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Technical Report—

RESEARCH

EFFECT OF WATER LEVEL FLUCTUATIONS ON SHORE SPAWNING KOKANEE IN OKANAGAN LAKE

1981

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1. INTRODUCTION

Kokanee (Oncorhychus nerka) are the major sportfish in Okanagan Lake. In 1980, over 200,000 were caught during 268,000 hours of fishing (Houston, unpubl.).

Although kokanee generally spawn in streams, approximately one-half the population in Okanagan Lake spawn along the shoreline. Spawning takes place in mid-October and fry emerge the following spring. During this period the lake level is usually lowered to minimize flood damage during spring runoff. Consequently, there are often heavy egg losses.

This problem has prompted a re-examination of the water level control plan and this, in turn, has generated the need to know more about shore spawning kokanee. This study involved two major components: pertinent information found in available literature concerned with shore spawning kokanee; and data obtained from 1980/81 field investigations. All of this information was combined in order to obtain a complete overview of shore spawning kokanee in Okanagan Lake. Major areas of study were: numbers and distribution of shore spawners; hatching and emergence dates; mortalities at various stages of development; and effect of water level fluctuations.

2. METHODS

2.1. Study Site

For the purpose of this study, Okanagan Lake was divided into four quadrants (Figure 1). Enumeration and distribution of adults was plotted throughout the lake, but the remainder of the work was

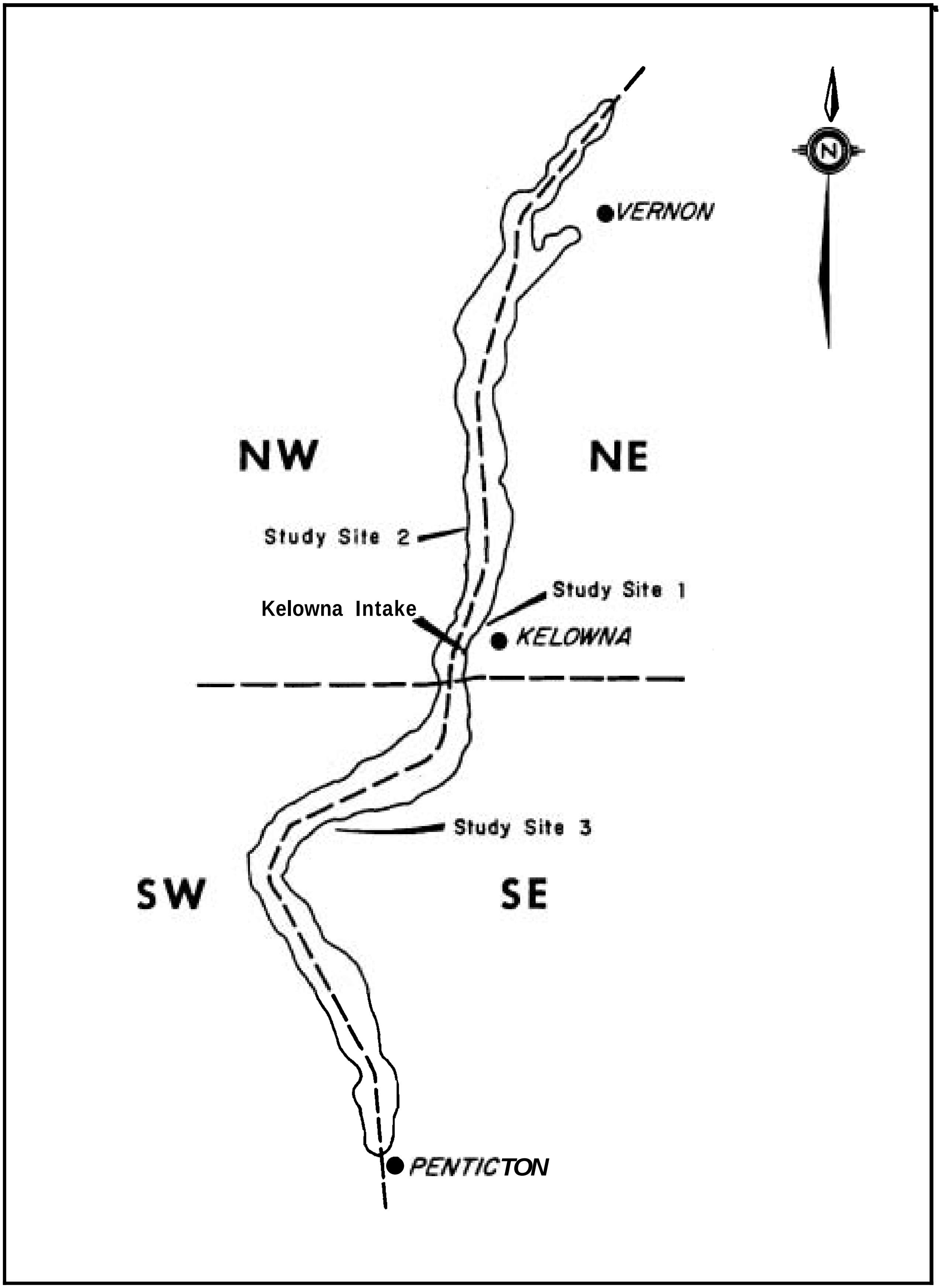


Figure 1 The four quadrants of Okanagan Lake

concentrated in the north quadrants. The site chosen for the majority of the work was located about 5 km north of Kelowna bridge on the east shoreline (Study Site #1). This area was chosen because of ease of access, abundance of eggs, and homogeneity of slope, substrate and egg densities. Additional sample sites were chosen in the northwest and southeast quadrants (Study Site #2 and #3 respectively) in order to compare timing of hatching and emergence.

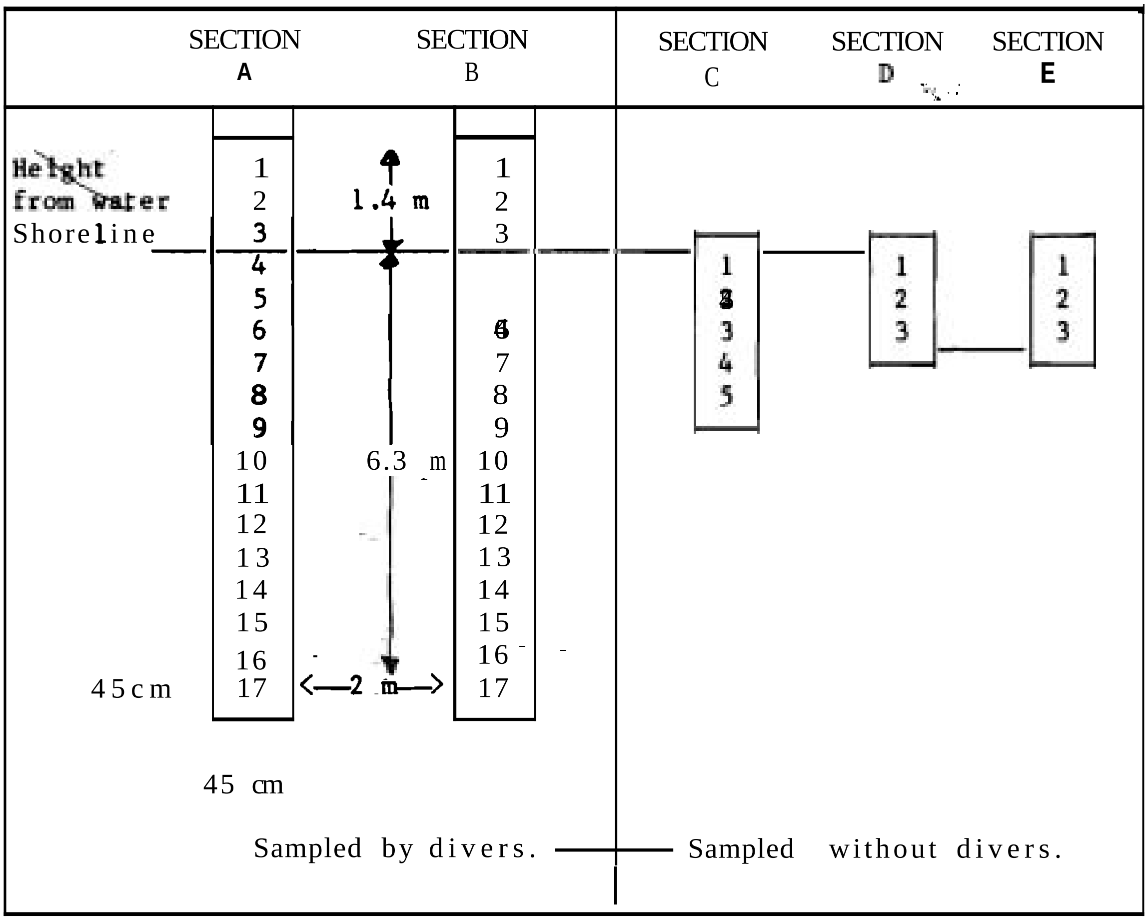
2.2. Numbers and Distribution of Spawning Kokannee

Adult spawning kokanee were enumerated visually from a boat and a helicopter during the estimated peak spawning times of October 27 to November 4, 1980. The time of spawning is considered sufficiently short that peak counts are representative of total counts (Halsey and Lea, 1973 and Smith, 1978). Numbers of fish and spawning locations were recorded in the field on air photos, then transferred to 1" = 1000 ft maps for future reference.

2.3. Egg Deposition Sites

Egg distribution in relation to gravel depth and water depth was examined at Study Site #1 on January 21, 22, 29, Feb. 4, 6 and 19, 1981. A grid made from 1 cm diameter metal bar consisting of a series of 45 cm square sections was anchored to the substrate, perpendicular to the shoreline (Figure 2). Each of the plots was dug to a gravel depth of 40 cm and the resulting number of eggs and alevins recorded. Sections A and B, which were sampled by divers (Figure 3), consisted of 17 plots. The remaining sections (C to E) were sampled by shore workers and consisted of 6 or less plots due to a limited diving budget and poor weather conditions.

FIGURE 2 Overhead view of grid sample pattern. Each plot is 45 cm square and each section is separated by 2 metres.



The digging process involved moving substrate by hand or with a small garden fork and sucking up any eggs or alevins with a 1" rubber hose attached to a 12-volt diaphram type plankton pump. The pump outlet ran into a pail so that eggs and alevins could be counted both by the diver at the time of collection and by the shore worker observing the bucket.

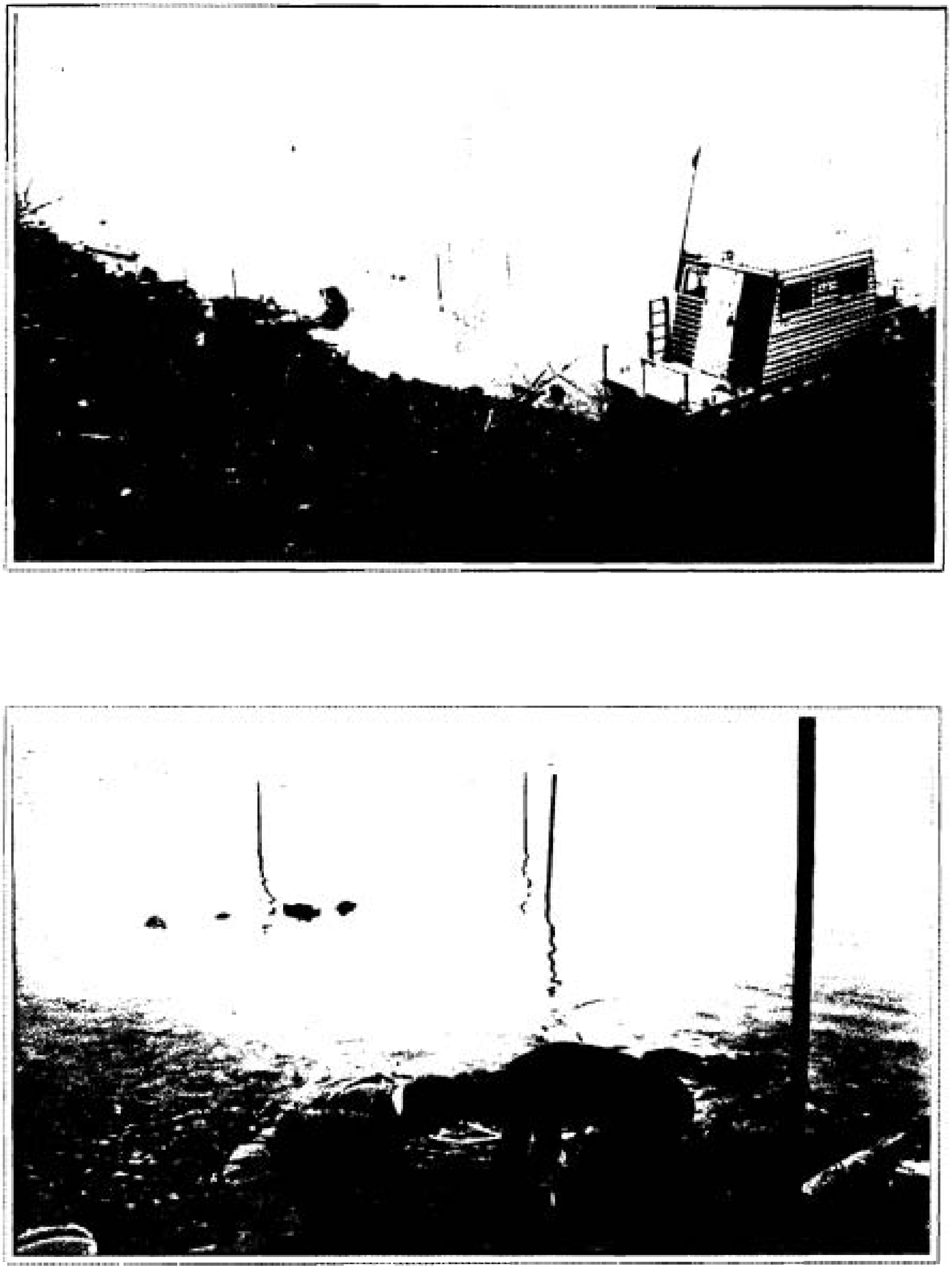


Figure 3 Egg deposition sampling sites

2.4. Hatching and Emergence

In addition to the sample plots, digging was carried out on January 8, March 5, 12, 20, 25, April 3 and 9 at Study Site #1 to determine hatching and emergence times. Digs were also carried out on January 20, 28, February 26 and March 20 at Study Site #2 and January 20 and 28 at Study Site #3 to compare timing of hatching and emergence for different areas of the lake. Poor access and weather conditions prevented more frequent digs. Emergence presented considerable difficulties since fish migrated after emergence and were therefore not observable. This problem was overcome by carefully examining the yolk sacs of the alevins and determining when they were within two weeks of emergence. The start of emergence was recorded as two weeks after that date. Emergence was considered complete when no more alevins were located. In addition, a Ryan thermograph was submerged throughout the incubation period in order that thermal units could be calculated.

An attempt was made to check time of emergence by planting eggs under a specially constructed basket which was to trap emergent fry in a screened area (Figure 4). However, the experiment was unsuccessfully concluded when all the planted eggs died.

2.5. Mortalities

Egg and alevin mortalities were recorded while carrying out the grid sampling method (described under Methods: 2. Egg Deposition Sites). Divers had great difficulty in determining mortalities because the eggs and alevins tended to break up and float away during the digging process. Therefore mortalities were only recorded for Sections C to E, covering water depths less than 27 cm (Figure 2). 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 by shovel

(McNeil, 1964). In this study, it was not possible to estimate the total egg deposition including broken egg shells, therefore mortality would be underestimated.

2.6. Effect of Water Level Fluctuations

To determine whether submergent fry migrated through the gravel to avoid desiccation as water levels dropped, a 1 metre long vertical screen extending 40 cm below the gravel was placed parallel to the shoreline approximately 1 metre from the waterline, prior to hatching (Figure 5). Both sides of the screen, and a control area extending 0.5 meters from either end were carefully excavated on March 12. The screen's function was to act as a barrier to lakeward (away from shore) migration by the alevins within the gravel.

An estimate of incubation mortalities caused by lake drawdown was made by applying total eggs collected in all grids for Sections A and B to the number of eggs collected in those grids which would be dewatered during incubation. From this data, a percent mortality was calculated. Only Sections A and B were considered since they covered the greatest depth range.

3. RESULTS

3.1. Numbers and Distribution of Spawning Kokanee

Approximately 150,000 adult kokanee spawned on the shores of Okanagan Lake in 1980 (Table 1). There has been a reduction in abundance since Mysis relicta became established in the early 1970's, although numbers have increased in recent years (Table 2).

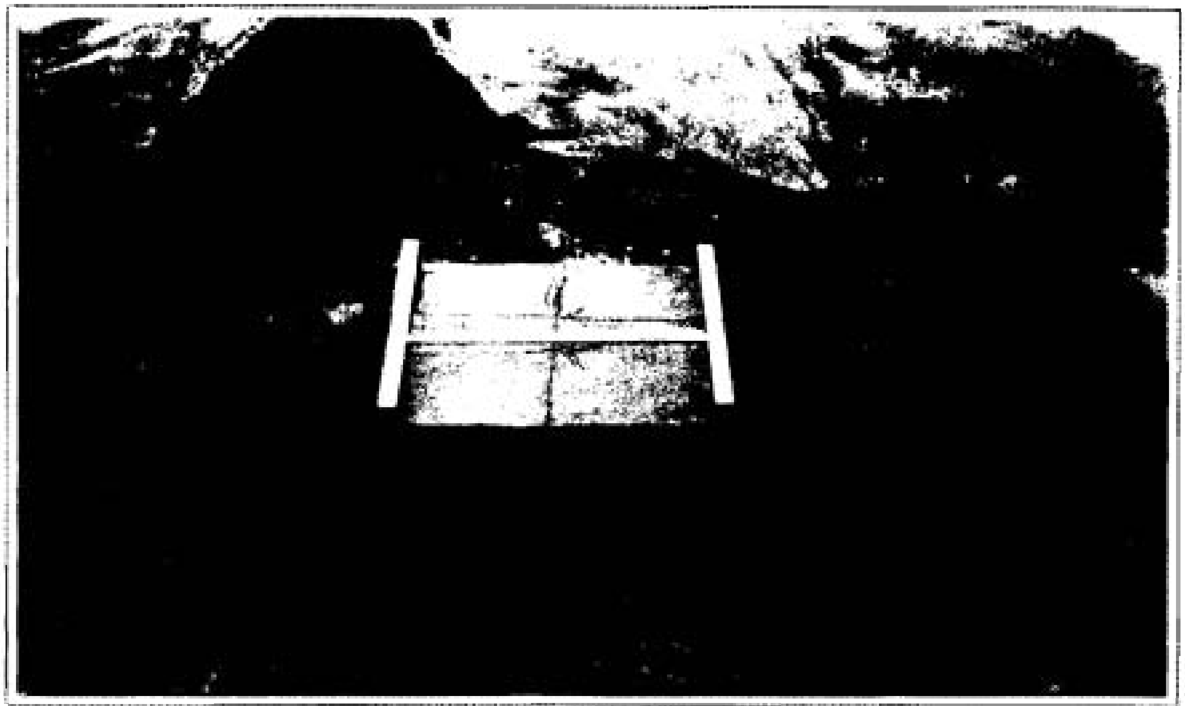


Figure 4 Fry emergence trap

Figure 5 Fry migrotion screen

TABLE 1 Distribution and abundance of shore spawning kokanee in Okanagan Lake in 1980.

	Sector of Lake				
	SW	SE	NE	NW	TOTAL
No. of kokanee	0	73,445	31,115	45,405	149,965
No. of spawning sites	0	113	133	106	352
Shoreline used (km)	0	3.5	2.0	1.5	7
No. of kokanee/site	0	552	275	428	426
Shoreline/site (m)	0	30	17	14	21
No. of kokanee/m of shoreline	0	21	17	33	22

TABLE 2 Comparative numbers of kokanee spawning on shore in years for which records are available.

Year	No. of Adults	Length of Shoreline Utilized	Reference
1980	149,965	7 km	Martin, Matthews, Musa, 1980
1979	116,000		Region 8 Fisheries Records
1978	50,000		"
1977	545,000		"
1974	729,000	9 km	"
1971	518,000		Halsey and Lea (1973)

3.2. Egg Deposition Sites

3.2.1. Substrate

The major factor governing location of spawning areas seemed to be substrate. Spawning occurred in both gravel and large angular up to 300 cm in diameter but the majority took place over angular rock 10 cm to 20 cm in diameter. Smaller gravels were only used if free of large quantities of fines (Figure 6). In an earlier study, the Fish and Wildlife Program introduced both large angular rock and round gravel. Both substrates were used but gravel was preferred.

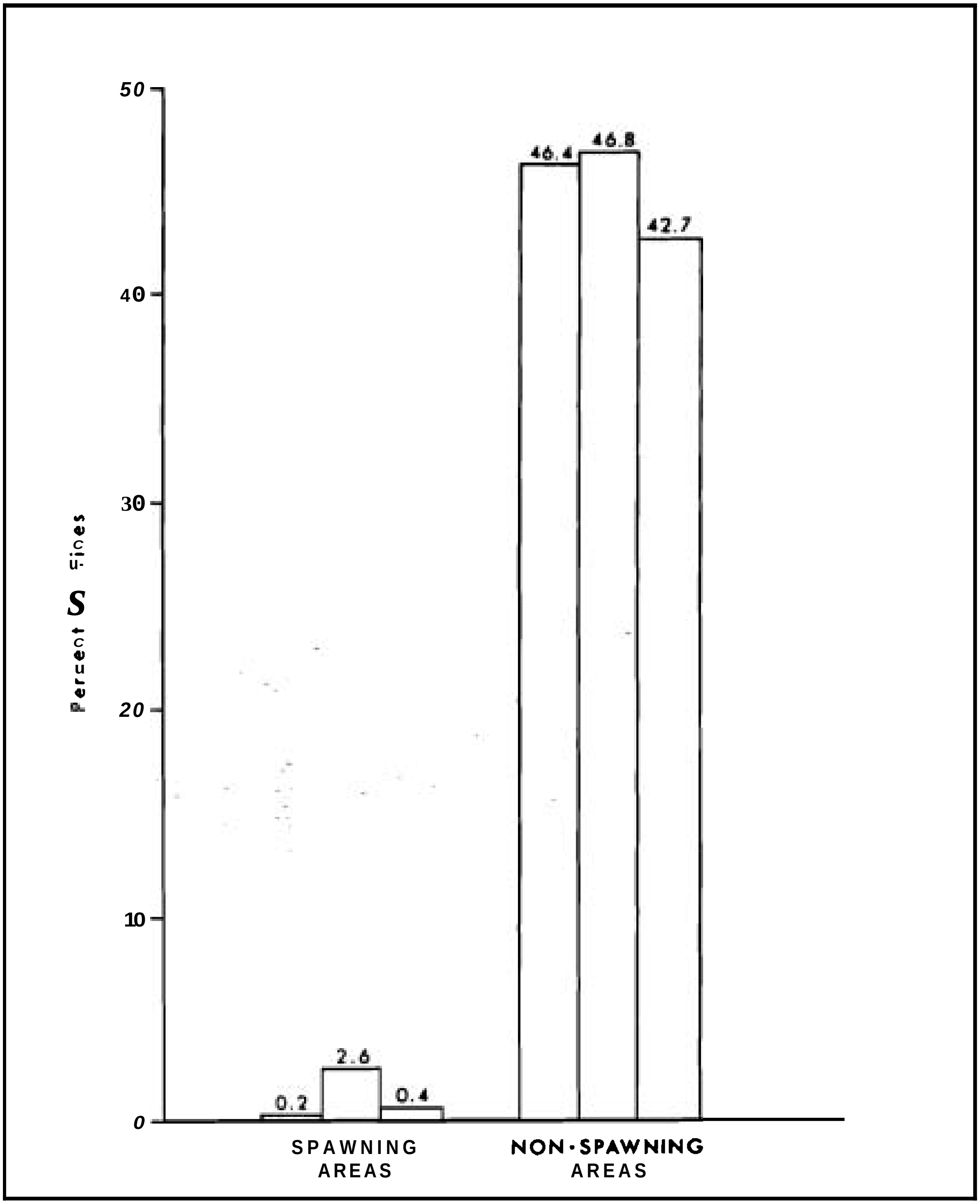


Figure 6A

Percent fines (particles passing through No. 4 sieve) in substrate used and not used by spawning kokanee.

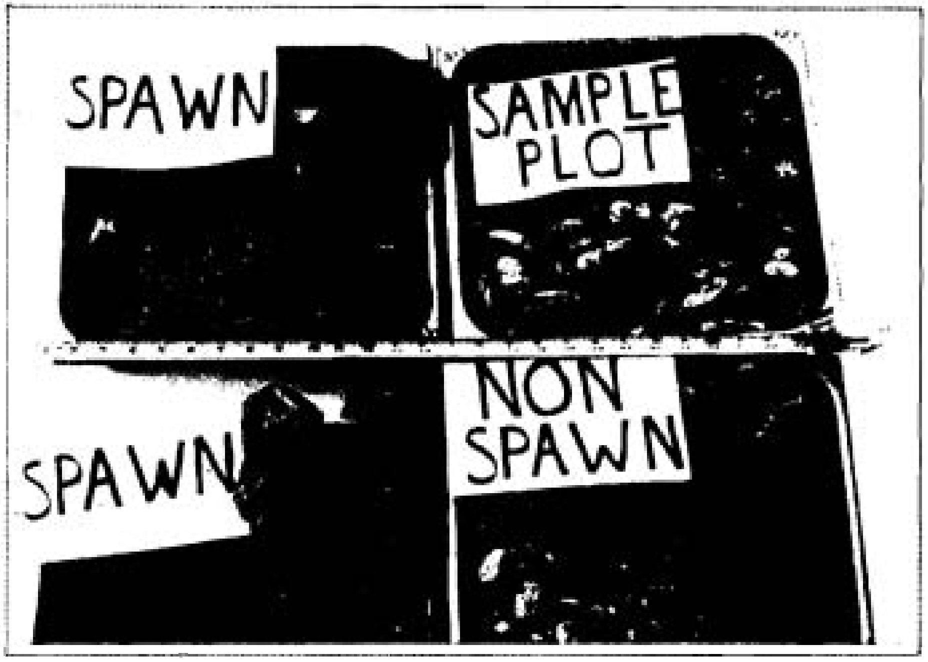


Figure 6B Substrate used for spawning; substrate from experimental plot and substrate not used for spawning.

3.2.2. Oxygenation

Olsen, 1968 suggested that upwelling water on lake currents are required to oxygenate shore spawning eggs. This does not seem to be the case in Okanagan Lake where Halsey and Lea (1973) found no evidence of springs in shore spawning sites.

3.2.3. Aspect

The direction the spawning site faced seemed to be unassociated with prevailing winds in Okanagan Lake (Halsey and Lea, 1973). The majority of spawning sites had aspects between northwest and northeast while prevailing winds are from the south throughout incubation (Penticton Weather Office).

3.2.4. Slope

The slope of the beaches used for spawning was highly variable (Halsey and Lea, 1973) and was not a factor selected by kokanee.

3.4.5. Gravel Depth

The majority of eggs were deposited 10 to 30 cm below the gravel surface. Most alevins, on the other hand, were found 20 to 45 cm under the gravel.

3.2.6. Water Depth

The depth of water covering spawning sites was consistent with an earlier study by Halsey and Lea (1973). Most eggs were deposited in 5 to 60 cm of water with the heaviest densities occuring approximately 20 cm below the surface (Table 3).

TABLE 3 Comparison of Water Depth and Total Eggs and Fry Located

Distance from Shore (ft)	Water Depth (ft)	Total Kokanee	%	% found by Halsey & Lea
1.5 - 3.0	0 - 0.5	699	23	44
4.5 - 6.0	0.5 - 1.0	889	53	62
7.5 - 10.5	1.0 - 1.5	197	60	79
13.5 - 16.5	1.5 - 2.0	742	78	96
19.5 - 22.5	2.0 - 2.5	460	100	100

3.3. Spawning, Hatching and Emergence Dates

The dates of spawning in 1980 were consistent with other years, but hatching and emergence times have not been previously recorded. Peak spawning period for 1980 ran from October 20 to November 5 while hatching occurred from January 6 to February 16 and emergence from March 17 to April 15, 1981.

Digs at Study Site #2 indicate there is some discrepancy in times at various locations throughout the lake with the southern portion being a few days earlier than the northern. Study Site #3 was abandoned after 2 digs due to poor access.

Table 4 gives more precise information on hatching and emergence as observed at Study Site #1.

TABLE 4 Hatching and Emergence Dates

Date	Percent Hatched	Percent within 2 weeks of emergence
Jan. 16	20	0
Jan. 21	26	0
Jan. 22	44	0
Jan. 29	58	0
Feb. 4	69	0
Feb. 19	100	0
Mar. 5	100	3
Mar. 12	100	24
Mar. 20	100	83
Mar. 25	100	100
Apr. 3	100	100

3.4. Egg Mortality

Despite problems with eggs and alevins decomposing and drifting away, mortality figures were fairly uniform for those sample areas which-yielded a sufficient number of eggs and alevins (Table 5). Overal-1 incubation mortalities were 90% for eggs and 9% for alevins.

TABLE 5 Mortality of Kokanee Eggs and Alevins

Section*	Plot*	Date 1981	No. of Eggs	Percent Mortality	No. of Alevins	Percent Mortality
C	1 6 2	-	-	-	-	-
	3	Jan. 29	150	80	66	17
	4	Jan. 29	528	91	192	8
	5	Jan. 29	413	92	120	10
	6	Jan. 29	488	89	141	13
D	1 6 2	-	-	-	-	-
	3	Feb. 4	201	90	128	4
E	1 6 2	-	-	-	-	-
	3	Feb. 19	110	100	80	3

* See Figure 2, page 4.
\- Not determined due to insufficient sample sizes (less than 100 eggs and/or alevins) or technical difficulties.

3.5. Effect of Water Level Fluctuations

The maximum water level for the 1980/81 kokanee incubation period on Okanagan Lake was 1122.0 ft. above sea level, while the minimum was 1121.41 (Table 6). This translates to a water level drop of 7.1 inches or 18 cm between October 15, 1980 and January 31, 1981. The water level began to rise again after January 31, 1981. Therefore, the majority of the water level recession occurred while the eggs were at the eyed stage and unable to escape desiccation. Water level rose after hatching therefore not requiring the alevins to migrate for that reason.

TABLE 6 Okanagan Lake Water Levels for 1980/81 Kokanee Incubation Period

Date	Water Level (ft. above sea level)	Date	Water Level (ft. above sea level)
Oct. 15	1122.0	Feb. 15	1121.42
Oct. 31	1121.77	Feb. 28	1121.49
Nov. 15	1121.73	March 15	1121.62
Nov. 30	1121.62	March 31	1121.66
Dec. 15	1121.46	April 15	1121.74
Dec. 31	1121.47		
Jan. 15	1121.42		
Jan. 31	1121.41		

A 15.4% egg mortality due to lake drawdown was calculated for Section A and 6.7% for Section B. Therefore, the average egg mortality was approximately 11%.

The migratory blockage screen (Figure 5) was excavated on March 12 with the following results: Screened - 146 alevins
Unscreened - 33 alevins

It should be noted that the screen and control were of approximately the same area and involved an equal volume of substrate.

4. DISCUSSION

There has been a dramatic reduction in the abundance of kokanee shore spawners since the early 1970's which may be linked to the introduction of Mysis relicta in 1966. A five to ten year lag between introduction and high abundancies of mysids have been observed in other large lake systems. Many of these large lakes have exhibited dramatic declines in kokanee abundance following the establishment of Mysis. The decline in kokanee survival is thought to be a result of a reduction in abundance and a change in species composition of the macro zooplankton due to predation and competition by Mysis.

The 1974 survey of shore spawning kokanee in Okanagan Lake indicated they utilized approximately 9 km of shoreline compared to 7 km in 1980 (Table 2). This is a significant reduction, but when numbers of spawners for those two years are compared, the difference in area may largely be a function of kokanee abundance.

Shore spawning activity has remained concentrated over the southeast, northeast and northwest quadrants of the lake (Figure 1) over the past 10 years, but has become restricted to the more productive sites within those quadrants more recently.

Similar results concerning substrate preference were encountered in Kerns and Donaldson's (1968) report on sockeye (Oncorhynchus nerka) in Ilamma Lake, Alaska, where 73% of all spawning took place over loosely stalked irregular rock 10 cm to 30 cm in diameter. The 1974 kokanee shore spawner survey of Okanagan Lake (Fish and Wildlife Program, Region 8, 1975) estimated 85% of shore spawning sites were similar to that described above.

Available literature does not provide comparative studies on sub-gravel depth of egg deposition for kokanee. The gravel depths in which eggs and alevins were located in this study indicate a post hatching downward migration. Dill (1968) demonstrated a similar downward migration for coho (Oncorhynchus kisutch) alevins. He found that depth of downward movement increased as substrate size increased. Some researchers feel this is simply a negative phototactic response to prevent premature emergence.

Halsey and Lea (1973) derived very similar results concerning depth of water at egg deposition sites. They found that 24% of all spawning activity occurred in 22 cm or 9 inches of water with a steady decrease down to 10% at 84 cm water depth. Utilization of spawning areas in water depths greater than 84 cm was negligible. This compares very favourably with our results, although there was greater variation between each depth, which may be due to differences in methods in the two studies. Time and budgetary constraints prevented us from sampling beyond a water depth of 76 cm, but Halsey and Lea's 1973 study indicated that approximately 83% of all spawning takes place in water depths less than 76 cm.

Peak spawning period in 1980 appears consistent with data available from previous studies. The 1974 Fish and Wildlife Program survey of shore spawning kokanee reported that spawning extends from October 10 to November 5 with the peak from October 15 to October 23. Halsey and Lea (1973) reported that spawners were observed as late as November 29 in 1973. Northcote, et al (1972) found the minimum residency time for shore spawners to be 13 days.

There is no data available with which to compare dates of hatching and emergence, for shore spawning kokanee. A comparison of temperature regimes during kokanee incubation in creek water and lake water indicates there is a very close similarity in thermal unit accumulation to the various developmental stages (Table 7).

TABLE 7 Thermal farenheit units accumulated to hatching and emergence'for lake incubated and creek water incubated (Penticton Creek Hatchery) kokanee eggs

	Start of Hatching	Start of Emergence
Penticton Creek Hatchery, 1980/81	1100	1650
Okanagan Lakeshore Spawners, 1980/81	1069	1624

Dates of hatching and emergence were also very close for the two groups but this will have a tendency to vary from year to year.

Results on incubation mortality are of limited value since we were restricted to less than 27 cm of water, therefore covering only a small portion of the spawning habitat. The overall mortalities of 90% and 9% were similar to results from Halsey and Lea (1973) who reported 86% egg mortality and 27% alevin mortality. The 18% difference in alevin mortality between the two studies could result from variations in sample sizes, sampling methods, and sampler efficiency.

Drawdown in Okanagan Lake generally occurs during the egg stage of kokanee incubation (Table 5). Slight alterations in the drawdown plan could greatly reduce mortalities resulting from water level fluctuations. For example, holding lake drawdown to a minimum during kokanee incubation will contribute to improved kokanee survival. Secondly, if the lake level was dropped during the alevin stage of development (as opposed to the egg stage), mortalities may be reduced due to the alevins ability to migrate within the gravel to escape desiccation.

Fast (1981) shows that alevins will migrate through the gravel under conditions of dewatering, moving greater distances in larger size grave1.

The egg mortality estimate of 11% resulting from the 1980181 lake **drawdown** is much lower than the 30% mortality reported by Halsey and Lea (1973). This is largely due to the additional 8 cm (total 25 **cm)** released from Okanagan Lake in 1973. When one considers the very high concentrations of eggs in 0 cm to 30 cm of water, a difference of 8 cm in **drawdown** could result in a much higher egg mortality.

Data from the migratory screen indicates a downward and lateral (lakeward) migration by the alevins. This may be an attempt to avoid desiccation.

5. RECOMMENDATIONS

1. Continue annual enmerations of shore spawning kokanee to monitor population changes and spawning locations.

2. Water level fluctuations should be minimal during kokanee incubation, particularly at the egg stage of development.

3. Place a reserve on areas of consistently high spawner use.

4. Continue to monitor yearly contribution of kokanee to the fishery through creel census.

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