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T. G. HALSEY
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Technical Report—

THE SHORE SPAWNING HABITAT
OF KOKANEE IN OKANAGAN LAKE

TASK 66E

THE SHORE SPAWNING HABITAT OF KOKANEE IN OKANAGAN LAKE AND THE EFFECT OF LAKE LEVEL CHANGES ON REPRODUCTIVE SUCCESS

by

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ABSTRACT

Kokanee shore spawning sites in Okanagan Lake were located on the east shore, north of Squally Point, and on the east and west shores, north of Kelowna in 1972; no sites were located south of Squally Point or in the extreme north-west arm of the lake. The physical characteristics (aspect, slope, gravel composition) of representative sites were described.

During the incubation period of 1972-73 an 0.85 ft (0.26 m) drop in lake level exposed about 30% of the shore spawning area; this probably caused a loss of about 30% of all eggs deposited.

INTRODUCTION

The object of this study, "Task 66E - Kokanee Shore Spawning Studies", under the Limnology Task Force of the Canada-British Columbia Basin Agreement was to locate and characterize spawning habitat and determine the effect of lake level fluctuations on the reproductive success of shore spawning kokanee (Oncorhynchus nerka) in Okanagan Lake.

An estimated minimum of 518,000 kokanee spawned on selected shores of Okanagan Lake in October 1971, (Northcote, et al, 1971). In 1972, no estimate of numbers was made but kokanee were observed spawning between October 26 and November 29 and spawning may have commenced in the southern area of the lake as early as mid-October.

Shore-spawned eggs incubate from the time they are deposited until about mid-March to April, (the precise time of emergence has not been determined) During this incubation period, developing eggs are subject to natural mortality from several sources and to mortality induced by drops in lake level. The time

at which drops in the lake level occur may greatly affect the degree of consequent mortality; if the lake level dropped after the eggs hatch, but before the alevins emerge from the gravel, it is quite conceivable that they could avoid dessication and/or freezing by following the dropping water level through the gravel. If the lake level drops prior to hatching, then, of course, the eggs are subject to unavoidable mortality.

METHODS

Location of Spawning Sites

The shoreline of Okanagan Lake was inspected periodically by boat during the period October 26 to November 29, 1972. The shoreline of Skaha Lake was similarly inspected on November 18.

Investigation of areas where spawning fish were not observed but where the substrate had been bared of epilithic algae, invariably revealed the presence of newly deposited kokanee eggs. The location of these sites along with those that fish were using at the time of observation were all recorded on large scale maps and later transferred to compose Figure 1.

Characteristics of Spawning Sites

(i) Aspect

The aspect of spawning sites was recorded as a compass direction of a line drawn perpendicular to the shore line.

(ii) Slope

The slope was calculated from a transect on a compass

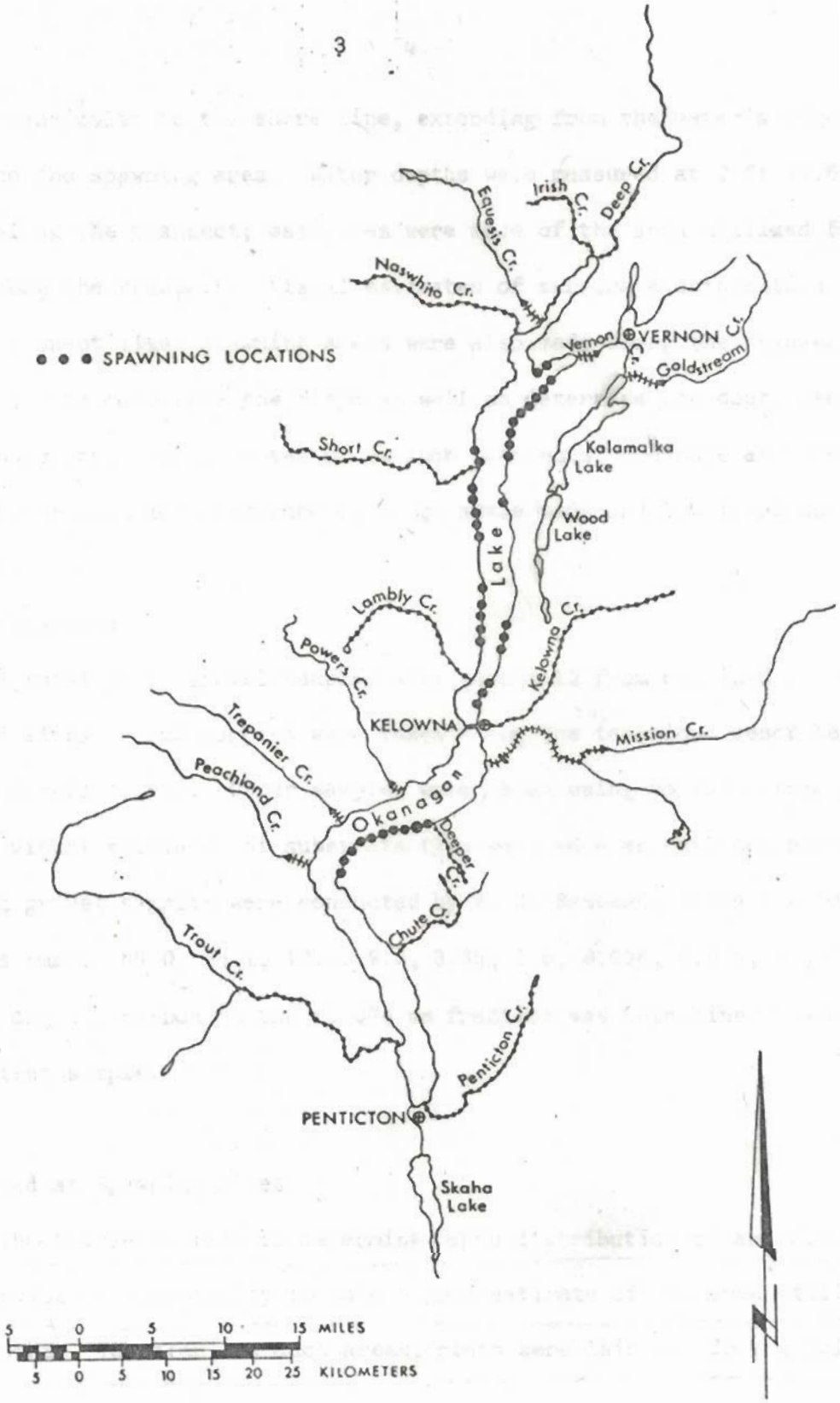


Fig. 1. Location of shore spawning habitat of kokanee in Okanagan Lake (autumn 1972). Streams shown are used by stream spawning kokanee

bearing perpendicular to the shore line, extending from the water's edge to a depth beyond the spawning area. Water depths were measured at 2 ft (0.6 m) intervals along the transect; estimates were made of the area utilized for spawning along the transect. Visual estimates of substrate composition in both utilized and un-utilized spawning areas were also made along the transect. These data were used to calculate the slope as well as determine the depth range over which spawning occurred. A total of 26 such transects were made at representative sites and these locations recorded on large scale maps and low level aerial photographs.

(iii) Substrate

A total of 17 gravel samples were taken; 12 from utilized and 5 from un-utilized sites. Some samples were taken using the technique described by McNeil and Ahnell (1964). Other samples were taken using no volumetric sampling device and visual estimates of substrate type were made as outlined above. Analyses of gravel samples were conducted by B. C. Research using the following sieve sizes (mm): 64.0, 38.1, 19.0, 9.5, 3.35, 1.0, 0.296, 0.074, <0.074; percentage organic carbon in the <0.074 mm fraction was determined where there was sufficient sample.

Area Utilized at Spawning Sites

The transects made to determine depth distribution of spawning habitat did not provide an opportunity to make a good estimate of the area utilized at various depths. To calculate such areas, plots were laid out in the following manner:

(i) A 30 ft (9 mm) baseline was laid parallel to the shoreline and 4 transects

at right angles to the baseline, were run over the spawning area at 10 ft (3 m) intervals.

(ii) Measurements of depth were made at 2 ft (0.6 m) intervals along each of the 4 transects.

(iii) This layout was represented on grid paper at a scale of 1 ft (0.3 m) per 1/4 inch and the spawning areas plotted.

(iv) The depths recorded from all plots and transects were adjusted to the lake level of November 1, 1972 (about the time of peak spawning activity). From the adjusted baseline, the utilized area was calculated for each 0.5 ft (0.2 m) depth interval.

Locations of plots were recorded on low level aerial photographs. The level of Okanagan Lake was recorded at the Penticton dam by staff gauge by the B. C. Department of Highways and Water Service of Canada.

Survival of Eggs

Samples of eggs were taken from several sites with a shovel from excavations approximately 1 ft^3 (0.03 m^3) in size. Eggs were collected with a small dip net and digging in each hole continued until eggs were no longer found - usually at a depth of about 12 inches (30 cm). Samples were taken in January and March. All eggs and alevins were first preserved in Gendre's fluid and later transferred to 100% ethanol alcohol. Counts of live and dead eggs and alevins were later made.

The conventional method of estimating mortality from all sources in a stream environment is dependent upon an estimate of total egg deposition and should take into account the number of broken egg "shells" when sampling has been

done by shovel (McNeil, 1964). In this study it was not possible to obtain an estimate of total egg deposition and broken egg shells were ignored; estimates of survival are therefore biased considerably upwards.

RESULTS

Location of Spawning Sites

The distribution of spawning sites in Okanagan Lake in 1972 was similar to that recorded by Northcote et al (1972).

The southern (south of Peachland Creek and Squally Point) arm and the extreme north arm were not used by shore spawning kokanee. Both the east and west shores of the lake were utilized except for the west shore south of Kelowna (Fig. 1).

Spawning kokanee were not observed in Skaha Lake and no significant amount of suitable spawning habitat was observed.

Characteristics of Spawning Sites

Representative sites in Okanagan Lake chosen for detailed studies of spawning habitat are shown on aerial photographs in Figure 2; the locations of the photographs are indexed in Figure 3.

(i) Aspect

Aspect was recorded at 26 sites where transects (T) were run and 30 sites where area plots (P) were constructed (Fig. 4).

(ii) Slope

The calculated average slope of spawning habitat was 13.4%; slopes

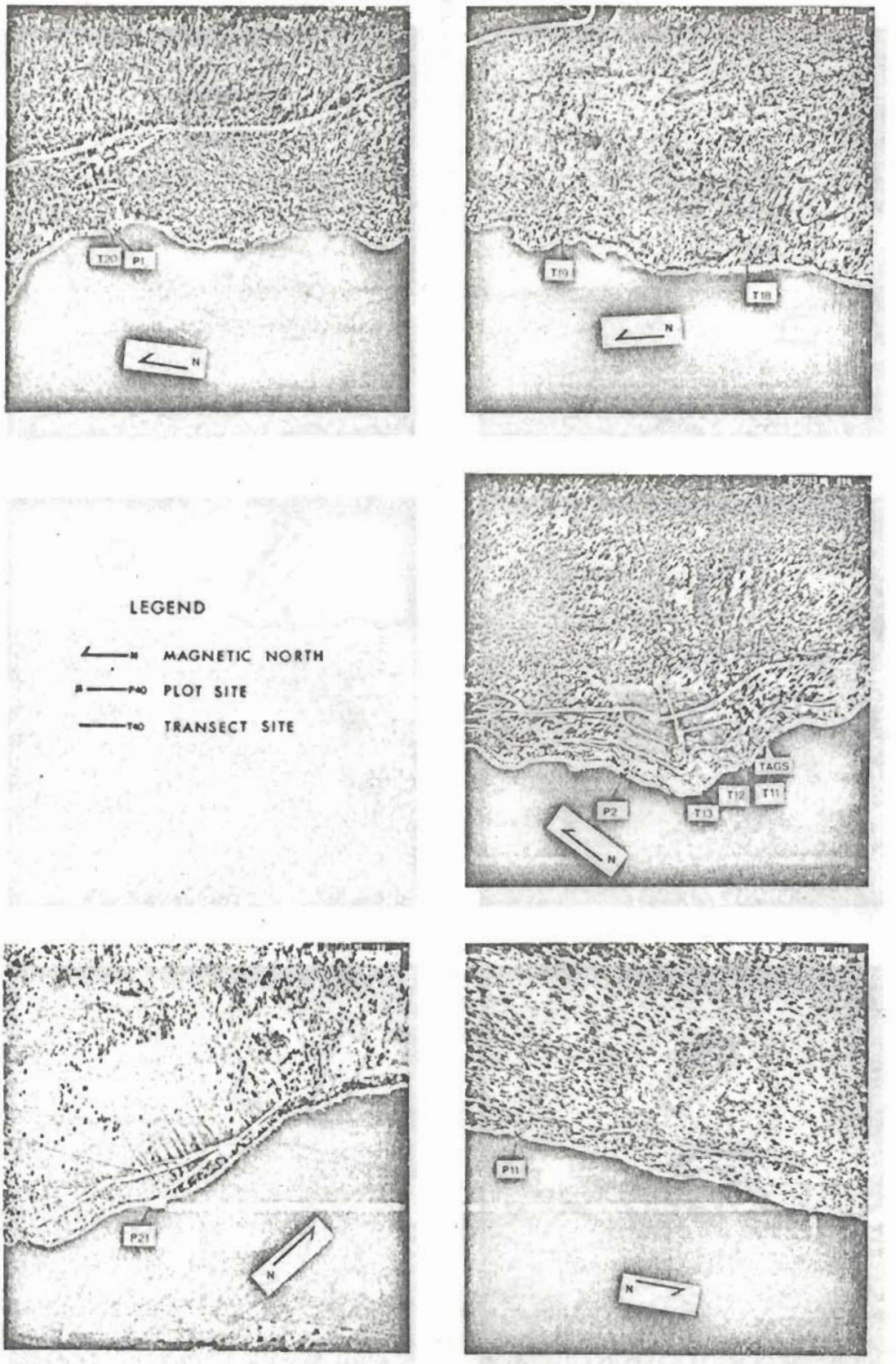
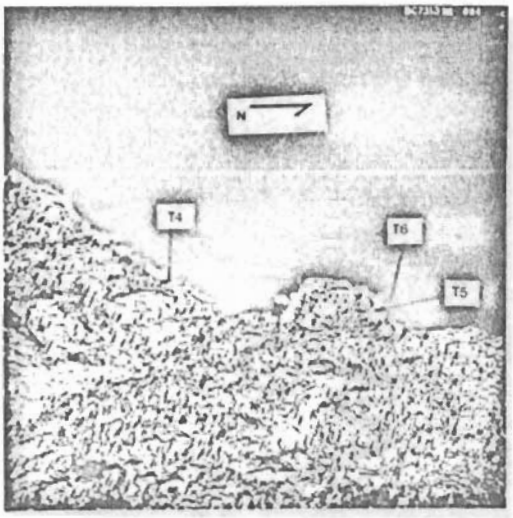
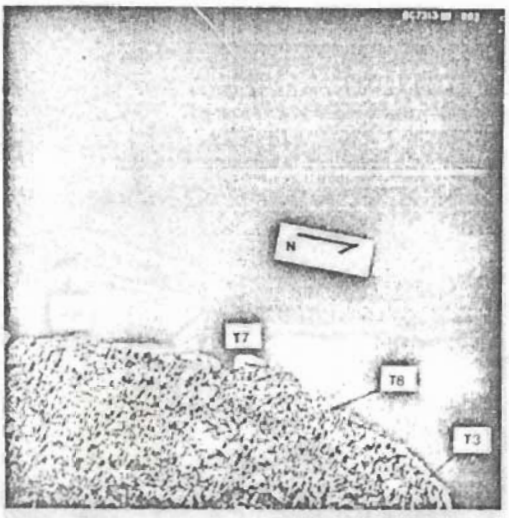
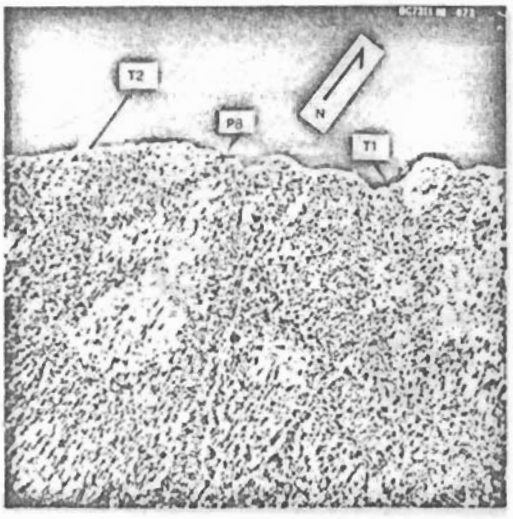
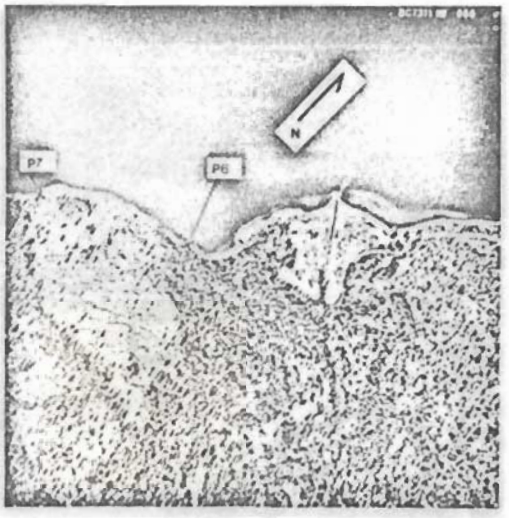


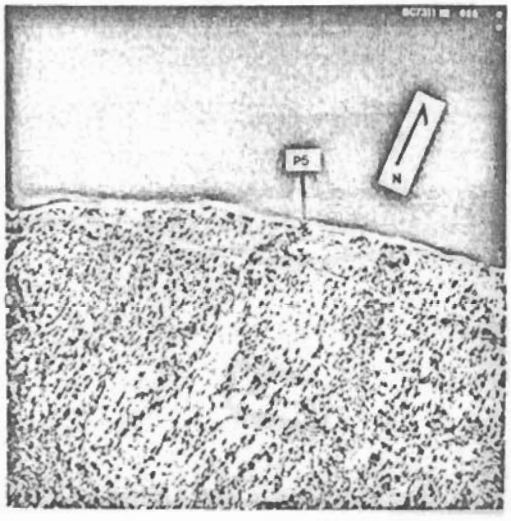
Fig. 2. Representative sites of shore spawning habitat where areal plots (P1, P2, etc.) and transects (T1, T2, etc.) were taken.


N
T4
T6
T5


N
T7
T8
T3


T2
P8
N
T1


N
P7
P6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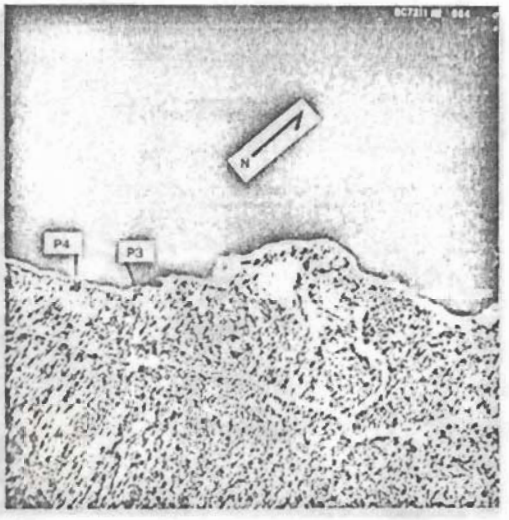
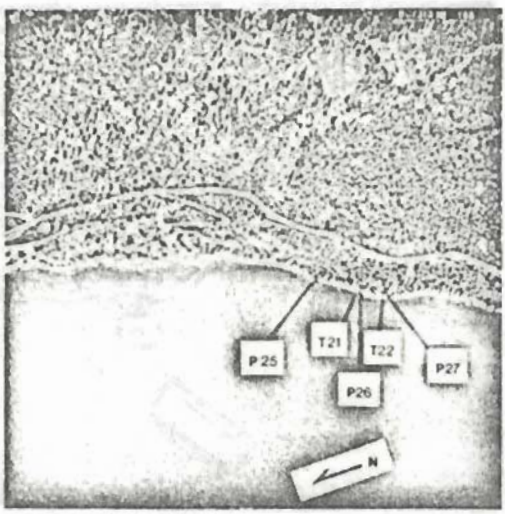
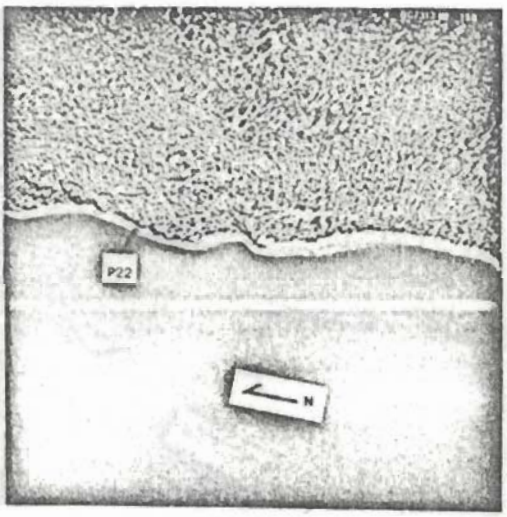

N
P4
P3


P 25
T21
T22
P26
P27
N


disturbed area
P28
P29
T23
P30
N


P24
T26
N


T24
N
T25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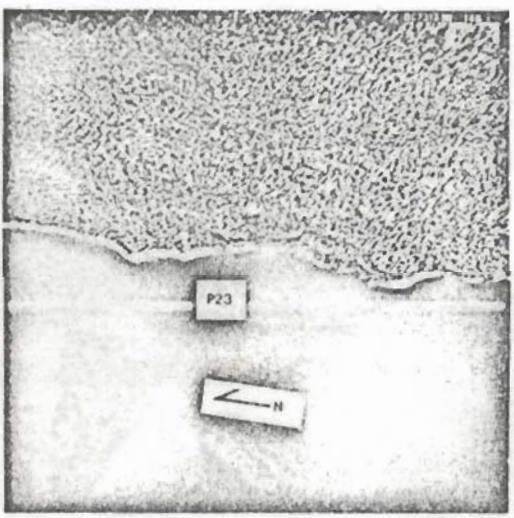
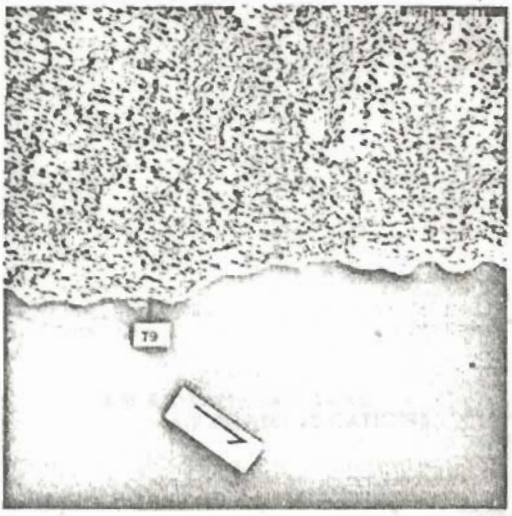
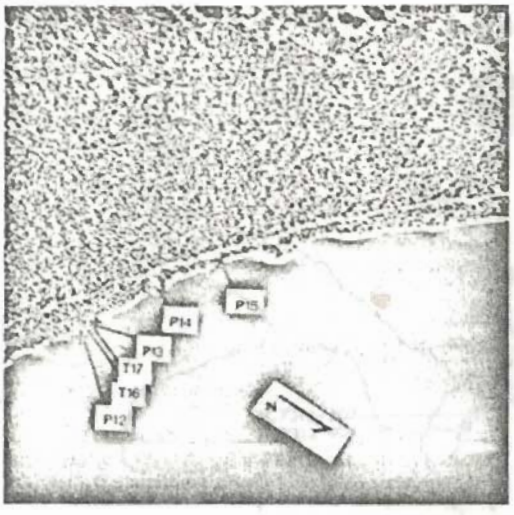

P23
N


T9


N
T10
P9
P10


P15
P14
P13
T17
T16
P12
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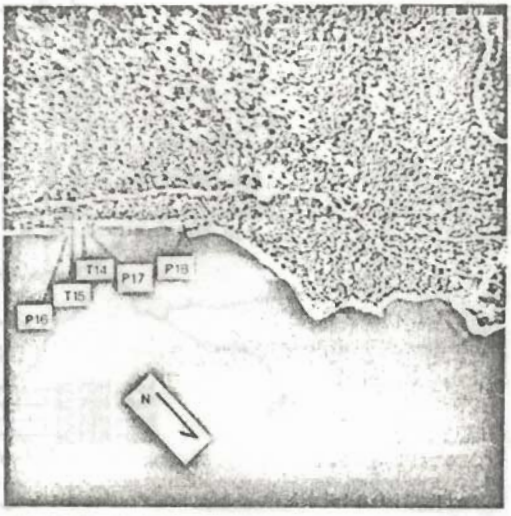
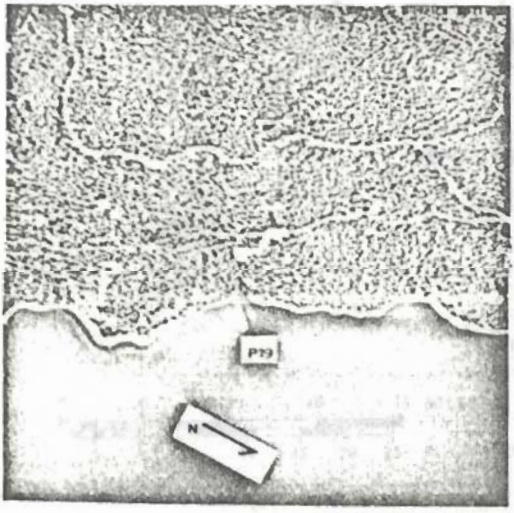
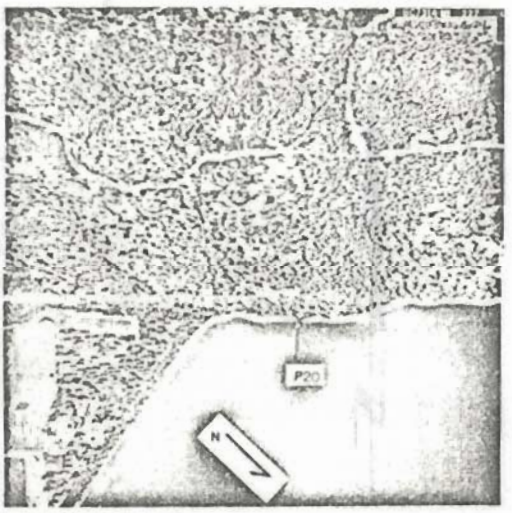

T14
P17
P18
T15
P16
N


P19
N


P20
N

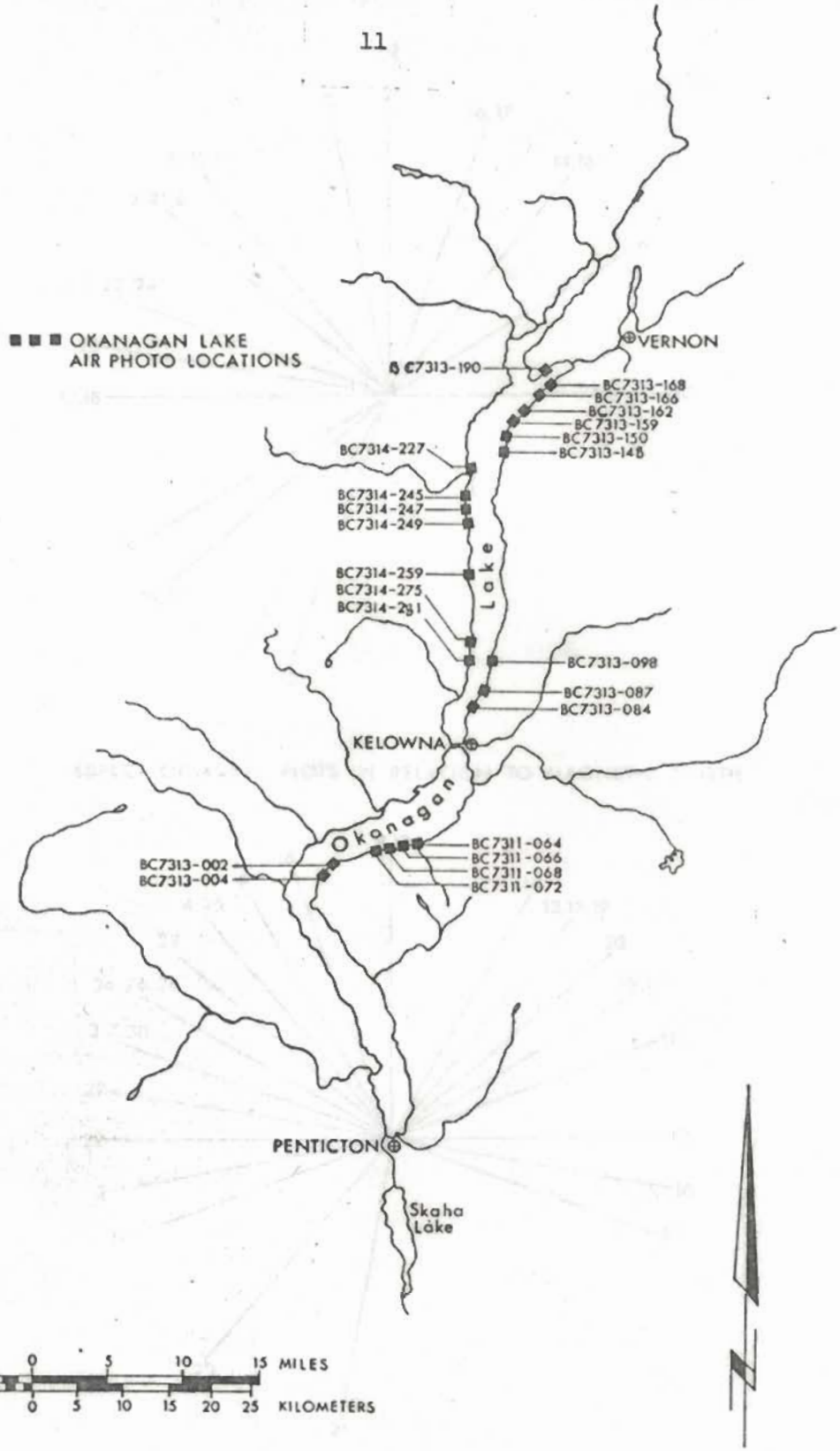
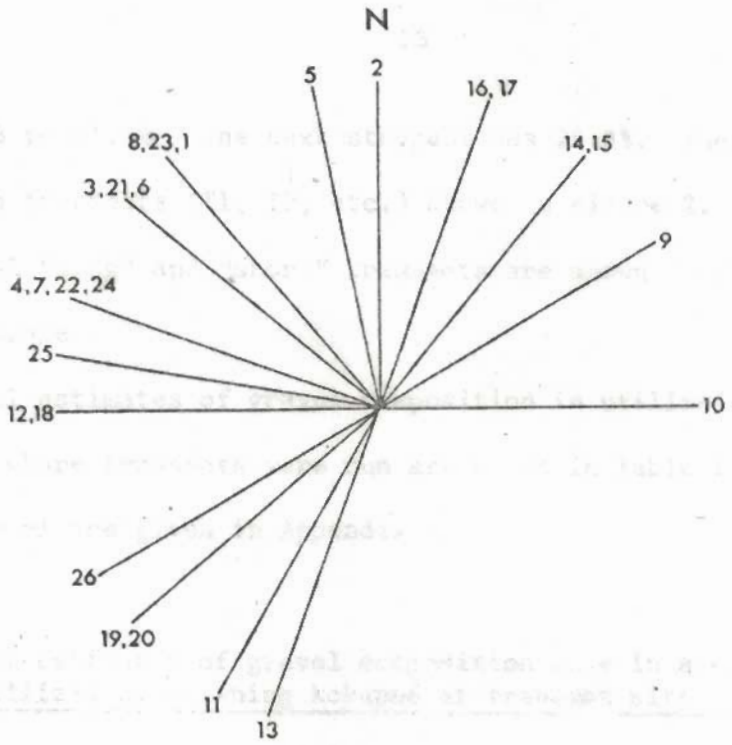


Fig. 3. Location of aerial photographs used to show transect and plot sites. Numbers shown for each location are the numbers of the photographs shown in Figure 2.

ASPECT OF TRANSECTS IN RELATION TO MAGNETIC NORTH



ASPECT OF AREAL PLOTS IN RELATION TO MAGNETIC NORTH

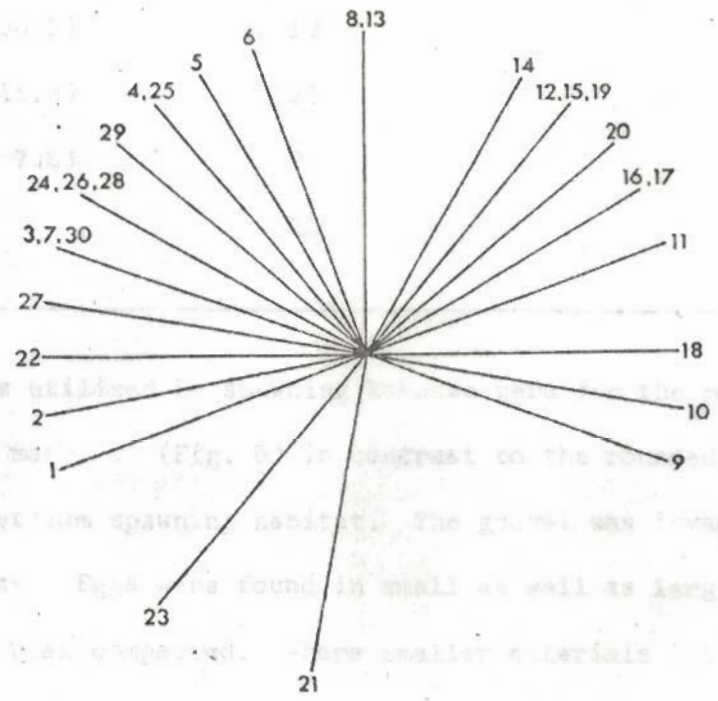


Fig. 4. Aspects of spawning sites where transects and areal plots were taken. Numbers represent individual transects and plots shown in Figure 2.

ranged from 4.6 to 41.6% - the next steepest was 25.8%. These calculations were based on the 26 transects (T1, T2, etc.) shown in Figure 2. Examples of the slope of typical "long" and "short" transects are shown in Figure 5.

(iii) Substrate

Visual estimates of gravel composition in utilized and un-utilized spawning areas where transects were run are shown in Table 1. Results of sieve analysis of gravel are given in Appendix 1.

Table 1. Visual estimates of gravel composition made in areas utilized and un-utilized by spawning kokanee at transect sites.

Gravel Size inches	(cm)	Utilized Percent Composition	Un-utilized Percent Composition
7 - 12	(17.8-30.5)	10	37
6 - 12	(15.3-30.5)	19	26
3 - 6	(7.5-15.3)	26	17
1.5- 3	(3.8- 7.6)	24	7
<1.5	(3.8)	21	13

Gravels utilized by spawning kokanee were for the most part angular, sharp, fractured material (Fig. 6) in contrast to the rounded, more eroded gravels associated with stream spawning habitat. The gravel was invariably loosely stacked, regardless of size. Eggs were found in small as well as large material but in no case was the material compacted. Where smaller materials 1.5 in. (3.8 cm) were utilized, larger rocks and cobbles were often present.

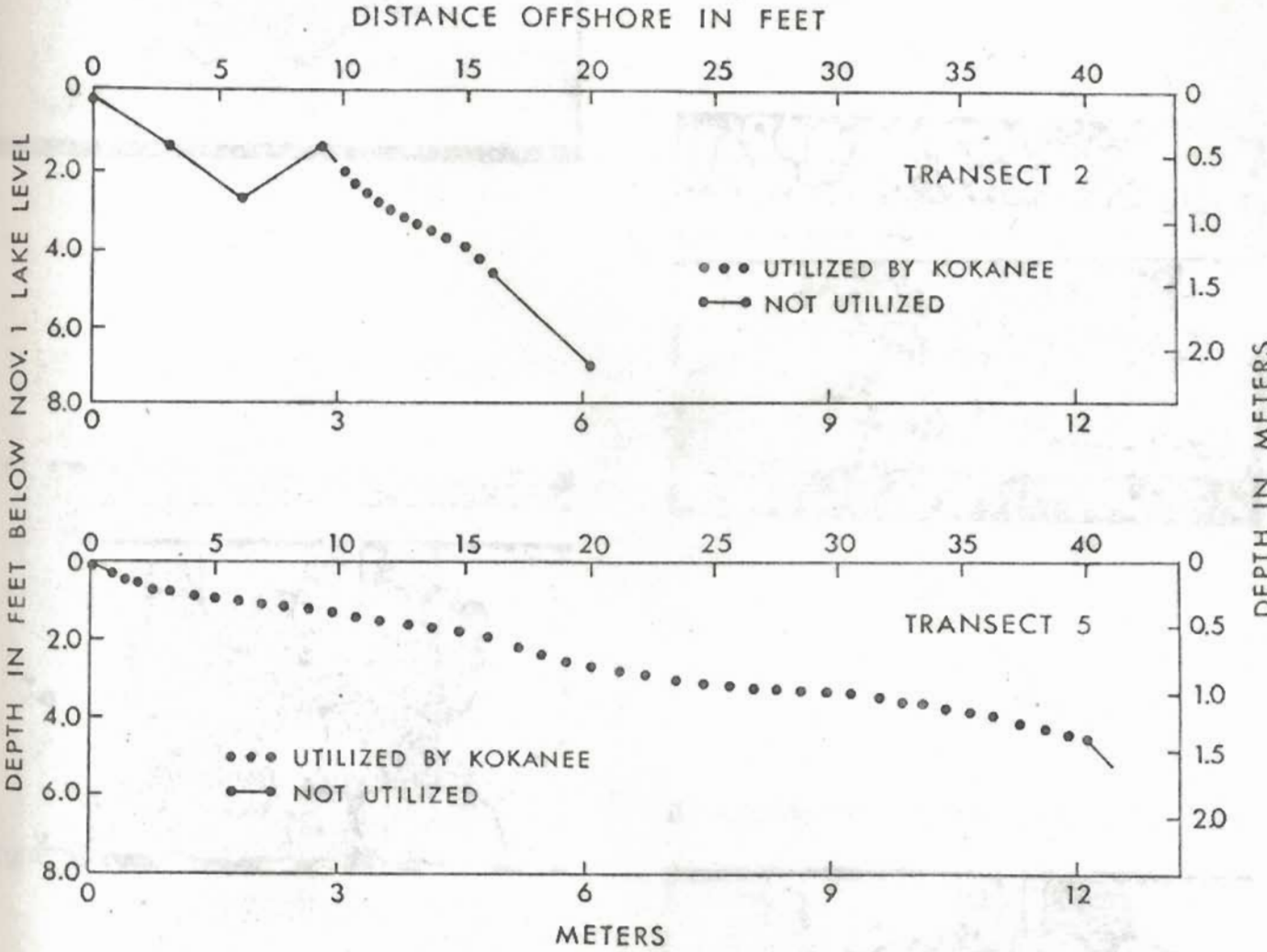


Fig. 5. Slopes and utilized depth intervals of typical shore spawning habitat in Okanagan Lake taken on a short (number 2) and long (number 5) transect.

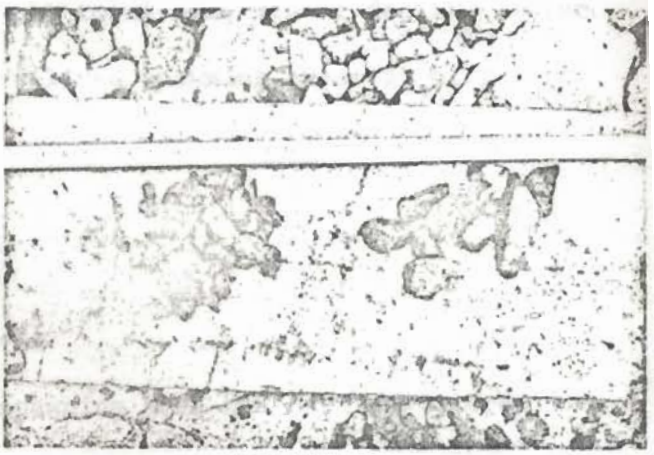


Fig. 6. Examples of gravel types utilized by shore spawning kokanee in Okanagan Lake.

Area Utilized for Spawning at Different Depths

About 83% of all spawning area was located between the depths of 0.5 (0.2 m) and 2.5 ft (0.8 m); just over one-half of the area was between 0.5 (0.2 m) and 2 ft (0.6 m), only about 6% of the total area was at depths greater than 3 ft (0.9 m) (Fig. 7). Variation in utilized spawning areas at different sites can be seen in Table 2.

Survival of Eggs

(i) Determined by changes in lake level

By January 28, about 30% of the spawning area had been de-watered due to a drop in lake level (Fig. 7). Although eggs still in water beneath exposed gravel near the water's edge were alive, it is safe to assume that about 30% of a eggs deposited suffered a 100% mortality. Indeed, with the above exception, all de-watered spawning areas revealed dessicated and/or frozen eggs. After January 28, the lake level rose and no further losses would have occurred from that source.

(ii) Determined by natural causes

In areas where eggs were continuously covered by water attempts were made to determine natural mortality rates; these attempts were minimally successful. The greatest reliability can be placed on the estimates of survival for January and very little reliability in those for March; it appears from the March data that some emergence had taken place prior to that date (Appendix 2).

Approximate survival of eggs to January was 79% and by March 18% of those eggs remaining were alive; the respective figures for alevins were 79%

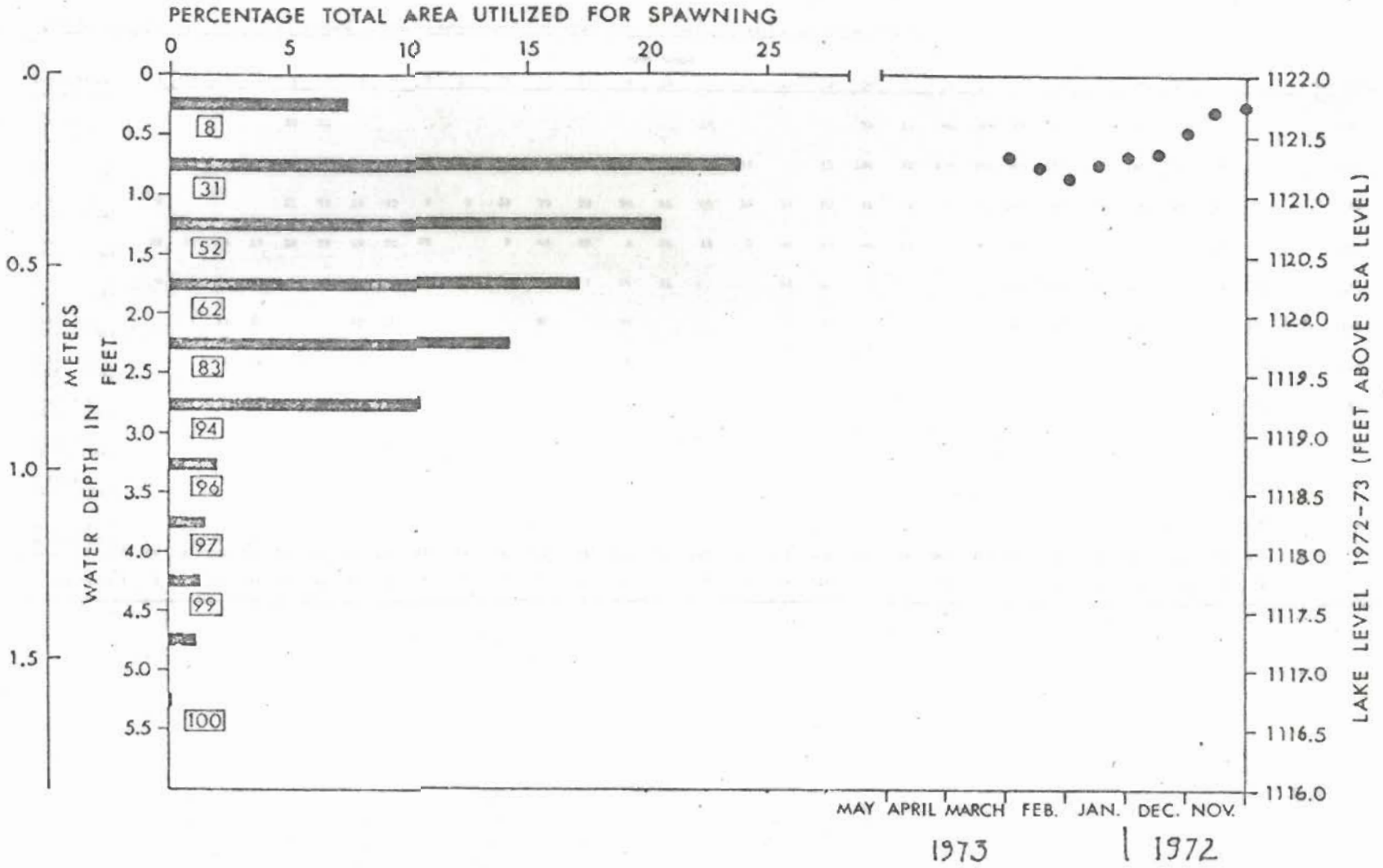


Fig. 7. Percentage of total area of gravel utilized by spawners at different depths at plot sites number 1 to 30. [8] etc. accumulated percentage of total area utilized at different depths. Changes in lake level during the 1972-73 incubation period are shown at the right of the figure.

Table 2. Area of gravel (square feet) utilized by spawning kokanee at 0.5 ft (.02m) depth intervals, recorded at plot sites 1 to 30.

Depth Range in feet (m)	Plot Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total for Range	Percent of Total	Accumulated Percent of Total
0 - 0.5 (0 - 0.2m)					33	11										19				76	11	20	60	22	50		84	68			454	7.5	7.5
0.5 - 1.0 (0.2 - 0.3m)					48	76		48		77	4	70	38	47	4	48	19		13	134	32	170	206	67	107		130	96	15		1449	23.8	31.3
1.0 - 1.5 (0.3 - 0.5m)	8				21	79	16	72	6	2	23	79	23	20	41	69	33	29	93	98	26	54	60	146	84	2	78	72	27		1252	20.6	51.9
1.5 - 2.0 (0.5 - 0.6m)	22	14	16	17	10	75	16	70	59		7	48	27	3	38	33	5	40	63	39	10			180	73	29	114	16	20		1043	17.2	69.1
2.0 - 2.5 (0.6 - 0.8m)	4	61	29	42	3	15	24	40				67	7	34	21			28	15	7				142	133	24	115		3	60	874	14.3	83.4
2.5 - 3.0 (0.8 - 0.9m)		7	99	27			47	11				51		35				4	24					60	68	16	39			153	633	10.4	93.8
3.0 - 3.5 (0.9 - 1.1m)		1	5	16			3							8												4				95	127	2.0	95.8
3.5 - 4.0 (1.1 - 1.2m)				2																										90	92	1.5	97.3
4.0 - 4.5 (1.2 - 1.4m)																														82	82	1.3	98.6
5.0 - 5.5 (1.5 - 1.7m)																														66	66	1.1	99.7
Total Area of Each Plot Site Ft^2	34	83	149	104	115	237	106	241	65	79	34	315	95	142	104	169	57	101	208	353	79	244	326	617	515	75	560	252	65	550			
(Approx m^2)	3	8	14	97	11	22	10	22	6	7	3	29	9	13	10	16	5	9	19	33	7	23	30	57	48	7	52	23	2	51			

and 93% (Table 3). Sampling for eggs was stratified; one half of the samples were taken at depths greater than 1 ft (0.3 m) and the other at depths less than 1 ft (0.3 m). There was no apparent difference in percent survival between the two depths (Appendix 2).

Table 3. Number of live and dead alevins sampled from selected spawning sites and approximate percentage survival to January and March.

	January	March
Number of samples	35	30
Total number eggs sampled	2442	353
Total number alevins sampled	210	320
Average survival of eggs (%)	79	18
Average survival of alevins (%)	79	93

DISCUSSION

While shore spawning habitat was located over most of the length of Okanagan Lake, its specific location is probably determined by a combination of physical characterstics such as substrate, aspect and slope that combined, provid an environment suitable for successful incubation.

Aspect alone did not appear to be the most important factor determining spawning site location because there was a wide range of exposures (Fig. 4). However, the majority of the aspects measured fall between north west and north east. The prevailing winds are from the north during the incubation period which

would probably provide most wave action on north facing beaches. Olsen (1968) suggests that lake currents are primarily responsible for providing oxygenated water to developing sockeye eggs in a similar shore spawning habitat of Iliamna Lake in Alaska. As no ground water was detected in Okanagan Lake sites, the aspect would have to be such that wave action and/or lake currents would provide an adequate exchange of water for successful incubation.

The slope of shore spawning sites, like aspect, was recorded over a wide range of values and therefore did not appear to be the principal factor determining site location.

One characteristic common to all spawning sites was the type of gravel, its composition and particularly the degree of compaction. Characteristically, gravels were loosely stacked without fines and small gravels; this factor appeared to be the most important requirement for spawning habitat. Very similar gravel types are shown for beach spawning habitat of sockeye in Iliamna Lake (Kerns and Donaldson, 1968). On shores in Okanagan Lake where there was no spawning, the gravels were invariably compacted and the interstices of the larger material packed with smaller gravel and fines. This point was reinforced by observations of spawning kokanee utilizing artificially crushed and placed gravel around the footings of boat docks. This gravel, like that on many natural sites was angular in shape, loosely stacked and exposed to water movement from wave action or lake currents.

If kokanee eggs hatched successfully in artificially crushed gravel, there may be a possibility of providing artificial shore spawning habitat at

minimal cost compared to artificial stream spawning channels.

An average of about 30% of all eggs deposited in 1972 were probably killed because of the drop in water level that occurred between November 1 and January 31. This conclusion is based on the assumption that eggs were distributed at the same density over the entire depth range; there are no data to indicate whether or not that was the case. Normally, spawning salmonids select the best spawning areas first and it is not uncommon to see later spawners using the same preferred areas. The largest portion of the utilized spawning area was between 0 and 2.5 ft (0.8 m); if that is an indication of a preferred spawning habitat, there may be a higher density of eggs in that depth range than at depths greater than 2.5 ft (0.8 m). If that was the case, then a loss of eggs greater than 30% may have occurred.

There were no data found in the literature on natural mortality of shore spawning salmonids. The highest survivals of salmonid eggs in streams are generally correlated with highly porous spawning beds (McNeil and Ahnell, 1964). The shore spawning sites in Okanagan Lake were certainly very porous compared to the stream-type spawning habitat. It may be that the estimates of natural survival given in this paper at least indicate that survival in the lake environment may be higher than that usually recorded for streams.

ACKNOWLEDGEMENTS

The assistance of the Fish and Wildlife Branch Hatchery staff at Summerland was greatly appreciated. Some of the survey work would not have been possible without the able assistance of Les Molnar.

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Appendix 1. Sieve analysis (amount retained in gm) of gravel samples taken from utilized and un-utilized shore spawning sites in Okanagan Lake.

Site Location	Transect 18	Transect 18	Transect 21	Transect 21	Plot 6	Plot 6	Plot 6	Plot 10	Plot 20	Plot 20	Plot 25	Plot 27
Sieve Size mm					Utilized Spawning Areas							
64.0	155.9	1630.1	4309.2	3331.1	2877.5	2268.0	4082.4	3458.7	5868.5	7894.2	1360.8	1049.0
38.1	850.5	907.2	1956.2	1956.2	609.5	1020.6	1587.6	2466.5	1417.5	1672.7	1658.4	396.9
19.0	1757.7	1233.2	2310.5	3572.1	2282.5	1445.9	3132.7	1913.6	1601.8	609.5	2849.2	1445.9
9.5	1219.1	708.8	14.2	42.5	708.5	1587.6	467.8	482.0	241.0	28.4	411.1	2041.2
3.35	433.4	850.5	1.3	1.7	191.3	454.5	34.9	6.8	126.8	2.7	0.3	116.3
1.0	11.0	7.8	1.0	1.5	6.8	87.7	4.4	2.6	2.5	1.1	0.4	26.9
0.297	3.1	2.9	0.6	0.7	1.1	16.2	1.2	1.5	1.2	0.7	0.5	20.9
0.074	4.2	6.0	0.6	0.5	0.9	11.2	0.8	1.6	0.7	0.7	2.4	19.1
<0.074	1.8	2.7	0.1	0.1	0.2	1.8	0.4	0.4	0.3	0.1	0.2	11.4
Total Weight (g)	4436.7	5332.2	8593.7	8906.4	6678.3	6893.5	9312.2	8333.1	9260.3	12209.1	6286.0	5127.6
% Organic Carbon in Fraction <0.074 mm	Insufficient Sample (I.S.)	4.4	I.S.	I.S.	I.S.	2.3	I.S.	I.S.	I.S.	I.S.	I.S.	I.S.

Site Location	Transect 12-13	Transect 12-13	Transect 19	Transect 21	Transect 21
Sieve Size mm		Un-utilized Spawning Areas			
64.0	2126.3	3685.5	425.3	453.6	1616.0
38.1	396.9	1360.8	2126.3	411.1	595.4
19.0	921.4	1304.1	1502.6	2324.7	2409.8
9.5	765.5	1814.4	878.9	1190.7	2282.2
3.35	765.5	613.8	1006.4	15.7	507.1
1.0	608.2	12.4	566.7	1.7	346.3
0.297	314.7	1.7	140.3	10.1	298.7
0.074	91.2	1.2	59.8	18.4	164.0
<0.074	6.5	0.4		0.7	15.0
Total Weight (g)	5996.2	8794.3	6706.3	4426.7	8234.5
% Organic Carbon in Fraction <0.074 mm	1.5	I.S.	2.9	I.S.	1.9

Appendix 2. Counts of live and dead eggs and alevins taken from selected spawning sites in January 26 - 28 and March 20 - 21, 1973

Sample Locality	Depth Interval of Sample	Number of Live Eggs	Number of Dead Eggs	Number of Live Alevins	Number of Dead Alevin
		JANUARY			
T21	Dry Shore	47	3	1	1
"	"	48	14	3	0
"	"	37	7	0	0
"	<1 ft (0.3m)	40	14	1	4
"	"	60	4	0	0
"	"	56	25	0	0
"	"	48	16	1	3
"	>1 ft (0.3m)	16	7	0	0
"	"	48	8	0	1
"	"	47	22	1	1
P6	Dry Shore	42	0	4	1
"	"	103	12	10	0
"	<1 ft (0.3m)	84	11	4	0
"	"	38	2	14	0
"	"	58	6	7	2
"	"	175	17	36	2
"	"	215	38	43	5
"	>1 ft (0.3m)	14	3	7	0
"	"	53	1	3	0
"	"	119	12	23	3
"	"	46	6	3	0
"	"	28	6	6	0
T13	<1 ft (0.3m)	15	9	2	0
"	"	30	6	2	1
"	"	2	45	0	3
"	"	7	3	0	0
"	>1 ft (0.3m)	36	34	2	0
"	"	25	9	2	0
"	"	43	10	6	0
"	"	60	12	0	0
"	"	27	15	1	0
P20	<1 ft (0.3m)	87	35	0	0
"	"	16	2	0	0
"	>1 ft (0.3m)	43	11	1	0
"	"	36	13	0	0

Total Number of Eggs 2442

Total Number of Alevins 210

Sample Locality	Depth Interval of Sample	Number of Live Eggs	Number of Dead Eggs	Number of Live Alevins	Number of Dead Alevins
		MARCH			
T21	<1 ft (0.3m)	3	16	32	3
"	"	7	20	31	4
"	"	5	18	16	0
"	"	5	22	4	0
"	"	2	3	18	2
"	>1 ft (0.3m)	4	10	1	2
"	"	1	1	13	1
"	"	3	0	7	1
"	"	12	18	14	0
"	"	2	19	3	0
P6	<1 ft (0.3m)	0	0	11	0
"	"	0	1	26	0
"	"	1	0	20	1
"	"	3	0	23	0
"	"	2	0	17	2
"	>1 ft (0.3m)	0	3	3	0
"	"	0	2	7	0
"	"	0	0	8	0
"	"	0	10	18	1
"	"	1	5	17	0
P20	<1 ft (0.3m)	7	35	0	0
"	"	0	11	1	0
"	"	0	0	1	0
"	"	0	0	4	1
"	"	0	11	0	0
"	>1 ft (0.3m)	1	9	1	0
"	"	0	1	0	1
"	"	3	4	3	1
"	"	0	1	0	1
"	"	1	70	0	0

Total Number of Eggs 353

Total Number of Alevins 320


KETTLE RIVER DRAINAGE BASIN
xxxx Areas of shore spawning
oooo Suspected areas of shore spawning
NICOLA RIVER DRAINAGE BASIN
DRAINAGE BASIN
RIVER
BASIN
OKANAGAN
LAKE
KELOWNA
PENTICTON
VERNON
KALAMALKA L
WOOD L
SKAHA L
VASEUX L
Oliver
Coldstream
Aberdeen L
Belgo
Ideal L
Pearson Cr
Joe Riche Cr
Mission Creek
Crooked L
Postill L
Doves Cr
Scotty Cr
Swalwell L
Oyama L
Clarke Cr
Vernon Cr
Kelowna (Mill)
Rutland
Hydraulic
KLO
Ellison L
Winfield
Bellevue (Sawmill) Cr
Penticton
Turnbull Cr
Naramata Cr
Robinson
Chute
Ellis
Shuttleworth
Vaseux
Wolfcub
Inkaneep
Bald Range Cr
Lambly (Bear) Cr
Westbank
McDougall Cr
Powers Cr
Lambly L
Terrace
Shorts
Whiteman
Jackpine L
Trepanier
Peachland
Garnet
Eneas
Darke Cr
Summerland
Trout Creek
Shingle
Shatford
Isintok
Trout
Park
Hatton
Okanagan Falls
Scale: 1in. = 8mi.
5
0
5
10