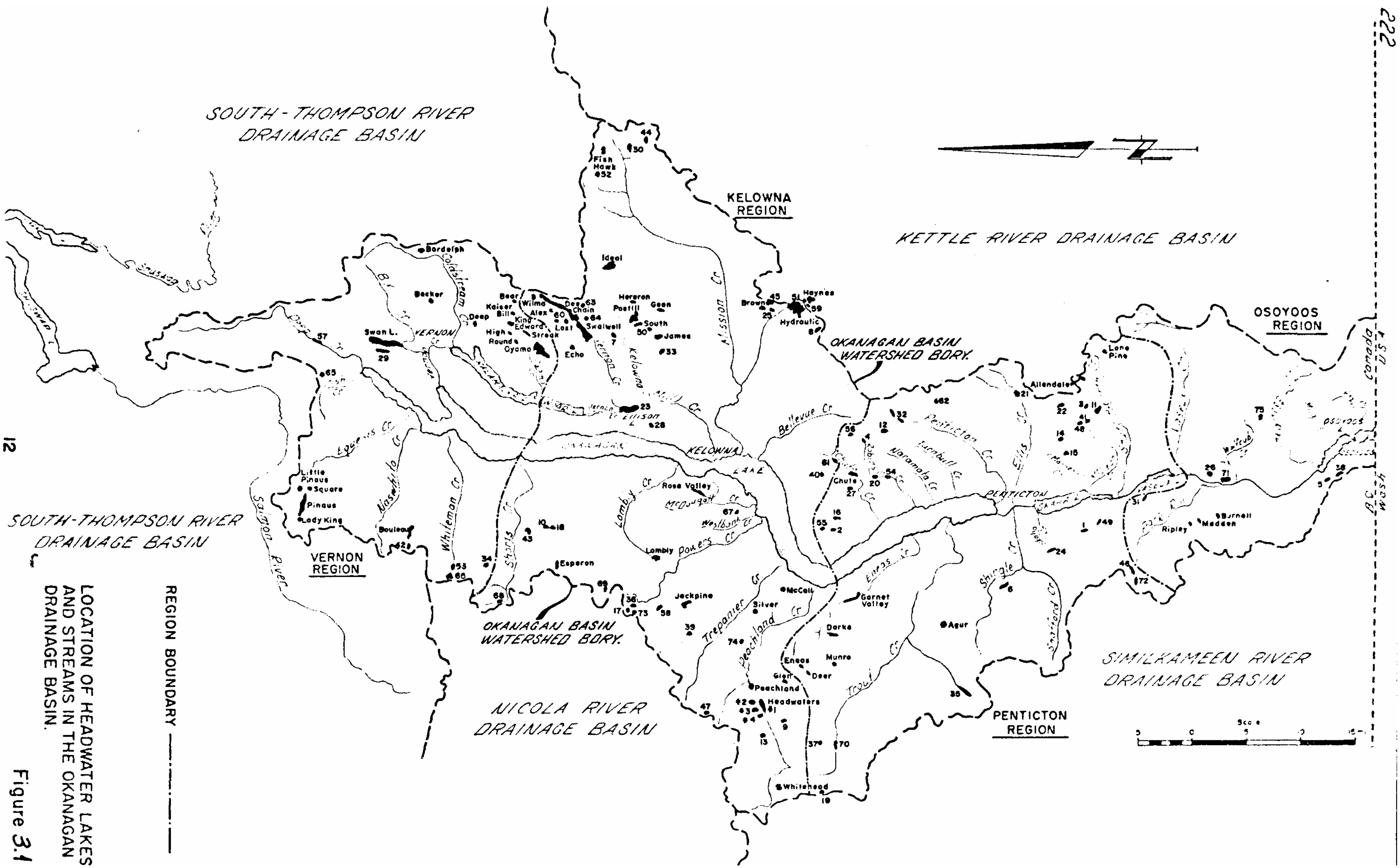
One hundred and thirty-seven Okanagan headwater lakes have been identified which either support sport fish populations or appear to have inherent potential to do so. Elevation plays the predominant role in delineating the fish productivity of these lakes, so it was necessary to stratify the analysis on this basis. Distribution of the 137 lakes on the basis of elevation is given in Table 3.1.A. The available lake surface area at different elevations is presented in Table 3.1.B.

TABLE 3.1

DISTRIBUTION BY ELEVATION OF 137 OKANAGAN HEADWATER LAKES WITH PRESENT OR POTENTIAL SPORT-FISHING OPPORTUNITIES

A. Numbers of Lakes:

Elevation (feet)	Key Lakes	Additional Lakes	TOTAL
< 3501	14	20	34
3501-4000	7	1	8
4001-4500	22 (+3)	20	45
4501-5000	8 (+2)	14	24
5001-5500	5	11	16
> 5500	1	9	10
TOTAL	57 (+5)	75	137



REGION BOUNDARY ——·——

LOCATION OF HEADWATER LAKES AND STREAMS IN THE OKANAGAN DRAINAGE BASIN.

Figure 3.1

TABLE 3.1 (cont'd)

B. Water areas of lakes at full supply level, acres

Elevation (feet)	Key Lakes	Additional Lakes	TOTAL
3501	1794	1605	3399
3501-4000	984	3	987
4001-4500	3862[a]	658	4520
4501-5000	480	326	806
5001-5500	175	644	819
5500	43	330	373
TOTAL	7338	3566	10904

The Okanagan headwater lakes support a significant and popular sport fishery centered primarily on rainbow trout. Brook trout and a few other species are distributed in a few of the lakes, but contribute very little to the overall angling catch. These headwater lake sport fisheries are, with certain exceptions, heavily dependent on artificial stocking of rainbow trout. There is some natural rainbow trout reproduction, particularly at higher elevations, and a few of the lakes are stocked with brook trout or other species. This analysis of headwater lake fishery capacities was conducted entirely on the basis of (specifically rainbow) trout.

Current fish stocking practice in British Columbia attempts to take account of lake carrying capacity for fry, anticipated utilization of the stock, and opportunities for natural reproduction. The general objective of stocking is to provide, on a continuing basis, "catchable" size (generally considered to be 1-2 pound) trout by age 2 or 3. On the basis of long experience ws well as specific studies (e.g. Smith, Halsey, Stringer and Sparrow, 1969) the province has developed a lake stocking formula which, when used with appropriate adjustment factors, has been a successful tool for the management of small to medium sized British Columbia trout lakes in which natural reproduction is inadequate or lacking.

For the present analysis, the current stocking formula was employed as a "proven" basis for estimating the carrying capacity of the Okanagan headwater lakes in terms of the numbers of trout fry they could annually be expected to accept efficiently. Stocking records provided an estimate of actual fry recruitment over a recent (1967-1971) five-year period. Harvest capacities were estimated on the basis of both the recent actual stocking and from the basic stocking requirement as given by the stocking formula. This required adjustment of fry inputs according to mortality rates of trout over the number of years required to grow to catchable size at the particular growth rates prevailing.

3.2 CAPACITIES OF LAKES TO ACCEPT TROUT FRY

The formula used to estimate the basic annual trout stocking requirement for British Columbia lakes has the form:

Basic carrying capacity for trout fry, at 2500/lb = K (limnetic area) + 10 K (littoral area)

Where:

Limnetic is that zone, expressed in acres, less than 6 meters (20 feet) in depth.

Littoral is that zone, expressed in acres, less than 6 meters in depth.

K is a stocking intensity factor based on total dissolved solids (TDS).

The basic fry carrying capacity (number of trout at 2500/lb) for any lake may be found as follows:

TDS, ppm	K	Fry Requirement per Acre	
		Limnetic zone	Littoral zone
250	350	350	3,500
200	300	300	3,000
150	250	250	2,500
100	200	200	2,000
50	150	150	1,500

The formula assumes a linear relation between TDS and trout carrying capacity for TDS values between 50 and 250 ppm. Carrying capacities for intermediate TDS values can thus be derived by direct interpolation. The procedure assumes that TDS = 250 for actual TDS values greater than 250, and it assumes TDS = 50 for actual values less than 50.

The morphometric and TDS parameters required for the estimation of basic fry carrying capacities are listed for the 57 "key" headwater lakes in Appendix A_2. Also listed are the elevations of the individual lakes and their surface areas at full supply level. The resultant basic fry carrying capacity estimates for these 57 lakes are detailed in Appendix B and are summarized according to elevation in Table 3.2

TABLE 3.2

DISTRIBUTION BY ELEVATION OF BASIC CARRYING CAPACITY FOR TROUT FRY. RECENT (1967 -1971) AVERAGE TROUT INTRODUCTIONS. AND PERCENT UTILIZATION OF FRY CARRYING CAPACITY BY STOCKING. 57 "KEY" OKANAGAN HEADWATER LAKES

Elevation (feet)	Number of Lakes	Basic fry carrying Capacity at 2500/lb equivalent		Recent Average Annual Trout Introductions at 2500/lb Equivalent		Utilization of Basic Carrying Capacity by Recent Stocking
		No. X 1000	No./Acre	No. X 1000	No./Acre	Percent
< 3501	14	4,225.2	2,355	552.5	308	13.1
3501-4000	7	987.5	1,004	160.1	163	16.2
4001-4500	22	3,498.8	906	883.1	229	25.2
4501-5000	8	694.7	1,447	91.6	191	13.2
5001-5500	5	262.7	1,501	41.1	235	15.6
> 5500	1	63.6	1,479	0.0	0	0.0
TOTALS	57	9,732.5		1,728.4		17.8

3.3 PRESENT STOCKING AND UTILIZATION OF FRY CARRYING CAPACITIES

Actual fish introductions to the 57 "key" Okanagan headwater lakes over the five year period 1967 to 1971 are given in Appendix B and are summarized in Table 3.2. Introductions to "additional" headwater lakes over the same period are outlined in Appendix C. For lakes not stocked in each year of the five year period, average annual rates of stocking were computed according to the number of years within the period since stocking was first initiated. Stocking data were obtained from Annual Reports of the B.C. Fish and Wildlife Branch.

Utilization of fry carrying capacity on the basis of stocking ranges from 0 to 25% and averages 18% among the "key" Okanagan headwater lakes (Table 3.2). Half of the trout planted, are stocked in lakes at elevations between 4001 and 4500 feet. This is also the elevation range which contains the greatest number of lakes and over half the combined "key" lake areas (Table 3.1.A).

It will be noted that in the present analysis all references to trout fry, as regards both carrying capacities and introductions, are made on the basis of fry at 2500 per pound equivalent. It has been determined (Halsey, personal communication) that rainbow trout fry produced naturally by the inlet-spawning population at Loon Lake, British Columbia move to the lake at about this average size. This accordingly seemed a reasonable basis for expressing carrying capacity estimates. In actual stocking practice, trout are regularly introduced at varying sizes depending on stock availability, hatchery rearing capacity, and particular management objectives. This is apparent from the size distribution of trout stocked recently in the Okanagan headwater lakes as given in Appendix D. It is necessary, when comparing and evaluating introductions, to convert the data to a common size basis. Progressively larger hatchery trout display progressively higher rates of survival-to-catchabie sizes. Therefore lesser numbers of larger trout need be stocked to provide equivalent numbers of catchable fish.

3.4 PRESENT AVAILABLE TROUT HARVEST CAPACITIES

3.4.1 Rationale and Methodology

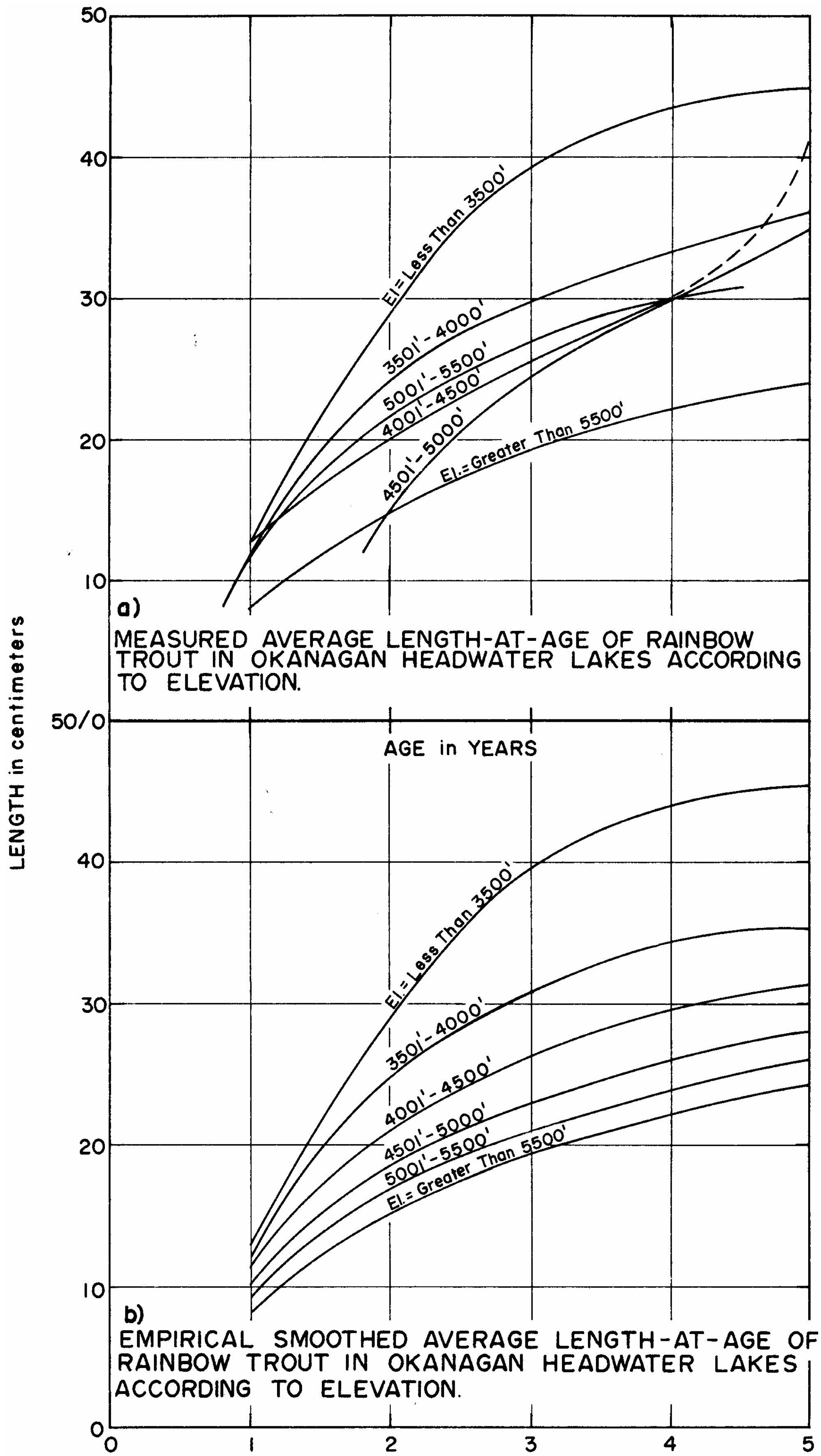
Present available trout harvest capacities for the Okanagan headwater lakes were estimated for a sustainable situation (assuming continued stocking or natural recruitment) as the amount of trout which can be harvested annually on the basis of present management in all its aspects, including recent stocking practice.

To estimate the particular trout harvest capacity for a particular lake, it was necessary to adjust the amount of fry recruitment (actual or potential) according to the estimated survival through to the mean catchable size. This in turn required estimates of the age composition of the angling catch, and also of survival from fry to the age-at-catching.

Growth of rainbow trout in eleven Okanagan headwater lakes was analyzed. Because of the uncharacteristically high levels of interspecific competition and reservoir manipulation in Hydraulic Lake, this lake was omitted from the analysis. For the remaining ten lakes examined, average lengths-at-age were determined for the different ranges of elevation (Figure 3.2a). Although certain anomalous growth patterns are apparent, it is clear that decreasing elevation promotes generally accelerated growth among trout in this series of lakes. An empirical set of "smoothed" growth (by length) curves was drawn (Figure 3.2a)incorporating the apparent trends in the available data. These curves were assumed to be representative of the average rates of growth of rainbow trout at the particular elevations; however, they are not necessarily valid for any particular lake.

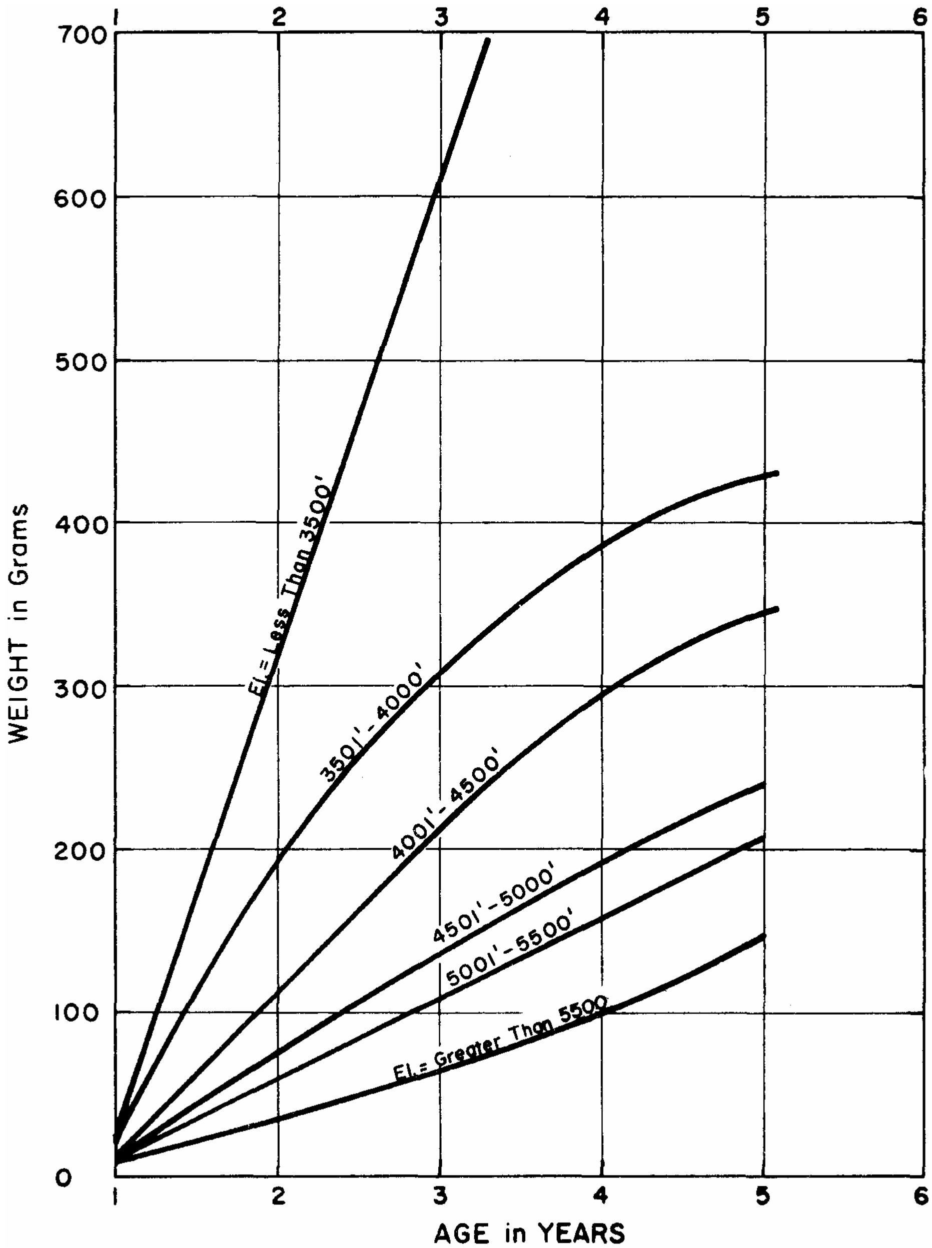
By combining the smoothed average length-at-age values with the length-weight relationship for rainbow trout in the headwater lakes, a set of empirical average weight-at-age curves was derived (Figure 3.3). This then provided a mechanism for estimating the average age-at-catching of rainbow trout from the average size (length or weight) in the catch according to elevation.

Survival rates of rainbow trout in the Okanagan headwater lakes could not be directly estimated from the data at hand. The procedure adopted was to establish a general framework of reasonable survival rates from the literature and other sources, and then to adapt the available information for Okanagan headwater lakes to this general pattern. It is of course appreciated that specific survival rates will vary tremendously depending on particular circumstances not the



LENGTH in centimeters
AGE in YEARS
50
40
30
20
10
50/0
40
30
20
10
0
0
1
2
3
4
5
El.= Less Than 3500'
3501'-4000'
5001'-5500'
4001'-4500'
4501'-5000'
El.=Greater Than 5500'
a)
MEASURED AVERAGE LENGTH-AT-AGE OF RAINBOW TROUT IN OKANAGAN HEADWATER LAKES ACCORDING TO ELEVATION.
El.= Less Than 3500'
3501'-4000'
4001'-4500'
4501'-5000'
5001'-5500'
El.= Greater Than 5500'
b)
EMPIRICAL SMOOTHED AVERAGE LENGTH-AT-AGE OF RAINBOW TROUT IN OKANAGAN HEADWATER LAKES ACCORDING TO ELEVATION.

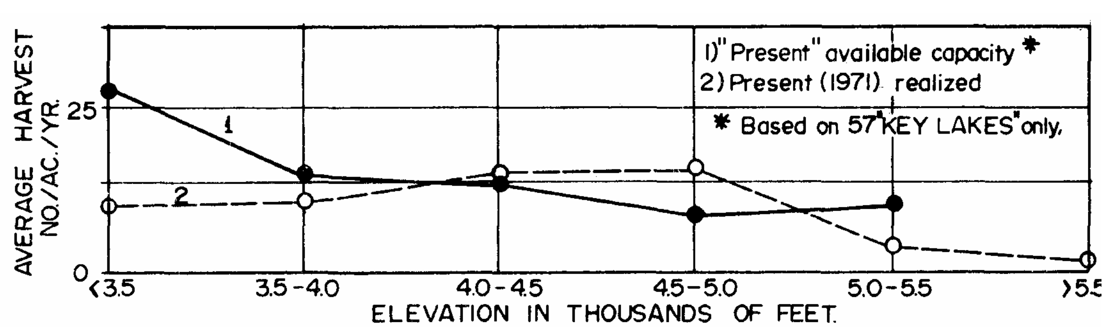
Figure 3.2



EMPIRICAL SMOOTHED AVERAGE WEIGHT-AT-AGE OF RAINBOW TROUT IN OKANAGAN HEADWATER LAKES ACCORDING TO ELEVATION.

Figure 3.3

DISTRIBUTION BY ELEVATION OF PRESENT TROUT HARVEST



CAPACITY AND PRESENT (1971) REALIZED HARVEST, OKANAGAN HEADWATER LAKES.

Figure 3.4

least of which is the intensity of fishing.

Taylor (personal communication) has suggested that survival of rainbow trout in British Columbia lakes may generally tend to be of the following approximate orders of magnitude:

10% eggs to fry
25% fry to over-yearlings
50% annually, 1 year to 3 years

Interpolating the conversion factors presented by Smith, et al . (MS 1969) for stocked rainbow trout suggests a similar or slightly lower early survival of approximately 15% from fry at 2500/lb to fish at 50/lb. Trout at 50/lb. would be in the range of fall fingerlings to yearlings in the Okanagan headwater lakes, depending on the particular productivity. Eipper (1960) indicates that survival of stocked rainbow trout in unexploited ponds in New York averages about 30% during the first summer, 50% in the two succeeding summers, and 60-80% over winter. Survival in these ponds is greatly influenced by temperature which is generally less optimal than in Okanagan headwater lakes. Needham, Moffet and Slater (1945) found that average survival of brown trout (*salmo trutta*) in Convict Creek, California was about 15% over the first 18 months. Hartman (1959) noted anftual survivals from 19-24% among mature rainbow trout in four of the New York Finger Lakes which are subjected to considerable fishing pressure.

From this overview it was concluded that reasonable ranges of average trout survival in the Okanagan headwater lakes might be 15-20% for fry to yearlings, and 50-80% per year thereafter. The next step was to attempt to refine these estimates specifically for the Okanagan lakes. Twelve lakes, representing a range of elevations from 2800 to 5200 feet, were selected for this analysis, on the basis rf the following characteristics:

1) Medium to heavy angling intensity (in 1971)
2) Catch per acre and average size of trout caught on record (for 1971)
3) Probable lack of natural reproduction
4) Predator and competitor species few or absent
5) Reservoir manipulation and drawdown not excessive
6) Stocked in at least three of the five years (1967-1971).

The average age-at-catching of trout in each of these takes was determined from the average weight of fish harvested according to the weight-at-age relation based on elevation (Figure 3.3). From the average age-at-catching, the corresponding year of stocking was identified, and the corresponding number of fry (on the basis of 2500/lb) actually stocked per acre was determined (from Annual Reports of the B.C. Fish and Wildlife Branch). Several hypothetical combinations of annual survival rates, based on the ranges 15-20% for fry to yearlings and 50-80% thereafter (see above) were then superimposed upon the number of trout of all age classes (to age 6). The estimated population at the mean catchable age (taken as mean age-at-catching, + 0.25 years to account for the fact that the bulk of fishing occurs during June-July) was then compared with the number of fish taken by angling (in 1971). That combination of survival rates which yielded virtual populations most consistent with the recorded catch (as per Appendix E) was interpreted as the "most-probable" annual survival pattern for these rainbow trout populations. These "most probable" annual survival rates are given in Table 3.3. The following assumptions are inherent in this derivation of survival:

1) That rainbow trout do not reproduce naturally in the lakes selected for this analysis, and that they are not differentially subjected to predation or competition from other species or to unusual mortality influences such as excessive drawdown. As indicated earlier, the lakes were specifically chosen to minimize such interactions, and it is considered probable that these conditions were very nearly met.

2) That annual catches in these particular lakes are, on the average, at or near the present available harvest capacity. To this end, the lakes were selected for medium to heavy angling intensity; however it is certain that most of them are not in fact exploited to capacity. This discrepancy would tend to result in some under-estimation of survival rates by the method employed.

TABLE 3.3

"MOST PROBABLE" AVERAGE SURVIVAL RATES FOR STOCKED RAINBOW TROUT STARTING FROM FRY AT 2500/LB. IN THE OKANAGAN HEADWATER LAKES

Age, years	Annual Survival	Cumulative Survival
1	0.20	0.2000
2	0.50	0.1000
3	0.60	0.0600
4	0.75	0.0450
5	0.75	0.0338
6	0.50	0.0169

3) That all trout caught by angling are of a single year class represented by the average age in the catch. Error introduced on this account would tend to result in some over-estimation of survival rates by the method employed.

4) That errors introduced via assumptions 2) and 3) above tend to cancel,

5) That annual survival rates for trout are the same for all categories of Okanagan headwater lakes regardless of elevation or other conditions. While specific factors (such as differential fishing mortality) would dearly contribute to differential survival among individual lakes, this in itself does not negate the use of these "most probable" survival estimates for the lakes as a group.

Average size estimates are available for rainbow trout in the 1971 angling catch from 33 of the 57 "key" headwater lakes. These values are presented as unweighted averages, according to elevation, in Table 3.4. The corresponding mean age of trout in the angling catch was estimated from the average size for each range of elevations according to the weight-at-age curves given in Figure 3.3. The cumulative survival to the mean catchable age characteristic of each elevation was then estimated from the average survival rates presented in Table 3.3. The mean catchable age for purposes of this survival estimation was taken to be the mean age-at-catching, + 0.25 years (to account for the fact that the bulk of the angling occurs during the summer). All estimates of mean age-at-catching and of cumulative survival are summarized according to elevation in Table 3.4.

TABLE 3.4

AVERAGE SIZE AND AGE-AT-CATCHING. AND CORRESPONDING CUMULATIVE SURVIVAL OF RAINBOW TROUT AMONG 33 OKANAGAN HEADWATER LAKES ACCORDING TO ELEVATION, 1971.

Elevation (feet)	Number of Lakes	Average Size in Angling Catch[a]		Corresponding Mean Age At Catching[b]	Cumulative Survival to Mean Catchable Age[c]
		Pounds	Grams	(Years)	
< 3501	6	0.65	295	2	0.0900
3501-4000	5	0.48	218	2	0.0900
4001-4500	12	0.44	200	3	0.0562
4501-5000	7	0.52	236	4	0.0422
5001-5500	2	0.38	172	4	0.0422
> 5500	1	0.24	109	4	0.0422

[a] From Koshinsky (1972a) (Okanagan Basin Study Manuscript Report)
[b] As per Figure 3.3
[c] Mean catchable age is taken as mean age-at-catching, + 0.25 years to account for the fact that the bulk of angling occurs during June-July. Survival estimates are derived from Table 3.3.

Harvest capacities were estimated on the basis of recent stocking and of estimated fry carrying capacity. Estimates were made for each of the 57 "key" takes separately. Average size values and corresponding average and survival parameters for particular elevations (Table 3.4) were employed throughout, even for those lakes for which actual size estimates were available.

The derivations proceeded according to the following important assumptions:

1) That there is no natural reproduction of trout in these headwater lakes. In fact, considerable natural reproduction is known to occur, particularly at the higher elevations. The effects of this error are to -

   (a) Over-estimate the hatchery stocking requirement

   (b) Under-estimate the present available harvest capacity.

2) That trout are stocked as fry or under-yearlings. Higher potential harvest capacities would of course be achieved by stocking older fish.

3) That all trout caught by angling are of a single year class represented by the average age in the catch. In fact, some fish of other ages are bound to contribute to catches; however a cursory consideration of size-frequency characteristics indicates that the Okanagan headwater fisheries do tend to be heavily based on single year classes. Substantial errors are probably not introduced on this account.

4) That valid average size, age, and survival parameters for trout harvested from these headwater lakes can be derived according to elevation, and that those averages can be applied on the basis of elevation to lakes or groups of lakes for which actual data are lacking. It is certain that specific situations will produce significant departures from such averages; however the over-riding importance of elevation to the biological productivity of these lakes as determined during a headwater limnology study, seems to imply that this procedure is basically valid.

3.4.2 Present Available Harvest Capacities

Harvest capacities on the basis of recent (1967-1971) actual stocking (Appendix B) in conjunction with the appropriate survival estimates (Table 3.4) are given for the 57 "key" lakes in Appendix F. These estimates are summarized according to elevation in Table 3.5a and in Figure 3.4. Present available trout harvest capacities for 19 "additional" headwater lakes stocked during 1967-1971 are outlined in Table 3.5b. The latter contribute relatively little (14% by number) to the overall present available harvest capacity for Okanagan headwater lakes. It is noted that these derivations are somewhat hypothetical in that they are based on average trout stocking over a five-year period. Consequently the resulting fish productive capacities are not strictly referable to any specific "present" time frame.

3.5 DISCUSSION OF PROCEDURES AND RESULTS

As has been stressed above, the present analysis of trout harvest potentials in the Okanagan headwater lakes proceeded from an assumed set of parameters and relationships which, although certainly operative in a general sense, have not been proven in detail in the present setting. Elevation was identified as the key influence on trout productivity in the headwater lakes. The analysis proceeded on the basis of stratification on this account. Trout carrying capacities

TABLE 3.5a

DISTRIBUTION BY ELEVATION OF "PRESENT" AVAILABLE TROUT HARVEST CAPACITIES[a], 57 "KEY" OKANAGAN HEADWATER LAKES

ELEVATION FEET	NUMBER OF LAKES	TOTAL AREA AT FULL SUPPLY LEVEL (ACRES)	TOTAL NUMBER	TOTAL WEIGHT (POUNDS)	NUMBER PER ACRE	POUNDS PER ACRE
< 3501	14	1,794	49,732	32,326	27.7	18.0
3501-4000	7	984	14,407	6,915	14.6	7.0
4001-4500	22	3,862	49,628	21,836	12.9	5.7
4501-5000	8	480	3,866	2,011	8.1	4.2
5001-5500	5	175	1,736	659	9.9	3.8
> 5500	1	43	0	0	-	-
TOTALS	57	7,338	119,369	63,747		

TABLE 3.5b

DISTRIBUTION BY ELEVATION OF "PRESENT" AVAILABLE TROUT HARVEST CAPACITIES[a], 19 "ADDITIONAL" OKANAGAN HEADWATER LAKES

ELEVATION FEET	NUMBER OF LAKES	TOTAL AREA AT FULL SUPPLY LEVEL (ACRES)	TOTAL NUMBER	TOTAL WEIGHT (POUNDS)
< 3501	3	124	8,127	5,283
3501-4000	0	0	0	0
4001-4500	5	237	3,964	1,744
4501-5000	3	27	1,259	655
5001-5500	5	374	4,740	1,801
> 5500	3	32	1,535	368
TOTALS	19	794	19,625	9,851

TABLE 3.5c

DISTRIBUTION BY ELEVATION OF "PRESENT" AVAILABLE TROUT HARVEST CAPACITIES[a], 76 OKANAGAN HEADWATER LAKES STOCKED DURING 1967-1971

ELEVATION FEET	NUMBER OF LAKES	TOTAL AREA AT FULL SUPPLY LEVEL (ACRES)	TOTAL NUMBER	TOTAL WEIGHT (POUNDS)	NUMBER PER ACRE	POUNDS PER ACRE
< 3501	17	1,918	57,859	37,609	30.2	19.6
3501-4000	7	984	14,407	6,915	14.6	7.0
4001-4500	27	4,099	53,592	23,580	13.1	5.8
4501-5000	11	507	5,125	2,666	10.1	5.3
5001-5500	10	549	6,476	2,460	11.8	4.5
> 5500	4	75	1,535	368	20.5	4.9
TOTALS	76	8,132	138,994	73,598		

[a] Based on average annual stocking, 1967-1971

[b] Based only on lakes actually stocked.

and harvest potentials were identified and expanded in relation to elevation.

It is emphasized that the estimates of "average" growth, survival, angling catch, and other parameters are based on a small number of lakes within the various elevation ranges. Confidence of estimates is generally lowest at both extremes of elevation. Growth data for elevations below 3500 feet, for example, were available for only one lake - Pinaus. This is the deepest known Okanagan headwater lake, and may accordingly be rather unrepresentative.

The present available trout harvest capacities of the Okanagan headwater lakes, based on the recent stocking record, are estimated to lie between 10 and 30 fish per acre annually (depending on elevation) for those lakes actually stocked. This is equivalent to a range of 5 to 20 pounds per acre. Present available harvest capacity on this basis does not exceed 139,000 trout weighing 73,600 pounds for all 137 headwater lakes, and 119,400 trout weighing 63,700 pounds for the 57 "key" lakes alone.

Present (1971) realized trout harvest, confined almost entirely to the 57 "key" lakes as indicated by effort distribution, is 125,500 trout weighing 63,400 pounds. Numbers harvested are slightly in excess of numbers theoretically available on the basis of stocking alone. This is probably indicative of natural reproduction.