June 1995

KOKANEE IMPACTS ASSESSMENT AND MONITORING ON LAKE PEND OREILLE, IDAHO CHAPTER 1

KOKANEE IMPACTS ASSESSMENT AND MONITORING ON DOWRSHAK RESERVOIR, IDAHO, CHAPTER 2

Annual Progress Report:

January - December 1994

Annual Report 1994

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CHAPTER 1
KOKANEE IMPACTS ASSESSMENT AND MONITORING ON LAKE PEND OREILLE, IDAHO

CHAPTER 2
KOKANEE IMPACTS ASSESSMENT AND MONITORING ON DWORSHAK RESERVOIR, IDAHO

ANNUAL PROGRESS REPORT

Period Covered: January - December 1994

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF TABLES (Cont.)

Paae

LIST OF FIGURES

LIST OF FIGURES (Cont.)

LIST OF APPENDICES

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

Paae

CHAPTER 1. KOKANEE IMPACTS ASSESSMENT AND MONITORING ON LAKE PEND OREILLE

ABSTRACT

In an effort to recover the declining kokanee *Oncot-hynchus nerka kennerlyi* population in Lake Pend Oreille, a study was proposed to evaluate the benefits of a higher winter elevation, thus providing more spawning gravel for kokanee. This project was designed to collect and compile baseline information on the kokanee population and potential spawning gravel in Lake Pend Oreille that can be used to help evaluate the effectiveness of future changes in lake level management.

We estimated the area of suitable quality spawning gravel at the current winter elevation (625.1 m) and at the proposed winter elevation (626.7 m). Gravels beneath the current winter elevation were generally characterized by a high percentage of fine sediments and a high degree of embeddedness. Of the total gravel available below the proposed elevation of 626.7 m, only 15% was available at current winter elevations.

Kokanee population estimates were made with a midwater trawl and hydroacoustic surveys in August and September. September population estimates were 6,760,OOO age 0, 380,000 age 1 + ,700,OOO age 2 + ,990,OOO age 3 + ,760,OOO age 4 + , and 70,000 age 5 + kokanee. Hydroacoustic surveys run alongside the trawl indicated that hydroacoustics can effectively estimate abundance of kokanee, with the exception of fry, which are too small to be completely distinguishable from opossum shrimp *Mysis relicta.* Historic estimates of wild kokanee fry indicate that winter elevations higher than 625 m and a stable elevation throughout the winter are positively correlated with kokanee fry abundance and survival.

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INTRODUCTION

Lake Pend Oreille supported the most popular kokanee *Oncorhynchus nerka kennerlyi* fishery in Idaho from the 1940s until the early 1970s. The sport and commercial fisheries provided an average annual harvest of one million kokanee and 360,000 hours of angling effort from 1951 to 1965 (Ellis and Bowler 1979). Sport anglers enjoyed average annual catch rates as high as 3.5 fish/h during the mid-l 960s. Kokanee harvest declined from 1965 to 1985, resulting in an annual harvest of less than 100,000 fish, with a mean catch rate of approximately 1 .O kokanee/h (Bowles et al. 1987). In addition to providing an important fishery, kokanee are the primary forage for trophy Gerrard rainbow trout 0. *mykiss* and bull trout *Salvelinus confluentus* in Lake Pend Oreille.

The decline of the kokanee population in Lake Pend Oreille has been largely attributed to the current operation of Albeni Falls Dam (Maiolie and Elam 1993; Paragamian and Ellis 1994). Evidence from historical population trends and harvest data indicates that winter pool elevation is correlated to kokanee abundance and harvest, and that winter drawdowns result in the loss of potential spawning areas (Maiolie and Elam 1993). Maiolie and Elam (1993) examined the elevation where spawning gravels occurred on historic spawning beaches. However, the area of spawning gravel that would be gained at different elevations was not estimated. Quantification and assessment of the quality of gravel available at various lake elevations in conjunction with continued monitoring of the kokanee population will help determine the potential outcome of a change in dam operation.

STUDY AREA

Lake Pend Oreille is located in the panhandle of Idaho (Figure 1). It is the largest lake in Idaho, with a surface area of 383 km^2, or about 38,300 ha, mean depth of 164 m, and maximum depth of 35 1 m. Mean surface elevation of Lake Pend Oreille is 629 m. Deep water habitat used by kokanee is considered to be 22,647 ha. The Clark Fork River is the largest tributary to Lake Pend Oreille. Outflow from the lake forms the Pend Oreille River.

Lake Pend Oreille is a temperate, oligotrophic lake. Summer temperatures (May to October) average approximately 9°C in the upper 45 m (Rieman 1977; Bowles et al. 1987, 1988, 1989). Thermal stratification typically occurs from late June to September. The N:P ratio is typically high (> 1 1) and indicates primary production may be P limited (Rieman and Bowler 1980). Mean chlorophyll "a" concentration during summer is approximately 2 micrograms/L. Summer mean water transparency (Secchi disk) ranges from 5 to 11 m. Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level stable at 628.4 m during summer (July-September) then reduces lake level to about 625.3 m during winter.

A wide diversity of fish species are present in Lake Pend Oreille. Kokanee entered the lake in the early 1930s from Flathead Lake, and were well established by the 1940s. Other game fish include Kamloops (Gerrard) rainbow trout, bull trout, rainbow trout, westslope

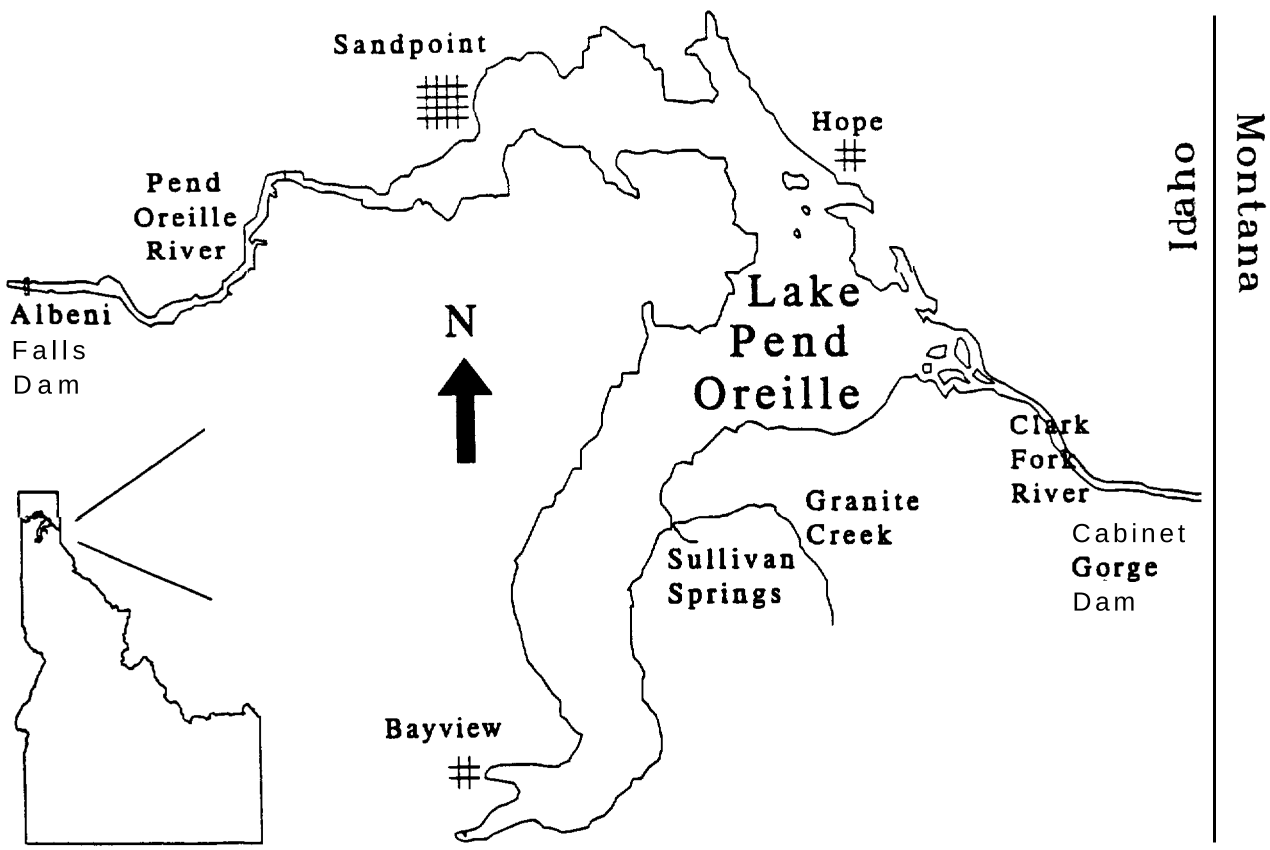

Figure 1. **Location of Lake Pend Oreille.**

cutthroat trout *0. clarki lewisi*, lake whitefish Coregonus *clupeaformis*, and mountain whitefish *Prosopium williamsoni*, in addition to several cool and warmwater species.

OBJECTIVE

To develop a basis from which to determine if a higher lake level in Lake Pend Oreille will be beneficial to the kokanee population.

METHODS

Spawning Gravel Availabilitv

Aerial Gravel Survey

With the assistance of the University of Idaho, we identified possible areas with spawning gravels by aerial survey of the lake shore from a fixed-wing aircraft on April 2, 1994. Lake Pend Oreille was approximately 625.1 m (2,051 ft) above mean sea level (msl) on this day, making the entire shoreline above the low-pool elevation visible. We videoed shoreline areas around the lake and then marked areas that appeared to consist primarily of gravel substrates suitable for kokanee spawning on a large-scale map for further assessment.

Shoreline Gravel Survey

From April 6 to April 9 1994, we conducted more detailed gravel surveys by walking shoreline areas identified during the aerial survey. Shoreline gravel surveys were conducted for two purposes. The first purpose was to assess the quality of gravels that, from the aircraft appeared suitable for spawning. After on-site examination, we identified and mapped sites composed of suitable spawning gravels, while areas considered unsuitable were excluded from further assessment. The second purpose of the shoreline surveys was to measure the surface area between lake elevation 625.1 m (2,051 ft) and 627.6 m (2,056 ft) at sites where gravels appeared suitable for spawning, which would then allow calculation of the spawning area made available by a higher lake elevation. We grouped potential spawning areas into 27 sections, delineated by accessibility, landmarks, or abrupt changes in shoreline character. In most cases, we further divided sections into specific sites to facilitate measurement of area. Shoreline areas were accessed by road or by boat.

On-site assessment of potential spawning areas was based on visual classification of gravels as suitable--those appearing relatively free of fine sediments (less than 4-6 mm diameter), or unsuitable--those appearing to exceed 35% fine sediments. For more accurate estimation of fine sediment percentages, and to confirm the accuracy of our field assessment, we periodically collected representative substrate samples with a 15-cm diameter core sampler by removing a plug of substrate to a depth of 10 cm. We collected samples in areas that appeared unsuitable as well as those areas that we initially categorized as suitable. Samples were oven-dried, sifted, and then weighed.

In areas classified as suitable for spawning, we measured the width and length of the gravel area that would be inundated and available for spawning at a lake elevation of 626.7 m. To measure width of the gravel band, we held a stadia rod at elevation 625.1 m (based on knowledge of Albeni Falls Dam forebay elevation) and used a level to identify a point on the shoreline corresponding to an elevation of 626.7 m. After marking the upper boundary of the available gravel band, we used a tape to measure width. Depending on the variability of the shoreline, we measured band width on a single beach from one to nine times. Beaches marked by a highly variable degree of shoreline slope resulted in a wide range of gravel band widths. At these beaches, we measured width at several sites and then calculated a mean band width. At sites where gravel was patchy and not distributed evenly from elevation 625.1 to 626.7 m, we measured the width of the suitable gravel bands and recorded their approximate elevation.

We used two methods to estimate length of areas classified as suitable for spawning. Sections characterized by areas of suitable gravel interspersed with unsuitable gravel, or sections with highly variable band widths, required frequent assessment of gravel quality. At these sections, we walked the entire shoreline and used a hip-chain (string counter) to measure exact length of suitable areas. At sections characterized by gravels of consistent quality, with less variable band widths, we first recorded suitable areas on a map, then used a cartometer to measure shoreline length.

In addition to measuring gravel from elevation 625.1 to 626.7 m, we estimated the amount of suitable spawning gravel below elevation 625.1 m, or the area currently available for kokanee spawning. We assumed that no suitable gravels were available below elevation 625.1 m unless suitable gravels were visible above that level. Because the lake elevation was near the low pool elevation (625.1 m) while conducting the gravel survey, classification of gravel below the 625.1 m mark as suitable was based on visual assessment. Most areas were characterized by a narrow band of clean gravel (relatively free of fines) at the low pool elevation. Beneath this band were typically gravels consisting of a high percentage of fine sediments, or a substrate composed entirely of silt or sand, so that in most cases suitable gravels below the winter pool elevation were confined to an area immediately next to shore. For this reason, width was calculated by measuring the distance that the clean gravels extended into the lake. In most areas we used a tape measure, although deep water occasionally required visual estimation. Length of the area below 625.1 m was estimated with the corresponding length of the 625.1 to 626.7 m band.

At each site, we used a mean width and total length to calculate total surface area of gravel gained at a lake elevation of 626.7 m, as well as the area of gravel currently available below elevation 625.1 m. A small number of sites were characterized by bands of gravel that did not cover the entire area from 625.1 to 626.7 m. The gravel at these sites was usually on the lower edge of the band (closer to 625.1 m than 626.7 m). Because of the slightly greater area of gravel at the lower elevations, we also calculated the amount of gravel available at elevations of 625.4 m (2,052 ft), 625.7 m (2,053 ft), 626.0 m (2,054 ft), 626.3 m (2,055 ft) by assuming a constant degree of slope at each site and using a ratio to estimate area. Gravel quality, shoreline slope, and wave activity (based on exposure to lake and prevailing winds) were similar within broad regions of the lake; therefore, we grouped the sections into the following lake regions: northwest, northeast, southwest, and southeast.

Kokanee Abundance

Midwater Trawling

Since 1974, trawling has been conducted on Lake Pend Oreille during the dark phase of the moon in August or the first week of September. This period is used because complete darkness is necessary to optimize capture efficiency (Bowler et al. 1979), and sampling late in the summer increases the capture efficiency of age 0 kokanee (Rieman 1992). In 1994, we trawled from August 5 to August 9 during the new moon. Because the new moon occurred in early August, we repeated a portion of the transects during the new moon in September as a check on the population estimates from August.

Lake Pend Oreille was divided into six sections or strata (Figure 2), and a stratified systematic sampling scheme was used to estimate kokanee abundance and density. Six transects were systematically selected within each section and one haul (sample) was made along each transect. These were the same transects used in kokanee population monitoring on Lake Pend Oreille since 1977 (Paragamian and Ellis 1994; Bowles et al. 1988, 1989; Bowler et al. 1979). The midwater trawl and sampling procedure is described in detail by Rieman (1992). The net was 13.7 m long with a 3 x 3 m mouth. Mesh sizes (stretch measure) graduated from 32, 25, 19, and 13 mm in the body of the net to 6 mm in the cod end. The trawl net was towed by an 8.5-m boat powered by a 140-hp diesel engine, at a trawling speed of 1.5 m/s. The vertical distribution of kokanee, as determined from echograms produced by a Raytheon Model 78841 depth sounder with a 20° hull-mounted transducer, was divided into 3.5 m layers. Usually 3 to 5 layers encompassed the vertical distribution of kokanee. We made a standard 3-minute tow in each layer (referred to as a step), so that each step-wise oblique tow was designed to sample the entire vertical distribution of kokanee. We determined trawl depth by the length of cable out from the boat. To ensure that the trawl accurately sampled depths where the kokanee were identified by the echosounder, we calibrated the cable length to actual depth by using a second boat, which was equipped with a Lowrance Model X-l 6 chart recording depth sounder. The second boat was positioned behind the trawler so that an echogram of the trawl was made as the trawl passed beneath. At least two echograms were made of the trawl at each step. We plotted actual depth of the top of the trawl (visible on the echograms; Appendix 1) as a function of the length of cable out from the boat. We then calculated expected depth at each step from the resulting regression (r^2 = 0.99).

Section	Area (hectares)
1	3.166
2	3,220
3	3,739
4	4,036
5	3,737
6	5,011

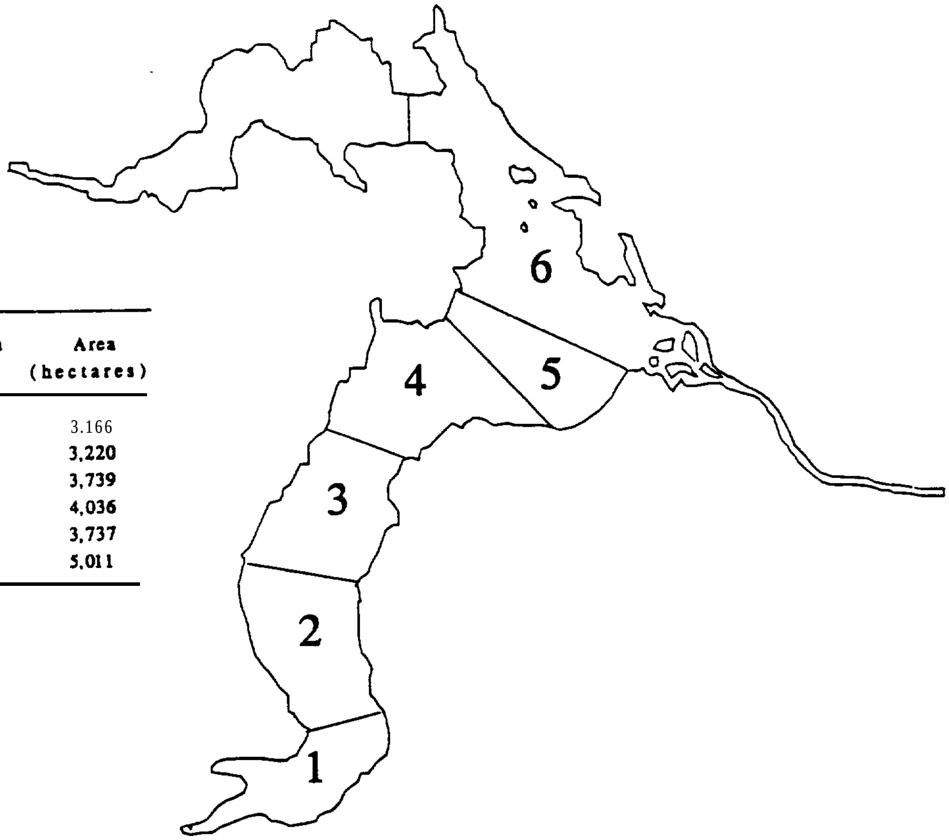

Figure 2. Six sections of Lake Pend Oreille used for midwater trawl estimates of kokanee population.

Each step sampled 2,508 m^3 of water over a distance of 270 m. Based on this estimate, total volume of water sampled for each trawl haul varied from 7,525 to 15,049 m^3, depending on the vertical distribution of kokanee and the number of steps. Fish from each sample were counted, measured, weighed, and checked for maturity, and sagitta otoliths, or scales, were excised from 5-l 0 individuals from each 10 mm length group for aging. All age classes of kokanee were collected.

Fish numbers/transect (haul) were divided by transect volume and the age-specific and total number of kokanee for each stratum and lake total were calculated using standard expansion formulae for stratified sampling designs (Scheaffer et al. 1979). Kokanee population estimates (total and by section) were divided by respective lake surface areas to calculate densities in fish/hectare for each age class. The area of each section was calculated for the 91.5-m contour; however, Section 6 (the northern end) was calculated from the 36.6-m contour because of shallower water. The 91.5-m contour was used because it represents the pelagic area of the lake where kokanee are found during late summer (Bowler 1978). Confidence intervals (95%) were calculated to compare estimates among age classes, lake sections, and years.

Hydroacoustic Surveys

Hydroacoustic surveys were conducted using a Simrad EY 500 split-beam echosounder. Initially, a minimum signal strength of -59 db was used to reduce interference by opossum shrimp Mysis *relicta.* This eliminated most shrimp from the survey; however, it also is likely that some kokanee fry were excluded. Therefore, we made acoustic density estimates utilizing all signals between -48 dB to -32 dB, which were thought to include age 1 + to age 4 + kokanee. These estimates were then compared to trawl density estimates for age 1 + to age 4+ kokanee.

During the August trawling effort in 1994, 18 of the 36 total transects were accompanied by the hydroacoustic boat to enable comparison of estimated densities. On September 7 and 8, all (9) trawl transects were accompanied by the hydroacoustic equipment. As a result of the total Lake Pend Oreille sampling effort in 1994, we have a total of 27 paired density estimates from the trawl catch and the hydroacoustic surveys. We used a linear regression to determine the strength of the relationship between the two methods.

Projecting Kokanee Density with Stock-Recruitment Curves

To determine the appropriateness of a stock-recruitment model for use with kokanee in Lake Pend Oreille, we assumed a five year life cycle (characteristic of most kokanee in Lake Pend Oreille) and plotted the numerical abundance of each age class (recruits) as a function of the numerical abundance of the same age class five years earlier (stock).

Using the equation of Ricker (1958)

$$R = (aP) * e^{(-b \cdot P)}$$

where: R = number of recruits
P = number of parental stock
a = constant representing density independent mortality
b = constant representing density dependent mortality

we plotted the stock-recruitment relationships using spawners (potential egg deposition; PED), age 0, age 1 + , and age 2 + . Because age 3 + and 4 + kokanee were not aged prior to 1986, we do not have estimates of their respective abundance and could only use these age classes in a combined estimate of age 3 + and 4 + kokanee. Because the contribution of the hatchery was only assessed for the age 0 kokanee, we did not attempt to exclude them from the analysis, even though evidence suggests they experience higher mortality rates than wild fry.

Spawner Counts

From 1972 through 1994 (with the exception of the years 1979-l 984,1993) spawner counts were conducted by walking shoreline areas (defined in Appendix 2) and tributaries once from 0800 to 1500 h during the first week of December, which is considered the peak of spawning activity. All kokanee seen from the shore were considered spawners, and the counts included any kelts observed. Shoreline areas surveyed were chosen because they have been documented as historical spawning sites (Jeppson 1959). In the 1950s and early 1970s spawning surveys were conducted by boat, shoreline counts, and by fixed-wing aircraft (Gibson 1973; Jeppson 1960). Although methodology of these early counts was not consistent, they are useful in defining areas that were historically important for kokanee spawning, and the relative importance of these areas. In 1992, an additional survey was conducted by attempting to count spawning kokanee from a boat over historical spawning areas around the lake.

In 1994, shoreline spawning kokanee were surveyed in the traditional method of walking the shoreline from December 1 to December 6. In addition, we conducted aerial counts of spawning kokanee on December 5 with a chartered Hiller 12E helicopter. The flight was an effort to determine whether kokanee could be seen from a low-flying helicopter, and ultimately, to determine if a helicopter survey could provide an accurate index of spawning activity throughout the entire lake in a short period of time.

Selected tributaries were censused by beginning at the mouth and walking the entire length of stream used by kokanee. Trestle Creek, which supports a run of early spawning kokanee, was also censused in late September or during the first week in October.

Fry Abundance and Lake Elevation

We estimated the abundance of kokanee fry by midwater trawl and then used otolith analysis in conjunction with size distribution to determine the number of hatchery versus wild kokanee. Estimates of wild fry abundance are available since 1978. We plotted wild fry abundance and wild fry survival rates (PED to fry) as a function of the amount of drawdown after November 15 and minimum winter elevation.

RESULTS

Spawning Gravel Availability

Location of Potential Spawning Sites

Sites considered suitable for spawning, based on visual assessment, were located throughout all regions of Lake Pend Oreille. A total of 30.2 km of shoreline distance was considered potentially suitable for spawning. The northwest and southwest regions had the greatest distances of suitable area, each with 8.8 km, while the southeast and northeast regions had 7.6 km and 5.0 km, respectively.

As expected, analysis of the dry weight of the substrate samples confirmed that all areas included as suitable for kokanee spawning consisted of less than 35% fines. Areas such as Sunnyside and Idlewilde Bay, which were not included, consisted of more than 35% fines (Appendix 3). These dry weights confirmed the accuracy of our field classification as either suitable or unsuitable.

Suitable spawning gravel sites were more apparent and appeared to be higher quality in regions exposed to greater wave activity, and the aerial survey accurately identified gravel sites in these regions. Gravels in these areas were more abundant and seemed to be of higher quality than more sheltered areas. In areas such as Ellisport Bay and Bottle Bay, where gravels were subject to less wave activity, gravels that appeared to be high quality during the aerial survey were not considered suitable during the shoreline survey.

Gravel Availability Based on Lake Elevation

Based on the shoreline lake survey, the estimated area of suitable gravel for kokanee spawning, available below a lake elevation of 626.7 m was about 231,000 m^2 (Table 1). Eighty-five percent of the suitable spawning gravel (an estimated total of 196,000 m^2), however, was located between the elevations 625.1 m and 626.7 m (above the current low pool elevation of Lake Pend Oreille) and would not be available under current operating procedures. The pattern where only a small percentage of suitable gravels occurred below the low-pool elevation was consistent throughout all regions of Lake Pend Oreille (Figure 3). Most sites were characterized by an evenly distributed band of gravel beginning at or immediately below the water level, and extending up to or beyond an elevation of 626.7 m. The generally even distribution of gravel, and a relatively constant shoreline slope resulted in a near linear increase of available gravel for every increase in lake elevation, with a slightly greater rate of increase at the lower elevations. Because the distinct gravel bands were usually, but not exclusively, located at the lower elevations of the 625.1-626.7 m area, and given the relatively inconsequential increase at lower elevations, the linear relationship is probably more appropriate for predicting available gravel at lake elevations (Table 2). Using a linear relationship, each increase in low-pool elevation of Lake Pend Oreille by 0.3 m would result in a gain of 39,145 m^2 of suitable spawning gravel.

Because of the near linear relationship between gravel gained and lake elevation, greatest increases in available gravel were in the areas with a gradual shoreline slope, such as the northwest and northeast regions. A total of 68% of the total gravel gained is from these two regions,' although they only comprised 46% of the total area by shoreline distance.

Kokanee Abundance

Abundance Estimates Based on Midwater Trawling

Midwater trawling and hydroacoustic surveys conducted from August 5 to August 9, 1994 resulted in lower than normal population estimates of all year classes of kokanee. Because the low abundance estimates may have been partially the result of sampling earlier in August than in previous years, in September we repeated a random sample of transects from each section with both the trawler and hydroacoustic equipment. These estimates resulted in higher population estimates of all year classes with the exception of age 1 kokanee (Table 3). September trawl data resulted in population estimates of 6,760,000 age 0, 380,000 age 1 + , 700,000 age 2 + , 990,000 age 3 + , 760,000 age 4 + , and 70,000 age 5 + kokanee. Regression analysis of kokanee densities based on trawling and on hydroacoustic surveys indicates a significant positive linear relationship (r^2 = 0.78).

Analysis of scale and otolith samples indicated extensive overlapping of age classes in the length frequency histogram (Figure 4), and suggested that length at age can only be accurately assessed by aging kokanee from each 10 mm size increment. Thirty-six percent of age 3 + kokanee were determined to be mature, 83% of age 4 + kokanee were mature, and 100% of age 5 + kokanee were mature. Based on these maturity estimates, there were 599,000 mature female kokanee in September, for a PED of 246 million eggs (mean fecundity was estimated using a length-fecundity regression; Rieman 1992). Density estimates, mean weight, size, standing stock, biomass estimates, and confidence intervals on population estimates from the 1994 trawling effort are in Table 4.

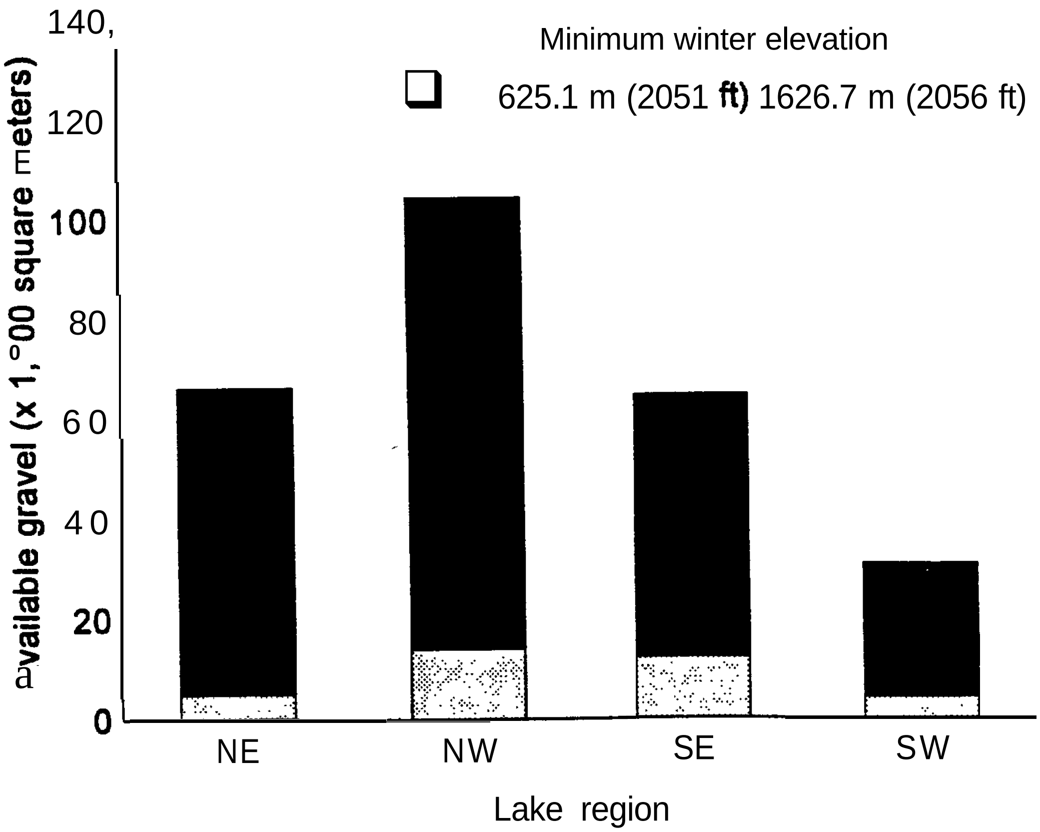

Figure 3. **Estimated spawning gravel available at the proposed winter elevation (626.7 m) and at the current winter elevation (625.1 m).**

Table 1. Area of suitable spawning gravel (m^2) for kokanee based on lake elevations of 625.1 (current low pool elevation) and 626.7 (proposed low pool elevation).

Region	Current area (below 625.1)	Area gained (625.1-626.7)	Total (below 626.7)
Northeast	4,907	56,449	61,356
Northwest	14,003	76,536	90,538
Southeast	12,193	40,430	52,623
Southwest	4,357	22,260	26,617
Total	35.460	195,674	231.134

Table 2. Estimated amount of suitable spawning gravels (m^2) below different lake elevations. Increase based on banded gravel accounts for the few sites where a gravel band occurred near elevation 625.1 and did not extend to elevation 626.7.

Elevation		Amount based on banded nravel	Amount based on linear increase
m	ft		
625.1	(2,051)	35,460	35,460
625.4	(2,052)	77,903	74,595
625.7	(2,053)	120,045	113,729
626.0	(2,054	160,767	152,864
626.3	(2,055)	198,417	192,000
626.7	(2,056)	231,134	231,134

CHPT1 TAB

Table 3. Estimated abundance (millions) of kokanee made by midwater trawl in Lake Pend Oreille Idaho, for 1977-l 994. To follow a particular year class of kokanee, read up one row and right one column.

sampling Year	Age class						415 + Densrty (N/ha)	Total
	o +	1+	2+	3+	4+	5+		
1994 (Sept)	6.76	0.38	0.70	0.99	0.76	0.07	36.9	9.68
1994 (Aug)	3.06	0.46	0.35	0.29	0.17	0.02	9.6	4.35
1993	3.17	1.48	1.30	2.00	1.02		45.1	8.97
1992	4.55	1.33	0.78	1.11	0.64		28.3	8.41
1991	1.98	0.83	1.77	0.77	0.27		11.9	5.62
1990	3.35	1.59	1.45	0.33	0.20		8.8	6.93
1989	4.48	1.17	1.20	0.45	0.37	0.04	18.1	7.71
1988	7.31	1.66	0.51	0.38	0.35		15.5	10.21
1987	3.55	0.78	0.84	0.43	0.42		18.6	6.02
1986	1.66	1.15	0.68	0.54	0.24		10.6	4.26
1985	1.79	1.03	1.24	0.37'			•	4.47
1984	2.63	1.51	1.21	0.28*			•	5.62
1983	2.14	2.28	0.50	0.29*			•	5.21
1982	3.84	2.77	0.64	0.87'			•	8.12
1981	2.31	1.36	0.79	0.74*			•	5.20
1980	1.69	1.00	0.96	1.03'			•	4.68
1979	2.01	1.31	1.70	0.67*			•	[illegible]
1978	1.82	0.71	2.00	1.29*			.	5.82
1977	2.01	1.17	2.95	0.65'			•	6.78

'Age 3 + and 4 + kokanee were not separated through aging prior to 1986.

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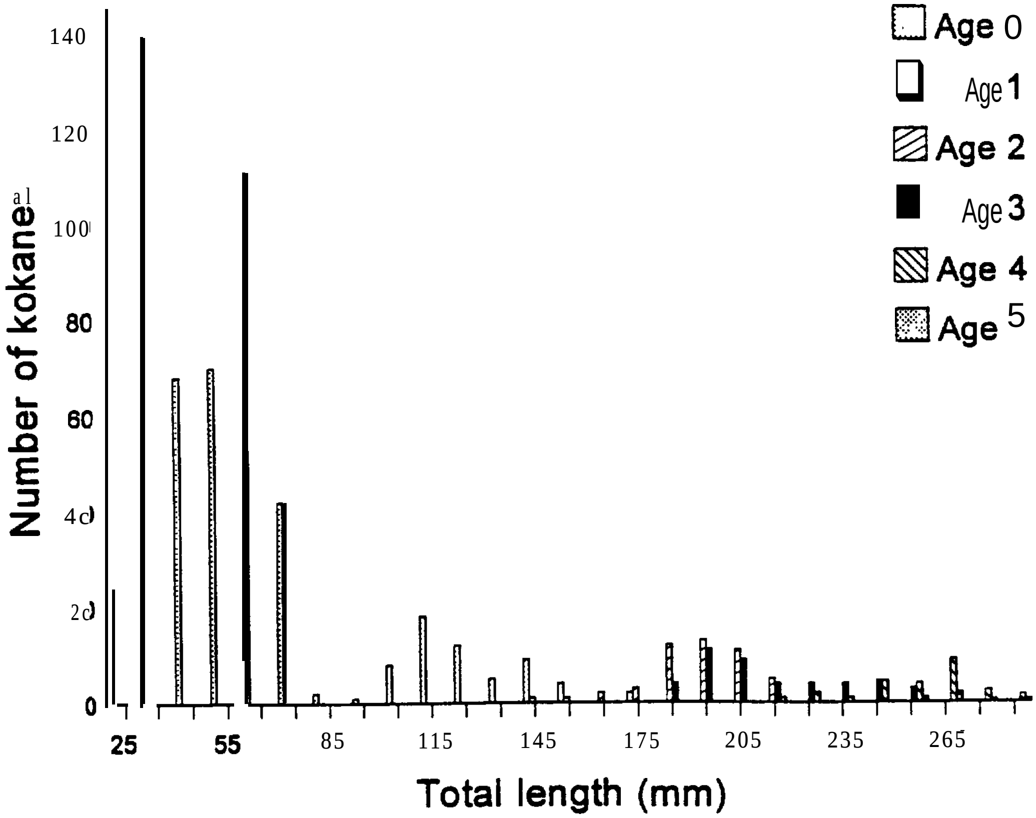

Figure 4. Length frequency by age class of kokanee captured by trawling in August 1994 in Lake Pend Oreille based on otolith and scale analysis.

Forecasted Estimates of Abundance 1995-l 998

The stock-recruitment models fit estimates of density since 1977 and suggest that density dependent mortality of kokanee in Lake Pend Oreille is a factor regulating the population. Years with high kokanee stock abundance were associated with low abundance of recruits, whereas years with low stock abundance produced high numbers of recruits (Figures 5-9). This trend fit the Ricker stock-recruitment model and its assumption of density dependent mortality, and was more appropriate than using a mean survival percentage with an assumption of a constant mortality rate. Stock-recruitment relationships using PED, age 0, and age 1 + indicate parental stock size explains a large portion of the variation in recruitment from year to year. Although the model explains less variation in recruitment for age 3 + and 4 + kokanee, this is likely a result of combining them into a single age class. Table 5 provides values for the stock-recruitment models and corresponding r^2 values of the various kokanee age classes.

Based on the stock-recruitment model and kokanee abundance since 1990, expected abundance in the years 1995-l 999 will range from 3.41 million to 4.18 million fry, 1 .1 to 1.55 million age 1 +, and 0.69 to 1.34 million age 2 + kokanee (Table 6). The stock-recruitment model forecasts wide fluctuations in abundance of age 3/4 + kokanee; however, the low r^2 value for this category indicates the model does not explain survival factors for these combined age classes, and abundance forecasts should be limited to the younger age classes and PED.

Spawner Counts

From 1972 to 1992 (excluding 1979-l 984), shoreline spawner counts ranged from under 800 kokanee (1978) to nearly 20,000 kokanee (1973). Most of the lakeshore spawning activity occurred in Scenic Bay around Bayview. The importance of Bayview as a spawning area in recent years is consistent with the spawning surveys from 1952 through 1958, which also indicate several thousand spawning kokanee near Bayview (Table 7). Unlike the 195Os, however, relatively few spawners (less than 500 kokanee) have been counted in the northeast region of Lake Pend Oreille in recent years (Hope, Trestle Creek, Ellisport Bay), whereas in 1952 and 1953, biologists estimated 28,100 and 25,750 spawners, respectively (Jeppson 1960).

Tributary spawner counts since 1972 have ranged from 3,726 kokanee to 21,513 kokanee, but have not shown any significant trend toward declining runs (Table 8). The mean from 1972 to 1978 was 9,635 kokanee, whereas the mean since 1985 was 8,346 kokanee. Although this represents a decrease, the mean of the, years since 1985 is not significantly lower than the mean from the 1970s (t-test; $p > 0.1$). In contrast, standardized shoreline spawner counts have shown a significant downward trend from a mean of 6,400 kokanee during the years 1972-l 978 to a mean of 1,921 kokanee in the years since 1985 (t-test; $p < 0.1$).

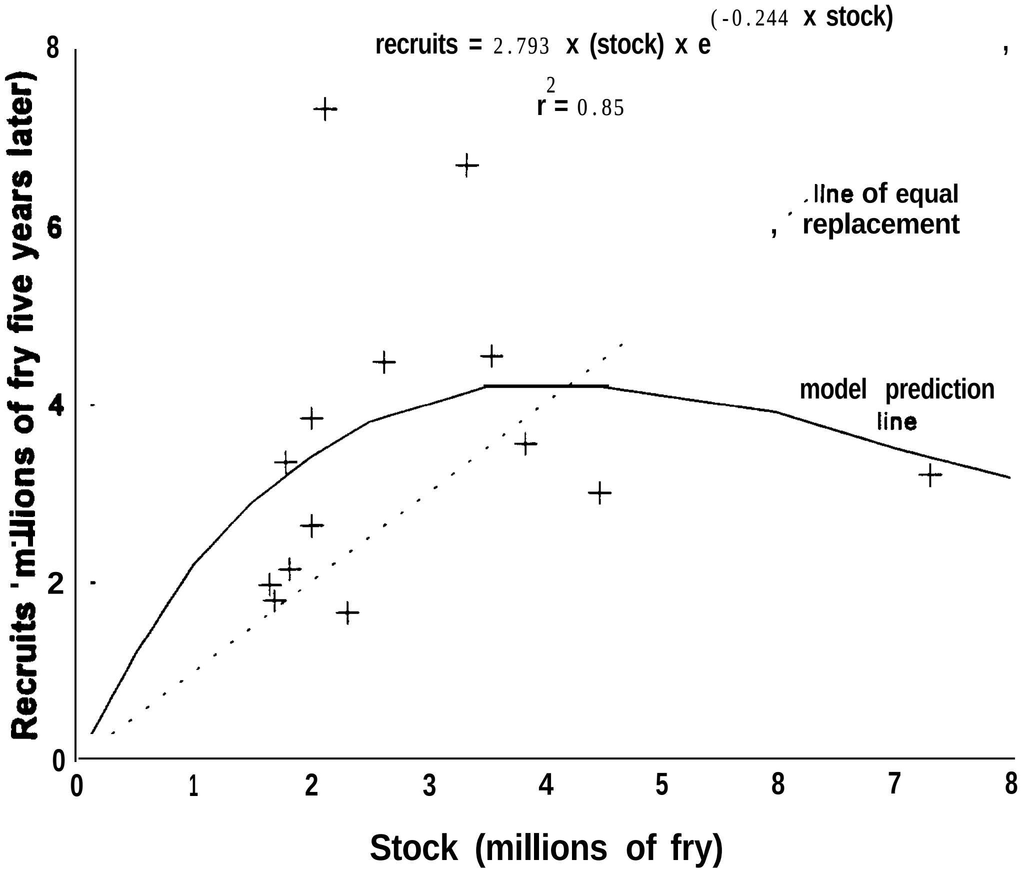

Figure 5. Abundance of age 0 kokanee (recruits) as function of age 0 abundance five years prior (stock).

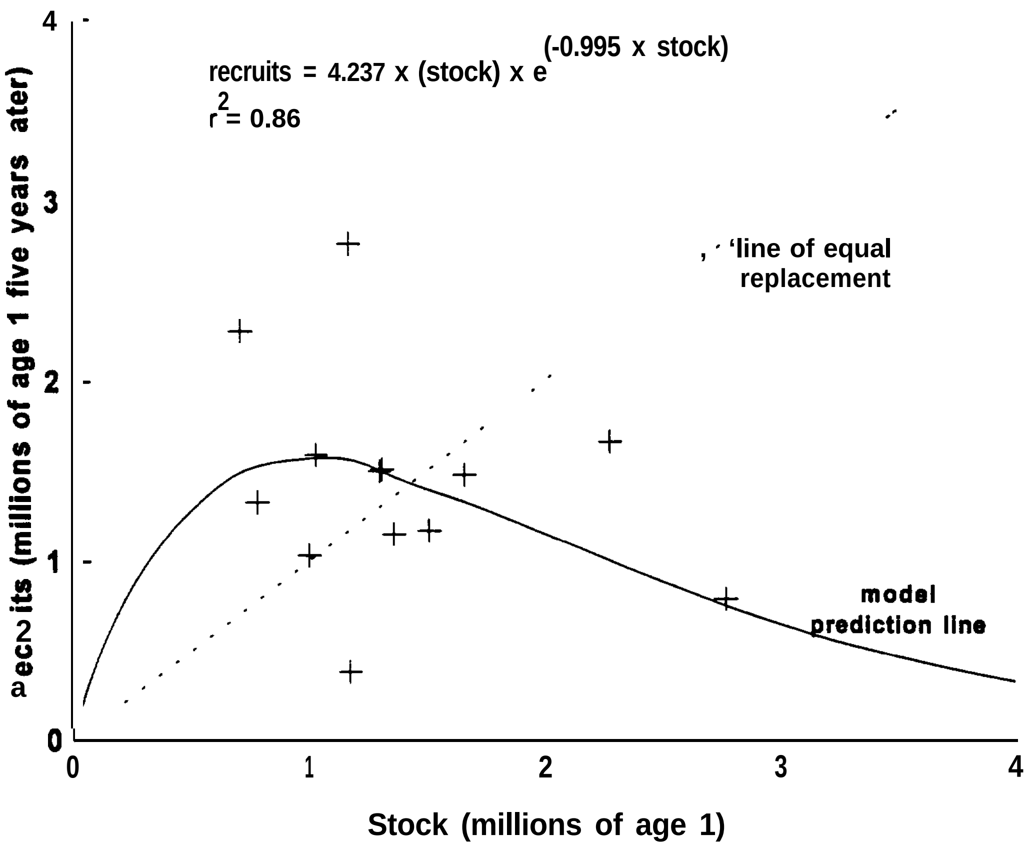

Figure 6. Abundance of age 1 + kokanee (recruits) as a function of age 1 + kokanee five years prior (stock).

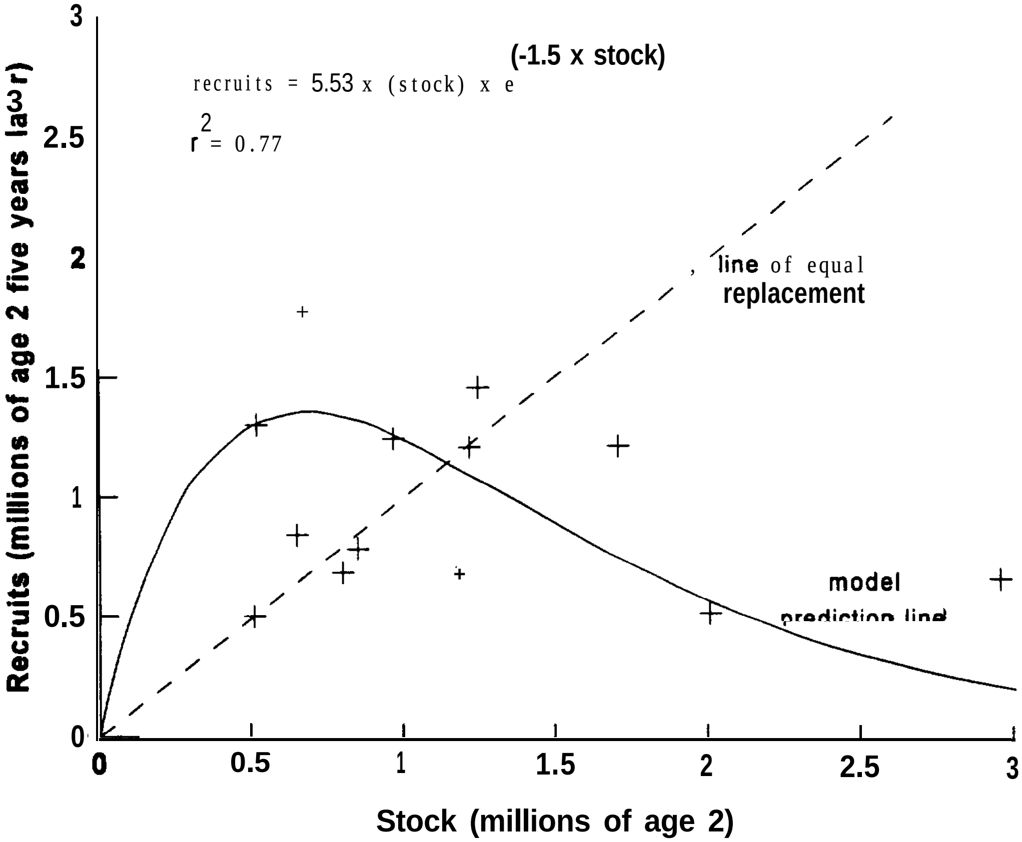

Figure 7. Abundance of age 2 + kokanee (recruits) as a function of age 2 + kokanee five years prior (stock).

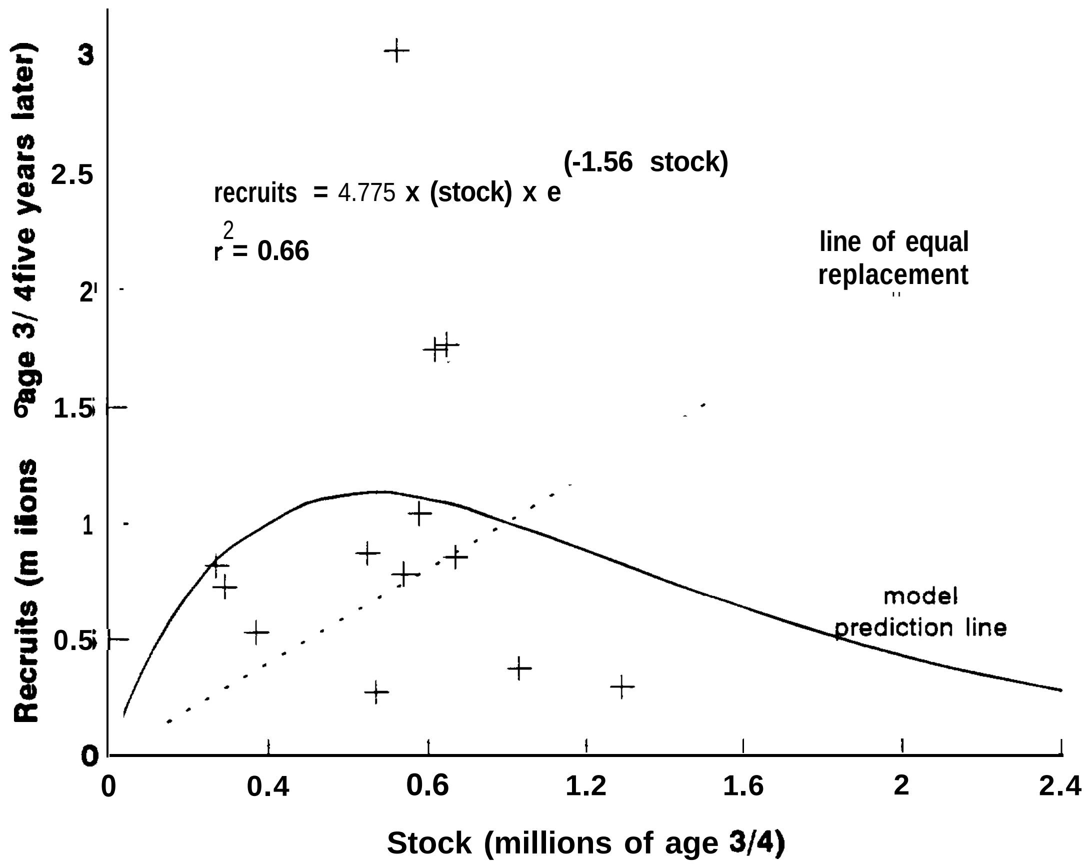

Figure 8. Abundance of age 3 + /4 + kokanee (recruits) as a function of age 3 + /4 + kokanee five years prior (stock).

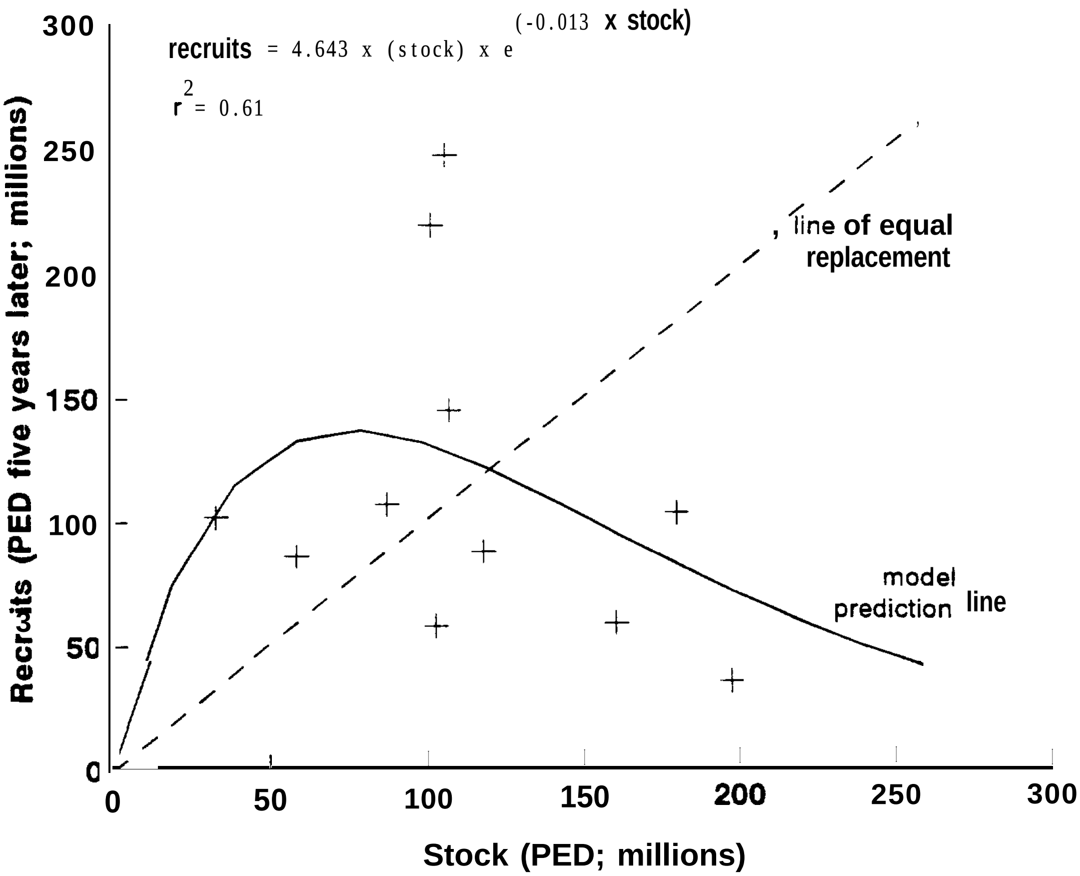

Figure 9. **Abundance of kokanee potential egg deposition (PED; recruits) as a function of kokanee PED five years prior (stock).**

Table 4. September 1994 population estimates (in millions, with 95% confidence intervals), density (fish/ha), mean weight (g), standing stock (kg/ha), length range, and mean total length (mm) of all age classes of kokanee based on trawl results.

	Age					
	0	1	2	3	4/5	Total
Population	6.76	0.39	0.70	0.99	0.84	9.68
(+/- 95% CI)	13%	85%	48%	46%	52%	
Density	299	17	31	44	37	427
Mean wetght	0.71	12	46	65	120	
Standing stock	0.21	0.20	1.4	2.8	4.43	9.04
Mean length	45	120	188	206	250	
Lenght range	21-89	90-I 70	140-210	180-250	21 O-280	

Table 5. Stock recruitment models (RIcker 1958) and the r^2 values of age 0, age 1 +, age 2 +, age 314 + combined, and potential egg deposition of kokanee in Lake Pend Oreille.

Age class	Model	r^2
0	Recruits = $2.793 \times stock \times e^{(-0.244 \times stock)}$	0.85
1 +	Recruits = $4.237 \times stock \times e^{(0.995 \times stock)}$	0.86
2 +	Recruits = $5.530 \times stock \times e^{(-1.50 \times stock)}$	0.77
3/4 +	Recruits = $4.775 \times stock \times e^{(-1 56 \times stock)}$	0.68
PED	Recruits = $4.843 \times stock \times e^{(-0.013 \times stock)}$	0.81

Table 6 Expected abundance (millions) of age 0. age 1 +, age 2 +, age 3/4+, and PED for kokanee in Lake Pend Oreille from 1995 to 1999, based on a stock-recruitment model.

	Aoe class				
Year	0	1+	2+	3/4 +	PED
1995	4.13	1.40	0.91	1.07	132.5
1996	3.41	1.55	0.69	0.98	136.1
1997	4.18	1.51	1.34	0.54	106.5
1998	4.09	1.45	1.02	0.13	61.8
1999	3.62	1.10	1.24	0.54	48.5

Table 7. Shoreline kokanee spawner counts in Lake Pend Oreille. Counts were conducted by walking the shoreline during the first week in December.

Year	Bayview	Farragut	Idlewild Bay	Lakeview	Hope	Trestle Creek area	Sunny-side	Garfield Bay	Camp Bay	Anderson Point	Total
1994	911	2	0	1	0	114	0	0	0		1,028
1992	1,825	0	0	0	0	0	0	34	0		1,859
1991	1,530	0		0	100	90	0	12	0		1,732
1990	2,036	0		75	0	80	0	0	0		2,191
1989	875	0		0	0	0	0	0	0		875
1988	2,100	4		0	0	2	0	35	0		2,141
1987	1,377	0		59	0	2	0	0	0		1,438
1986	1,720	10		127	0	350	0	6	0		2,213
1985	2,915	0		4	0	2	0	0	0		2,921
1978	798	0	0	0	0	138	0	0	0	0	936
1977	3,390	0	0	25	0	75	0	0	0	0	3,490
1976	1,525	0	0	0	0	115	0	0	0	0	1,640
1975	9,231	0	0	0	0	0	0	0	0	0	9,231
1974	3,588	0	25	18	975	2,250	0	20	0	50	6,926
1973	17,156	0	0	200	436	1,000	25	400	617	0	19,834
1972	2,626	25	13	4	1	0	0	0	0	0	2.669

CHPTI TAB

Table 8. Kokanee spawner counts in Lake Pend Oreille tributanes made by walking streams during the first week in December. Trestle Creek was also counted during the first week in October to census early-run kokanee.

Year	S. Gold	N. Gold	Cedar	Johnson	Twin	Mosquito	Lightning	Spring	Cascade	Trestle[a]	Trestle[b]	Total
1994	569	471	12	2	0	-	0	4,124	72	170	0	5,420
1992	479	559		0	20	-	200	4,343	600	660	17	6,878
1991	120	550		0	0	-	0	2,710	0	995	62	4,437
1990	834	458		0	0	-	0	4,400	45	525	0	6,262
1989	830	448		0	0	-	0	2.400	48	466	0	4,192
1988	2,390	880		0	0	-	6	9.000	119	422	0	12,817
1987	2,761	2,750		0	0	-	75	1,500	0	410	0	7,496
1986	1,550	1,200		182	0	-	165	14,000	0	1,034	0	18,131
1985	235	696		0	5	-	127	5,284	0	208	0	6,555
1978	0	0	0	0	0	0	44	4,020	0	1,589	0	5,653
1977	30	426	0	0	0	0	1,300	3,390	0	865	40	6,051
1976	0	130	11	0	0	0	2,240	910	0	1,486	0	4,777
1975	440	668	16	0	1	0	995	3,055	0	14,555	15	19,740
1974	1,050	1,068	44	1	135	0	2,350	9,450	0	217	1,210	15,525
1973	1,875	1,383	267	0	0	503	500	4,025	0	1,100	18	9,671
1972	1,030	744	0	0	0	0	350	2,610	0	0	1,293	6,027

[a] Early-run kokanee.
[b] Late-run kokanee.

CHPT1 TAB

We counted no shoreline spawners during the helicopter survey of the entire shoreline; however, we were able to observe and count several hundred kokanee in the lower reach of Granite Creek during the flight. The observations at Granite Creek demonstrated that kokanee could be seen from a slow-moving helicopter at low elevation, and we believe that had there been thousands, or even hundreds of kokanee spawning along the shoreline, we would have detected them. To prevent disturbing the residents of the Bayview shoreline, and to avoid Navy security concerns, we did not fly at a low elevation over Bayview, although we know from our counts earlier in the week that some shoreline spawning kokanee were present.

Fry Abundance and Lake Elevation

In general, we found higher numbers of wild kokanee fry in years with little or no drawdown after November 15 (r^2 = 0.34) (Figure 10). Years with wild fry abundances over 2 million fry all followed winters with less than 0.3 m of drawdown after November 15 (with the exception of 1983 year class), whereas winters with a drawdown greater than 0.3 m were usually followed by fry abundances of less than 2 million. We also found an apparent relationship between the percent survival of wild kokanee fry and winter elevation (r^2 = 0.46) (Figure 1 1), suggesting that in the past, higher winter elevations have increased kokanee fry survival. The highest recorded PED to wild fry survival rates were the 1982 year class (9.2%) and the 1983 year class (6.1 %). These two years are the only years since trawling began in 1977 when winter elevations exceeded 626 m, which is nearly 1 m higher than in recent years.

DISCUSSION

Spawning Gravel Availabilitv

Annual fluctuations in the level of Lake Pend Oreille, along with wave action and storm events, have resulted in shoreline areas characterized by clean, well washed gravel, free of fine sediments and likely well suited to kokanee spawning. Maiolie and Elam (1993) report the formation of a band of clean gravel about l-2 m below the summer pool elevation. Under the current 3.4 m winter drawdown of Lake Pend Oreille, however, this band of washed gravel becomes unavailable to spawning kokanee. In contrast to the well washed gravel substrate between the winter and summer lake levels, the substrate below the winter pool elevation is more characterized by large cobble and fine sediments (Maiolie and Elam 1993).

Historical kokanee spawner counts from the 1950s (Jeppson 1960) document the occurrence of spawning along gravel beaches throughout Lake Pend Oreille, and as far down the Pend Oreille River as Dover. In 1994, we found kokanee spawning was limited to the areas from the Scenic Bay public boat ramp to MacDonald's Resort, the shoreline near the Farragut State Park boat ramp, and at the Trestle Creek boat basin. Our shoreline gravel survey indicated that these sites were among the few areas with clean, suitable gravels below

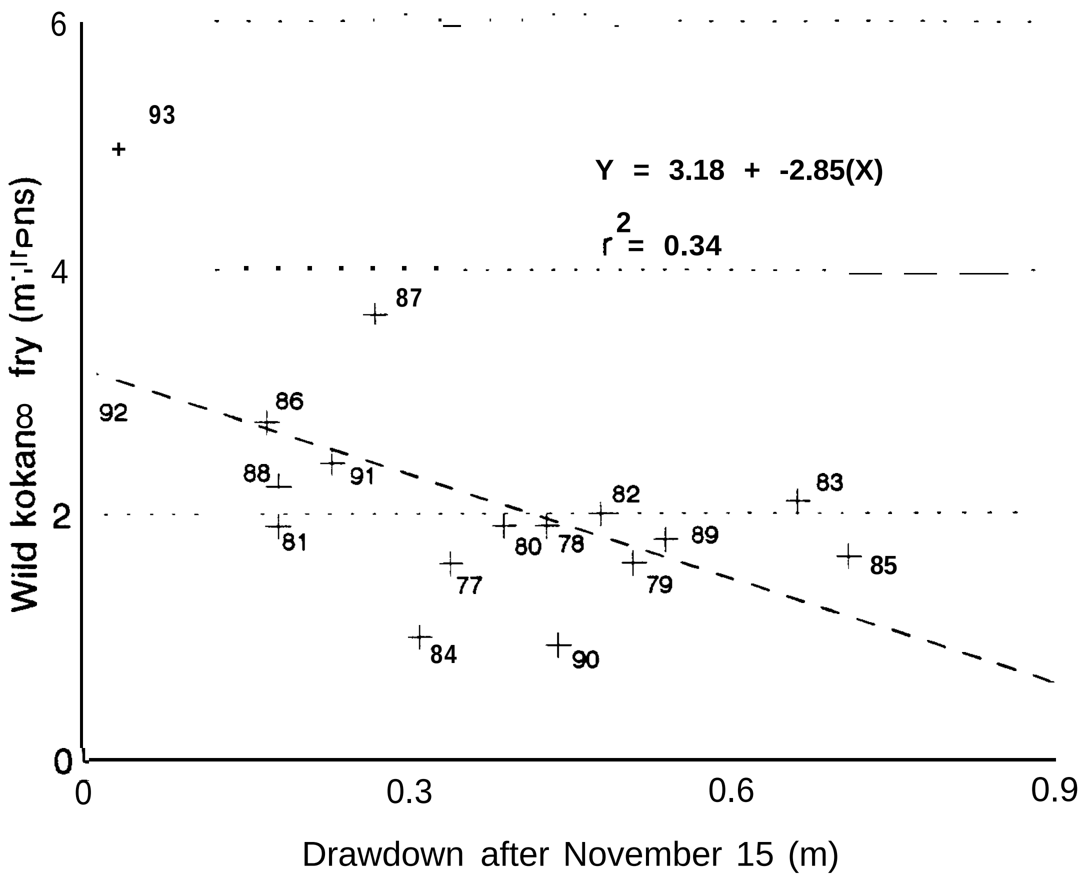

Figure 10. **The relationship between the decrease in elevation of Lake Pend Oreille after November 15 and the abundance of wild kokanee fry, based on trawling in late summer. Year classes were defined by the year the eggs were laid.**

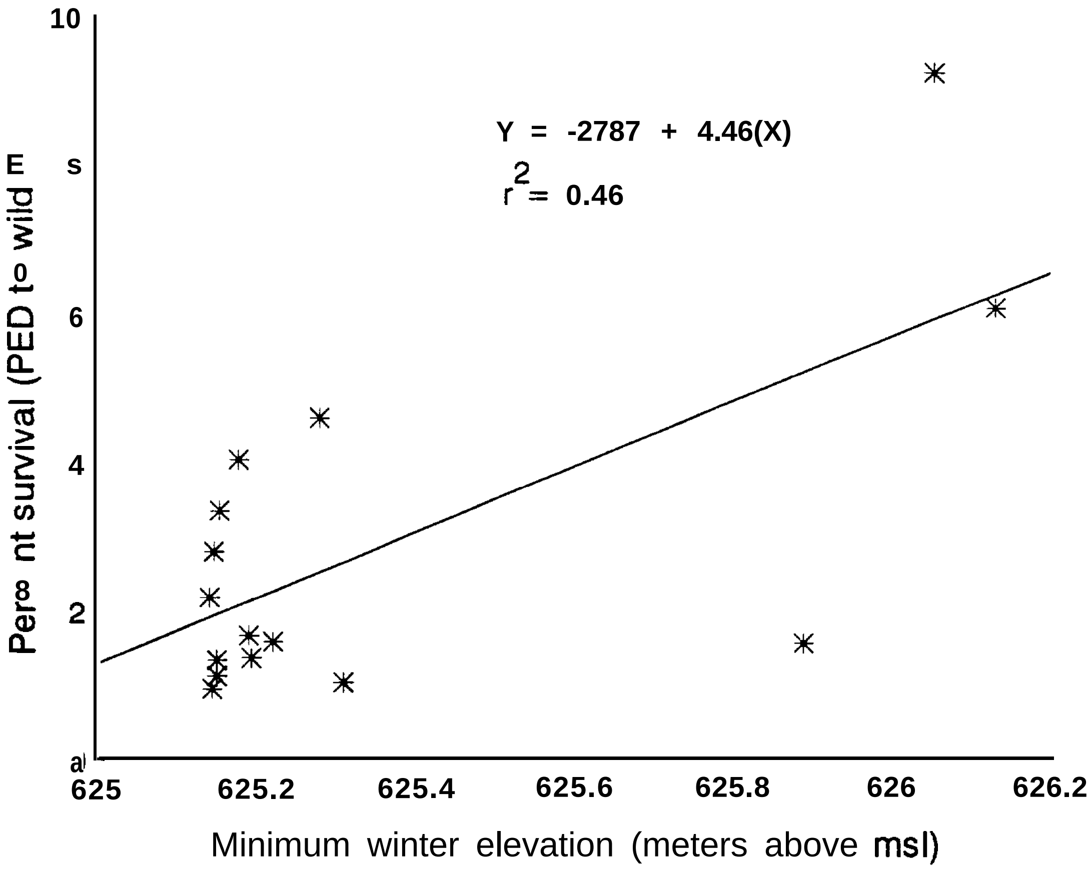

Figure 1 1. **The relationship between the minimum winter pool elevation of Lake Pend Oreille and percent survival of wild fry, based on potential egg deposition to late summer trawling.**

the winter pool elevation. We also found that suitable spawning gravel is abundant in historic spawning areas, but will not be available without higher water levels during the spawning season.

Based on an estimate of 10 pairs/m^2 (Jay Hammond, British Columbia Ministry of the Environment, personal communication) the total gravel currently available (35,460 m^2), as determined from our survey, is enough to support about 350,000 female kokanee. This is consistent with the mean number of spawning females since 1986 (315,000). By increasing the winter pool elevation to 626.7 m, we would provide an additional 195,000 m^2 of gravel and potentially provide spawning habitat for almost 2,000,000 spawning females. Each 0.3 m increase in elevation would potentially provide gravel for 390,000 spawning females.

Kokanee Abundance

The two parameters of kokanee abundance important to this study are actual abundance (historical and current) of each age class and expected abundance of the age classes based on abundance of previous age classes.

Actual Abundance

The positive relationship between density estimates in 1994 calculated from trawl data and those from the hydroacoustic data is evidence the trawl density and population estimates used since 1977 are an accurate reflection of the true kokanee population. The low kokanee densities in August 1994 are possibly the result of atypical patterns of kokanee distribution. Hydroacoustic surveys near shore indicated that in early August many kokanee may have been in shallow (< 91.5 m), near-shore areas which are not included in the trawl estimates. This pattern may be the product of an unusually hot, dry summer, or the result of trawling earlier in August than in past years. Although the September trawling effort resulted in higher population estimates of most age classes of kokanee than the August effort, the population is still lower than desirable. At best, the kokanee population appears to be sustaining levels of abundance reported in recent years. Although age 3 + and 4+ kokanee are relatively abundant based on 1993 and September 1994data, the younger kokanee are developing into very weak year classes. Estimates of age 1 + kokanee from both August and September indicate the lowest population of this age group since trawling began in 1977. Age 2 + kokanee are also well below the 17-year mean.

Abundance of kokanee as indicated by spawner counts since the 1950s clearly document the decline of shoreline spawning kokanee throughout all regions of the lake. This decline has persisted through the 1970s and 1980s. The relative stability of the tributary spawning runs supports the hypothesis that the decline in the kokanee population is largely related to the survival and habitat of the shoreline spawning stock, and is not a result of competition from opossum shrimp or predation. We have found no other factor other than the loss of shoreline spawning habitat to explain such a dramatic decline in the abundance of shoreline spawners, while tributary spawners seem to be returning in stable numbers.

Expected Kokanee Abundance

The historic fluctuation of kokanee age classes in Lake Pend Oreille (and in other kokanee populations), suggests that the effect of higher lake levels may not be evident without an estimate of expected year class abundance to compare with our actual estimates of year class abundance based on trawling. Estimation of the expected abundance of each kokanee age class is, therefore, critical in developing a basis from which to determine if a higher lake level in Lake Pend Oreille will benefit the kokanee population. Because kokanee abundance has been estimated for 17 years, and expected abundance is based on strength of previous year classes, data is available to help establish the best model for predicting expected abundance prior to trawling. Selection of a model to estimate kokanee abundance necessitates assumptions regarding factors driving the kokanee population.

The simplest method of estimating expected abundance of a year class would have been to assume a constant age-specific mortality from year to year and to apply a mean annual survival rate calculated from survival throughout previous years. However, age-specific survival rates in recent years appear too variable for this method to be reliable. For example, embryo survival (based on PED to wild fry) ranged from a low of 1.02% (1978 year-class) to a high of 7.69% (1983 year-class), and survival estimates of age 0 to age 1 + kokanee ranged from a low of 12% (1992 year class) to a high of 120% (1980 year class; survival rates exceeding 100% may be due to sampling error or changes in vulnerability to the sampling gear).

Aside from sampling error, much of the variation in survival rates was potentially due to the density of the respective year classes. Density has been shown to be negatively correlated with size of sockeye (Goodlad et al. 1974; Kyle et al. 1988; Burgner 1964) and also of kokanee (Rieman and Meyers 1990; Maiolie 1988). Size in turn has been shown to effect mortality rates of sockeye (Johnson 1965; Hyatt and Stockner 1985), and it seems likely that similar size-related, or other density dependent mortality effects may operate in some kokanee populations. Because of this apparent variation in survival, we believe that the model of stock and recruitment proposed by Ricker (1958), which incorporates density dependent survival rates into the estimate of year class abundance, is more appropriate.

The apparent fit of the stock-recruitment model to historic trends in the kokanee population enables us to forecast abundance of kokanee for the years 1995 through 1999 with densities based on trawling from 1990 to 1994. The stock-recruitment models indicated that kokanee are not recovering, and forecast relatively low numbers of harvestable fish in the coming five years. A change in the winter lake level will change the amount of available kokanee spawning habitat. When this occurs, the effect should be readily detected as a raising of the stock recruitment curve. Its shape would also be expected to change with more area above the line of equal replacement, indicating a more resilient population.

Lake Elevation and Frv Abundance

Wild kokanee fry were clearly more abundant following winters with minimal elevation drop after November 15, even though the winter pool elevation during most of those years was only about 625 m. While this trend is encouraging and may be a factor in kokanee survival, it would be unwise to conclude that winter elevation is inconsequential so long as the low pool is achieved by November 15. A stable winter elevation alone will not restore the kokanee population. Two recent years and the regression equation (Figure 10) all indicate that with no elevation change after November 15, wild fry numbers are improved, yet they are not at levels that will lead to historic numbers of adults. The 1992 year class, for example, was in the gravel during a winter of negligible drawdown after November 15. This year class became one of the highest on record for wild fry abundance, but suffered high mortality rates, became a weak year class by age 1 + (an estimated 380,000 kokanee), and will likely contribute little to the fishery. Sufficient adult kokanee abundance to support the harvest goal of 750,000 kokanee will probably require wild fry abundances far in excess of what has resulted from a stabilized winter elevation.

More important than a stable elevation after November 15 is the minimum winter elevation. A raised winter level will greatly increase the area of spawning gravels and bring historic spawning areas back into production. Fry would be produced in several regions of the lake, thereby reducing the potential for competition. The high survival rates of two of three year classes that were deposited during the only recent high water years indicate the importance of minimum winter pool elevation. This alone suggests that a higher winter elevation can benefit shoreline spawning kokanee and that more information is needed with the lake held at a higher level. Lake Pend Oreille has had winter elevations above 625.7 during only three years since 1977. Because most data points are around the current winter elevation of 625.1, additional data points at higher winter elevations would facilitate identification of significant relationships.

RECOMMENDATIONS

1. We recommend that a winter elevation of 627.6 m (2056 ft) be maintained on Lake Pend Oreille for a period of three consecutive years to determine if the increased availability in spawning gravel will benefit the kokanee population.

2. We recommend that prior to and during this elevation change, IDFG continue to monitor the kokanee population and density using midwater trawling, hydroacoustics, and spawner counts to identify the response to any changes in lake level management.

3. Spawning depth, substrate quality, and kokanee egg and fry survival should be closely monitored both before and after any elevation change.

4. **We recommend expanding the area currently defined as kokanee habitat (below the 91-m contour) to include shallower regions (up to 30 m). Trawl transects should be re-randomized to include these areas.**

5. **Lastly, we recommend continued sampling efforts allowing direct comparison between hydroacoustic and midwater trawl estimates of kokanee density that may contribute to the improved accuracy of both methods.**

ACKNOWLEDGEMENTS

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LITERATURE CITED

Bowler, B. 1978. Lake Pend Oreille kokanee life history studies. Idaho Department of Fish and Game, Job Performance Report, Federal Aid in Fish Restoration, Project F-53-R-l 3, Job IV-e, Boise.

Bowler, B., B.E. Rieman, and V.L. Ellis. 1979. Pend Oreille Lake fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-1, Boise.

Bowles, E.C., V.L. Ellis, D. Hatch, and D. Irving. 1987. Kokanee stock status and contribution of Cabinet Gorge Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract DE-Al 79-85BP22493, Project 85-839, Boise.

Bowles, E.C., V.L. Ellis, and D. Hatch. 1988. Kokanee stock status and contribution of Cabinet Gorge Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract DE-Al 79-85BP22493, Project 85-339, Boise.

Bowles, E.C., V.L. Ellis, and B. Hoelscher. 1989. Kokanee stock status and contribution of Cabinet Gorge Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract DE-Al 79-85BP22493, Project 85-339, Boise.

Burgner, R.L. 1964. Factors influencing production of sockeye *(Oncorhynchus nerka)* in lakes of southwestern Alaska. Verh. Internat. Verein. Limnol. 15:504-513.

Ellis, V.L. and B. Bowler. 1979. Pend Oreille Lake creel census. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-1, Job 1, Boise.

Gibson, H. 1973. Lake Pend Oreille kokanee spawning trends. Idaho Department of Fish and Game, Job Progress Report, Project F-53-R-8, Boise.

Goodlad, J.C., T.W. Gjernes, and E.L. Brannon. 1974. Factors affecting sockeye salmon (growth in four lakes of the Fraser River system. Journal of the Fisheries Research Board of Canada 31:871-892.

Hyatt, K.D., and J.G. Stockner. 1985. Responses of sockeye salmon *(Oncorhynchus nerka)* to fertilization of British Columbia coastal lakes. Canadian Journal of Fisheries and Aquatic Sciences 42:320-33 1.

Jeppson, P. 1960. Evaluation of kokanee and trout spawning areas in Pend Oreille Lake and tributary streams. Idaho Department of Fish and Game, Job Progress Report, Project F-53-R-l 0, Boise.

Johnson, W.E. 1965. On mechanisms of self-regulation of population abundance in *Oncorhynchus nerka.* Mitt. Internat. Verein. Limnol. 13:66-87.

Kyle, G.B., J.P. Koenings, and B.M. Barrett. 1988. Density-dependent trophic level responses to and introduced run of sockeye salmon *Oncorhynchus nerka* at Frazer Lake, Kodiak Island, Alaska. Canadian Journal of Fisheries and Aquatic Sciences.

Maiolie, M.A. 1988. Dworshak Dam Impacts assessment and fishery investigation, U.S. Department of Energy, Bonneville Power Administration, Contract No. DE-A179-87BP35167, Project No. 87-99. Portland, Oregon.

Maiolie, M.A., and S. Elam. 1993. Influence of lake elevation on availability of kokanee spawning gravels in Lake Pend Oreille, Idaho. U.S. Department of Energy, Bonneville Power Administration, Annual Progress Report, Project No. 87-99. Portland, Oregon.

Paragamian, V.L., and V.L. Ellis. 1994. Kokanee stock status and contribution of Cabinet Gorge Fish Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Final Report to Bonneville Power Administration, Contract DE-Al 79 85BP22493, Project 85-339, Boise.

Rieman, B.E. 1977. Lake Pend Oreille limnological studies. Idaho Department of Fish and Game, Job Performance Report, Project F-53-R-l 2, Job IV-d, Boise.

Rieman, B.E. 1992. Kokanee salmon population dynamics-kokanee salmon monitoring guidelines. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-l 4, Subproject II, Study II, Boise.

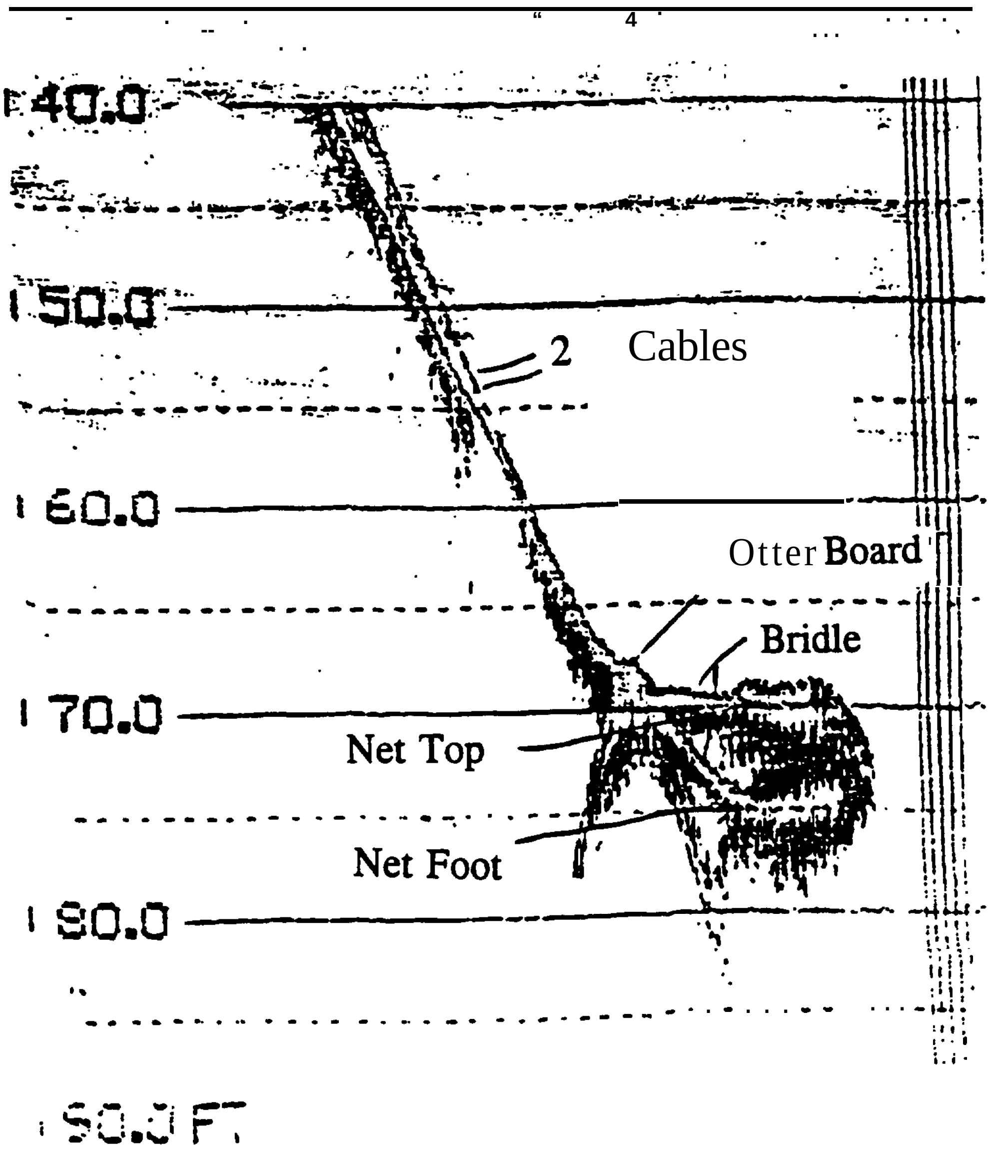
Rieman, B.E. and B. Bowler. 1980. Kokanee trophic ecology and limnology in Pend Oreille Lake. Idaho Department of Fish and Game Fisheries Bulletin 1, Boise.

Rieman, B.E. and D. Meyers. 1990. Status and analysis of salmonid fisheries - kokanee population dynamics. Federal Aid in Fish Restoration, Project F-73-R-l 2, Job Performance Report, Boise.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, No. 1 19.

Scheaffer, R.L., W. Mendenhall and L. Ott. 1979. Elementary survey sampling, second edition. Duxbury Press, North Scituate, Massachusetts.

APPENDICES



Appendix 1. **Echogram of midwater trawl. Cables, otter boards, and the bridle from the otter boards to the top and bottom of the net are clearly visible.**

Appendix 2. Definition of areas surveyed for shoreline spawning kokanee in Lake Pend Oreille since 1972.

Bavview

From MacDonalds to Navy Area (including Bayview Marina Docks, Boileus, Wheel Inn, JD's, Scenic Bay Resort Docks, Vista).

Farraout

From boat ramp up and down approximately I/3 km.

Idlewild Bay

From Buttonhook Bay north approximately I/3 km.

Lakeview

From resort up and down approximately I/2 km.

HoDe

From overpass up and down approximately I/3 km.
From Strong Creek up I/3 km - down to Boat Bay at Ellisport Bay Marina.

Trestle Creek Area

From boat ramp to mouth of Trestle Creek.

Sunnvside

From Sunnyside Resort up and down approximately I/3 km.

Garfield Bav

Along docks at Last Resort on east side of bay.
From boat ramp to Garfield Creek to north side approximately I/3 km.

Camp Bay

Entire area within confines of Camp Bay.

Fishermans Island

Entire island shorline - not surveyed since 1978.

Anderson Point

Not surveyed since 1978.

Appendix 3. **Lake Pend Oreille substrate composition (as percentage of fines, gravel, or cobble) during the April 1994 gravel survey.**

Site	Cobble >31.77 mm	Gravel 31.75 - 6.35 mm	Fines <6.35 mm
Haley Bay			
(shore)	2	96	2
(water)	29	55	16
Bottle Bay		38	
(shore)	37	23	25
(water)	50		27
Trestle Creek Area			
(shore)	44	39	17
(water)	22	37	41
Sunnyside[a]			
(shore)	15	20	66
Ellisport Bay			
(shore)	62	38	0
Maiden Rock			
(shore)	3	97	0
Navy Outpost[a]			
(shore)	0	40	60
Idlewild Bay[a]			
(shore)	12	48	40
Idlewild Point			
(shore)	37	49	6
Echo Bay			
(shore)	17	69	13
Graham Point			
(shore)	14	86	0
Lakeview			
(shore)	7	79	14

[a]Indicates sites that were not included as suitable spawning habitat.

Appendix 4. **Wild and hatchery fry abundance based on late summer trawling, potential egg deposition (PED), and percent survival of wild fry from PED.**

Year sampled	Fry		Previous year PED	PED-wild fry survival	Drawdown after 11/15
	Wild	Hatchery			
1977	1.8	0.04			
1978	1.57	0.22	117.1	1.37	0.40
1979	1.88	0.11	197.7	0.96	0.38
1980	1.6	0.09	119.4	1.34	0.38
1981	1.9	0.41	181.1	1.05	0.32
1982	1.66	1.90	41 .o	4.04	0.14
1983	2.0	0.14	21.7	9.20	0.48
1984	2.1	0.53	34.2	6.14	0.66
1985	1 .o		88.4	1.13	0.31
1986	1.65	0.01	104.1	1.59	0.71
1987	2.75	0.08	59.6	4.61	0.17
1988	3.63	3.68	108.3	3.35	0.27
1989	2.23	2.25	102.3	2.18	0.18
1990	1.79	1.56	107.1	1.67	0.54
1991	0.93	1.05	58.6	1.59	0.44
1992	2.42	2.13	86.3	2.80	0.23
1993	2.97	0.20	145.2	2.05	0.00
1994	5.00	1.62	218.5	2.29	
1995			246.0		

CHAPTER 2. KOKANEE IMPACTS ASSESSMENT AND MONITORING ON DWORSHAK RESERVOIR

ABSTRACT

We used midwater trawling and spawner counts to estimate kokanee abundance in Dworshak Reservoir. Based on trawling, population estimates of age 1 + and 2 + kokanee in 1994 were 984,OOOand 308,000, respectively, making them the highest since trawling began in 1988. We estimated density of age 2 + kokanee at 67 fish/ha. Spawner counts in Isabella, Skull, and Quartz Creek totalled 31,424 kokanee, which was the second highest since 1981. Kokanee abundance was negatively correlated to kokanee size, both in the spawning run and in the trawl catch. Modal size of age 2 + kokanee (235 mm) and spawning kokanee (238 mm) were the smallest yet recorded. The large number of kokanee in 1994 continues a trend indicating total discharge is strongly and negatively correlated to kokanee abundance and survival.

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INTRODUCTION

The Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program [903(e)(4)] authorized the Bonneville Power Administration (BPA) to fund studies to assess the impacts of Dworshak Dam operation on reservoir fisheries. Research began in 1987 and was a cooperative effort between the Idaho Department of Fish and Game (IDFG) and the Nez Perce Tribe of Idaho (NPT). IDFG evaluated kokanee *Oncorhynchus nerka kennerlyi* population dynamics and documented changes in reservoir productivity. The NPT Department of Fisheries Management investigated the status of smallmouth bass *Micropterus dolomieu,* rainbow trout 0. *mykiss* and their fisheries.

Additional data were collected in 1994 to continue to build on this data base and to provide information to the System Operation Review (SOR) being conducted by the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the BPA. By continuing to monitor the kokanee population in Dworshak Reservoir, we compile more evidence on the effects of changing dam operation that will ultimately help determine how to maximize kokanee survival.

STUDY AREA

Dworshak Dam is located on the North Fork of the Clearwater River 3.2 km upstream from its confluence with the mainstem (Figure 1). The dam is about 5.2 km northeast of Orofino in Clearwater County, Idaho. At 219 m high, it is the largest straight-axis concrete dam in the United States. Three turbines within the dam have a total operating capacity of 450 megawatts. Water can be discharged from the reservoir through the turbines, outlet gates, or tainter gates on the spillway.

Dworshak Reservoir is 86.2 km long and has 295 km of mostly steep shoreline. Maximum depth is 194 m with a corresponding volume of 4.28 billion m^3 at full pool. Surface area when full is 6,644 ha and mean depth is 56 m. It contains 5,396 ha of kokanee habitat (defined as area over 15.2 m deep). Mean annual outflow is 162 m^3/s. The reservoir has a mean retention time of 10.2 months. Retention time is variable depending on precipitation and has ranged from 22 months in 1973 to 6 months during 1974 (Falter 1982). Drawdowns of 47 m reduce surface area as much as 52% (3,663 ha). Dworshak Reservoir initially reached full pool on July 3, 1973.

The drawdown regime for Dworshak Reservoir changes annually depending on forecasted snowpack and operating criteria, such as water releases for salmon flows. During the summer of 1994, the pool elevation dropped markedly during July and August as water was released for anadromous fish flows. The reservoir was then held stable throughout the fall and winter.

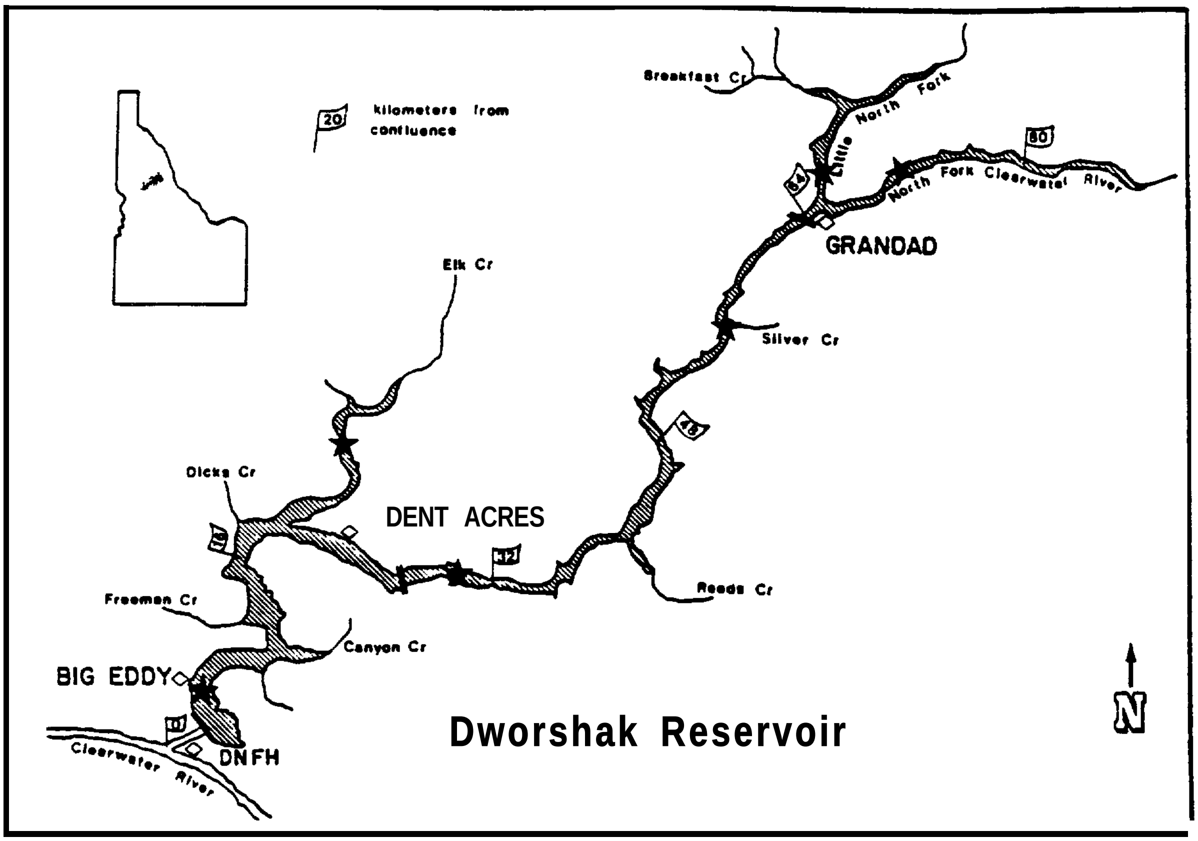

Figure 1. **Dworshak Reservoir and major tributaries, North Fork Clearwater River, Idaho. The reservoir was divided into three sections for sampling: Section 1 (dam to Dent Bridge), Section 2 (Dent Bridge to Grandad Bridge), and Section 3 (Grandad Bridge to end of pool).**

OBJECTIVE

To reduce the entrainment mortality of kokanee so that kokanee densities in the reservoir will increase to 30-50 age 2 + fish/ha, as measured by trawling.

METHODS

Estimatina Kokanee Abundance

Midwater Trawling

As in Lake Pend Oreille, we used oblique tows with a midwater trawl to obtain density estimates of kokanee and representative samples of fish for aging. The procedure is described in the previous chapter and further detailed in Rieman (1992). A stratified random sampling design was used to choose trawl locations. The reservoir was divided into three sections with Dent Bridge and Grandad Bridge serving as boundary lines (Figure 1). In 1994, the mean depth of the kokanee layer while trawling was approximately 20 m, and the forebay elevation of Dworshak Reservoir during the trawling was 478 m mean sea level (msl). Total area of kokanee habitat was, therefore, estimated inside the 457.2m msl (1,500ft) contour. Section 1 was the lower end of the reservoir 12,562 ha of kokanee habitat), section 2 the middle (1,499 ha of kokanee habitat), and section 3 was the upper reservoir (520 ha of kokanee habitat). We made five to seven trawls in each section. Reservoir sections were the same each year but trawl locations were randomized annually. Trawl direction was parallel to the long axis of the reservoir due to spatial limitations. We counted, measured, weighed, and checked fish from each sample for maturity and excised sagitta otoliths or scales from 5-10 individuals from each 10 mm length group for aging.

Trawling in 1994 was conducted from July 5-7, during the new moon. From 1988 to 1991, trawling was conducted at various times throughout the summer in order to determine the period that would most effectively allow capture of mature adults and kokanee fry. Since 1991, trawling has been conducted in July, which is considered to be before most spawning adults migrate up the reservoir, but after kokanee fry have moved into the reservoir and are large enough to be captured. Since 1988, trawling dates were July 1 l-l 3, 1988; June 5-7, 1989; June 27-30 1989; September 25-28, 1989; September 17-20, 1990; and July 8-l 2, 1991; July 27-30, 1992; July 19-22, 1993; and July 5-7, 1994.

Spawner Counts

We made visual counts of kokanee spawners by walking selected tributaries of Dworshak Reservoir to obtain a relative index of kokanee spawner abundance. Spawner surveys have been conducted since 1981 on or around September 25, which is considered the peak of the fall spawning run. In 1994, we conducted spawner surveys on September 26. Streams surveyed included Isabella, Skull, Quartz, and Dog creeks. Surveys ran from the creek mouth upstream to the end of the spawning run or to a migration barrier.

Potential Egg Deposition

We estimated potential egg deposition by first estimating the number of mature age 1 +, 2 +, and 3 + kokanee. We then calculated the mean length of the mature kokanee based on lengths of kokanee sampled by electrofishing tributaries during spawning. With spawner length, we calculated mean fecundity using a length to fecundity regression (Rieman 1992) which was then multiplied by the total number of mature females, based on an assumed 1: 1 male to female ratio.

Factors Affecting Kokanee Abundance

We redefined previously reported relationships between kokanee abundance and operation of Dworshak Dam by adding 1994kokanee population and survival estimates. Mean daily discharge was used as the independent variable with survival and abundance of age 1 + and 2 + kokanee as dependent variables.

To determine if density dependent factors were affecting the population, we plotted stock-recruitment curves based on a three year life cycle (Ricker 1954). Because spawner counts have been conducted since 1981 on three selected tributaries (Isabella, Quartz, and Skull Creeks), and they are a good indicator of the adult population (Maiolie and Elam 1992), they were used for abundance estimates in the model. Other age classes were not used because trawling did not begin until 1988, making only four data points available.

RESULTS

Kokanee Abundance

Abundance Estimates Based on Midwater Trawling

Four age classes of kokanee were captured by the trawl in 1994, consistent with previous years. Abundance of age 1 + and 2 + kokanee, based on trawling in 1994, was the highest since trawling began in 1988 (Table 1). Total estimated populations of the four kokanee age classes were 156,464 age 0, 984,130 age 1 +, 308,743 age 2 +, and 8,576 age 3 +. With the exception of age 2 + and 3 + kokanee, all age classes were distinct based on a length frequency histogram (Figure 2). Age was confirmed by scale and otolith analysis. Dissection of a sample of kokanee from each size group indicated that approximately 33% of the largest age 1 + kokanee (170-l 79 mm) were mature, but overall, less than 0.6% of the age 1 + population was mature. Only half of the smallest age 2 + kokanee (210-219 mm) were mature, but overall, 95% of the age 2 + kokanee were mature, and all age 3 + kokanee were mature. Highest densities of age 1 + and 2 + kokanee were between Dent and Grandad bridges (Section 2), whereas highest densities of age 0 kokanee were above Grandad Bridge (Section 3) (Table 2). Abundance, density, standing stock, and mean size estimates are in Table 3.

Spawner Counts

We counted 14,613 kokanee in Isabella Creek, 12,310 in Skull Creek, 4,501 in Quartz Creek, and 1,878 in Dog Creek in 1994. The total of Isabella, Skull, and Quartz creeks was 3 1,424 spawning kokanee. This total makes the 1994 spawner run, based on these three indicator streams, the second largest since counts began in 1981 (Table 4). Counts in Skull Creek and Quartz Creek were well over twice the previous means of 3,893 and 1,766 spawners, respectively.

Length of spawning kokanee ranged from 117 to 292 mm total length (TL), with a mode of 250-260mm. Mean size of males was 243 mm, and mean size of females was 239 mm. Two percent of the spawning kokanee captured by electrofishing were less than 150 mm. This unusually small group of spawners consisted of three male and seven female kokanee indicating that fish of both sexes had matured at a small size (Figure 3).

Spawner counts continued to be strongly correlated ($r^2 = 0.69$) with adult abundance estimates based on trawling (Figure 4). Following the 1993 spawner counts, the relationship appeared curvelinear; however, the 1994 counts were more consistent with a linear relationship, making the 1993 counts an unusually high outlying data point.

Potential Egg Deposition

Few age 1 + kokanee were mature (about 0.6%), and the total age 1 + contribution to PED was estimated at 828,000. Ninety-five percent of the age 2 + kokanee, and all age 3 + kokanee were considered mature. The high population estimates of these age classes resulted in a PED of 78,166,000, the highest PED since estimates began in 1988. Including the age 1 + contribution, we estimated the total PED for the 1994 spawning run at 78,994,000.

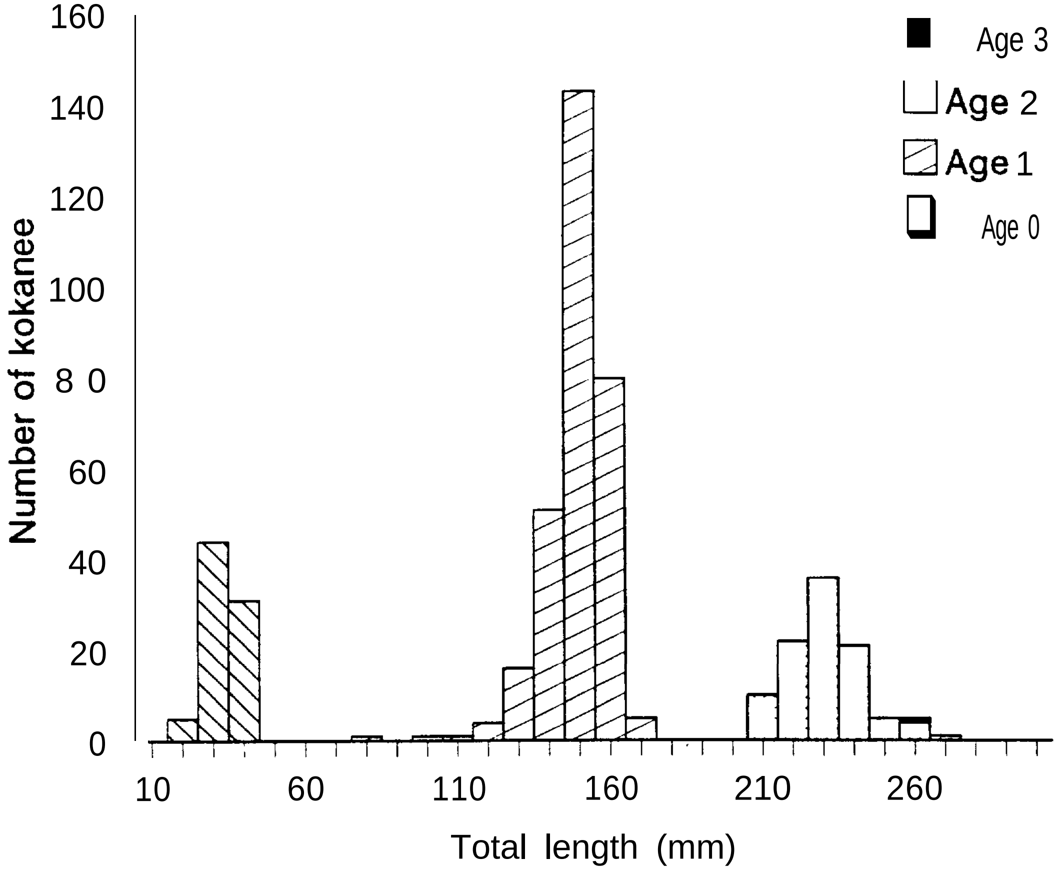

Figure 2. **Length-frequency distribution of kokanee caught by midwatertrawl in Dworshak Reservoir, July 5-7, 1994.**

Table 1. Estimated abundance (thousands) of kokanee made by midwater trawl in Dworshak Reservoir, Idaho, during July 1988-I 994. To follow a particular year class of kokanee, read up one row and right one column.

Sampling year	Age class o +	I+	2+	3+	2+/3+ density (fish/ha)	Total
1994	156	984	308	9	69.2	1,457
1993	453	556	148	6	33.6	1,163
1992	1,043	254	98		21.5	1,043
1991	132	208	19	6	4.6	365
1990"	978	161	11	3	2.6	1,153
1989[b]	148	148	175		32.4	471
1988	553	501	144	12	28.9	1,210

"Sampling in1990 was in September--likely resulting in underestimation of the 2+ and 3+ kokanee.
[b]Sampling in 1989 was conducted in late June.

Table 2. Densities of kokanee (fish/ha) based on trawling in three sections of Dworshak Reservoir in 1994.

	Aae 0	1	2/3
Section 1	4	210	58
Section 2	62	244	92
Section 3	105	149	53

CHPT2TAB

Table 3. Summary of 1994 kokanee population characteristics based on trawling.

	Aae				
	0	1	2	3	Total
Population (thousands)	156	984	308	9	1,457
(+/- 95% CI)	59%	15%	32%		
Density (fish/ha)	34	215	67	2	318
Standing stock (kg/ha)	17	5.8	6.6	0.2	29.6
Mean weight (g)	0.5	27	99	138	
Mean length (mm)	39	155	236	265	
Length range (mm)	28-80	100-l 79	21o-279	260-279	

Table 4. Number of kokanee spawning in selected tributaries to Dworshak Reservoir during September 1981-l 994.

Year	Isabella Creek	Skull Creek	Quartz Creek	Dog Creek	Total (Isabella, Quartz, Skull)
1994	14,613	12,310	4,501	1,878	31,424
1993	29,171	7,574	2,476	6,780	39,221
1992	7,085	4,299	1,808	1,120	13,192
1991	4,053	1,249	693	590	5,996
1990	10,535	3,219	1,702	1,875	15,456
1989	11,830	5,185	2,970	1,720	19,985
1988	10,960	5,780	5,080	1,720	21,820
1987	3,520	1,351	1,477	700	6,348
1986					
1985	10,000	8,000	2,000		20,000
1984	9,000	2,200	1,000		12,200
1983	2,250	135	66		2,451
1982	5,000	4,500	1,076		10,576
1981	4,000	3,220	850		8,070

Total does not include Dog Creek because it was not censused until 1987.

CHPT2TAB

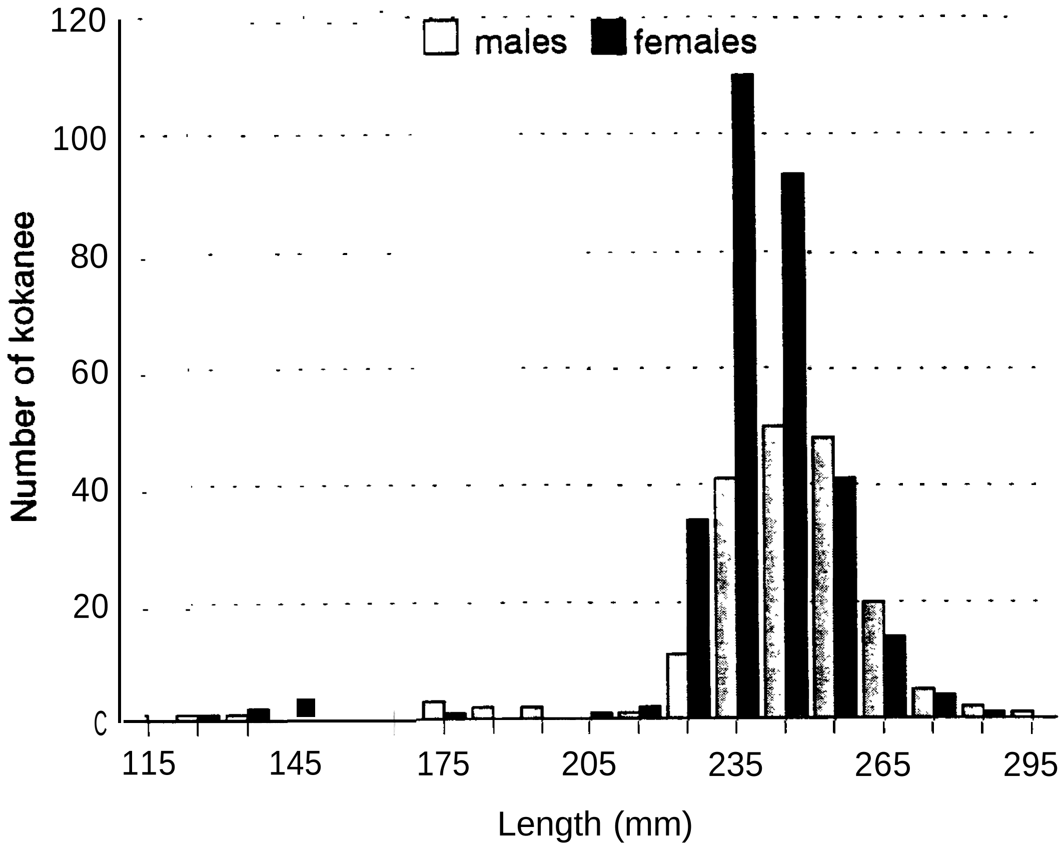

Figure 3. **Length-frequency distribution of spawning kokanee captured in Isabella, Skull, and Quartz creeks from September 21 to October 19, 1994.**

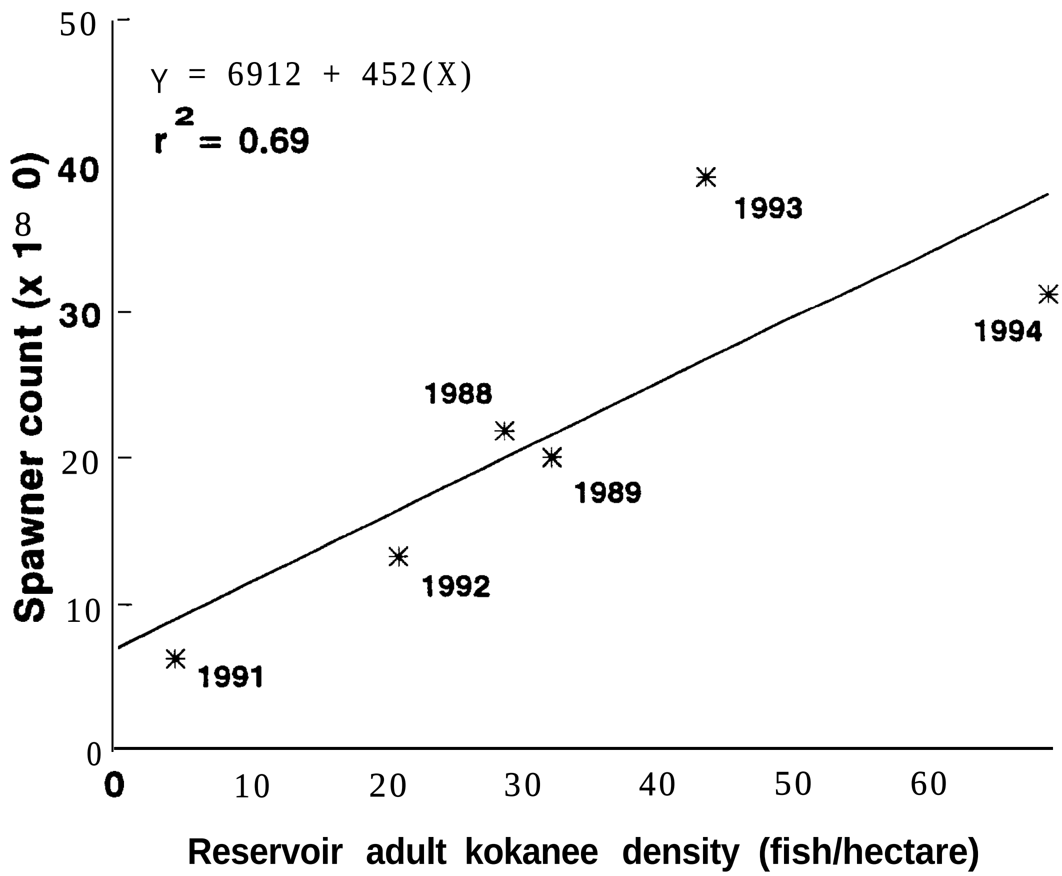

Figure 4. Relationship between the number of kokanee spawners on Isabella, Skull, and Quartz creeks and the number of mature kokanee determined by trawling Dworshak Reservoir, Idaho.

Factors Affecting Kokanee Abundance

Continuing a trend from recent years, abundance of age 1 + and 2 + kokanee were both negatively correlated (r^2 = 0.69 and 0.86, respectively) with mean daily discharge of Dworshak Dam (Figure 5 and 6). Tributary spawner counts were also inversely correlated (r^2 = 0.54) with discharge of Dworshak Dam (Figure 7). All relationships were curvelinear, so that the lower mean daily discharges resulted in exponentially higher kokanee populations.

Estimated age l-2 survival in 1994 was 56%, continuing a trend toward higher survival in recent years (Figure 8). Survival estimates from age l-2 were strongly and negatively correlated with mean daily discharge (r^2 = 0.94). Survival estimates from other year classes are less reliable because of the underestimation of fry and the varying percentage of kokanee maturing at age 2 from year-to-year.

Unlike the Lake Pend Oreille kokanee population, kokanee in Dworshak Reservoir did not exhibit the characteristic rise and fall of recruits with increasing parental stock (Figure 9). The scattered recruit points indicated that less of the variability in the Dworshak kokanee population is determined by the abundance of the parental stock than in the Pend Oreille kokanee population.

DISCUSSION

Kokanee Survival and Abundance

The strong relationship between discharge and kokanee abundance, combined with the poor fit of the Dworshak kokanee population to a stock recruitment model suggests that dam operation is a more important factor in driving the population than the abundance of the parental generation. Abundance of age 1 + and 2 + kokanee, as well as survival rates and the size of the spawning run, all indicate that increasing the total amount of water discharged during a one-year period (July l-June 30) will decrease survival and ultimately kokanee abundance.

The exponential fit of a line in Figures 6 and 7 make the 1994 kokanee abundance appear as expected based on a curvelinear relationship. An alternative explanation is that the data fit a linear regression equation and that 1994 abundance was much higher than expected. For the first time, selector gates of Dworshak Dam were kept in place during the winters of 1992-l 993 and 1993-l 994, and water was withdrawn at shallower depths (1 O-l 5 m) than during previous years. Recent hydroacoustic studies show this depth of withdrawal is above the winter distribution of kokanee and may have reduced entrainment rates. Thus, the use of the selector gates, as well as the drought conditions, could have been responsible for the increase in kokanee abundance.

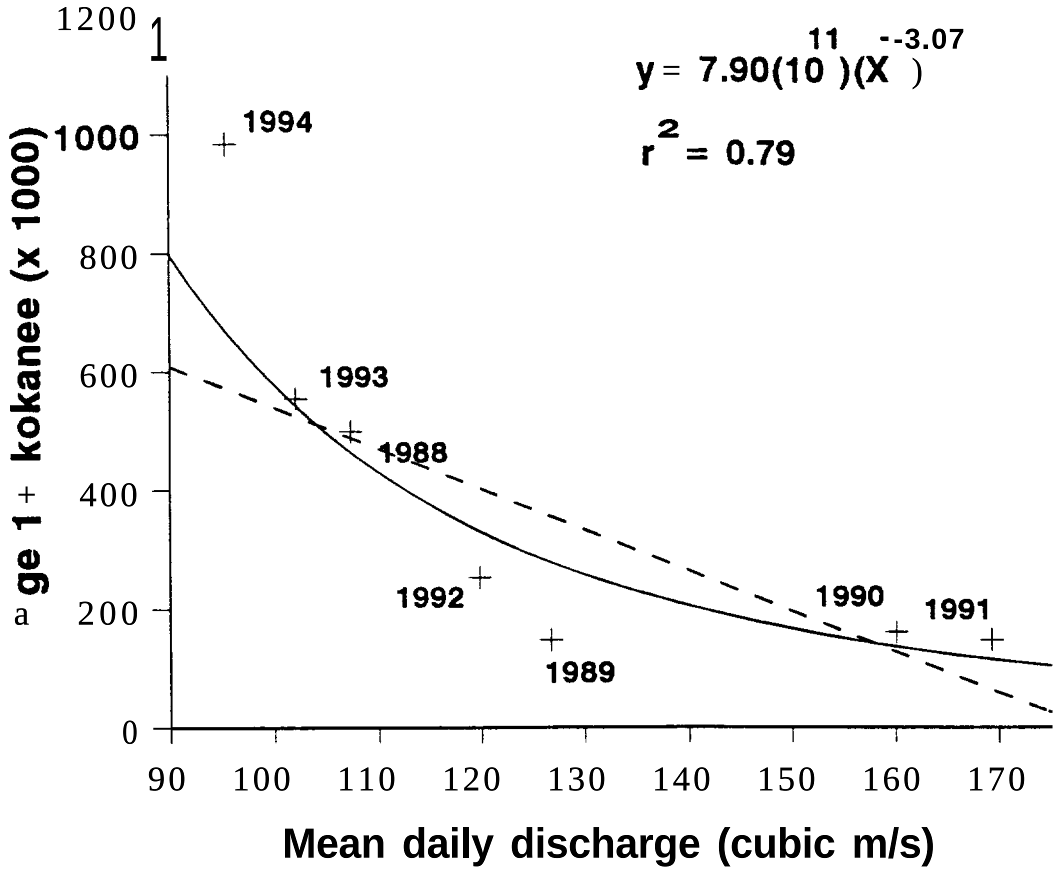

Figure 5. Relationship between amount of water discharged from Dworshak Dam from July 1 to June 30, and the estimated population of age 1 + kokanee based on July trawling. The relationship may be actually be linear (dashed line). A linear relationship shows the age 1 + kokanee population in 1994 was higher than expected and suggests the use of selector gates was effective. Model and r^2 values are for non-linear model.

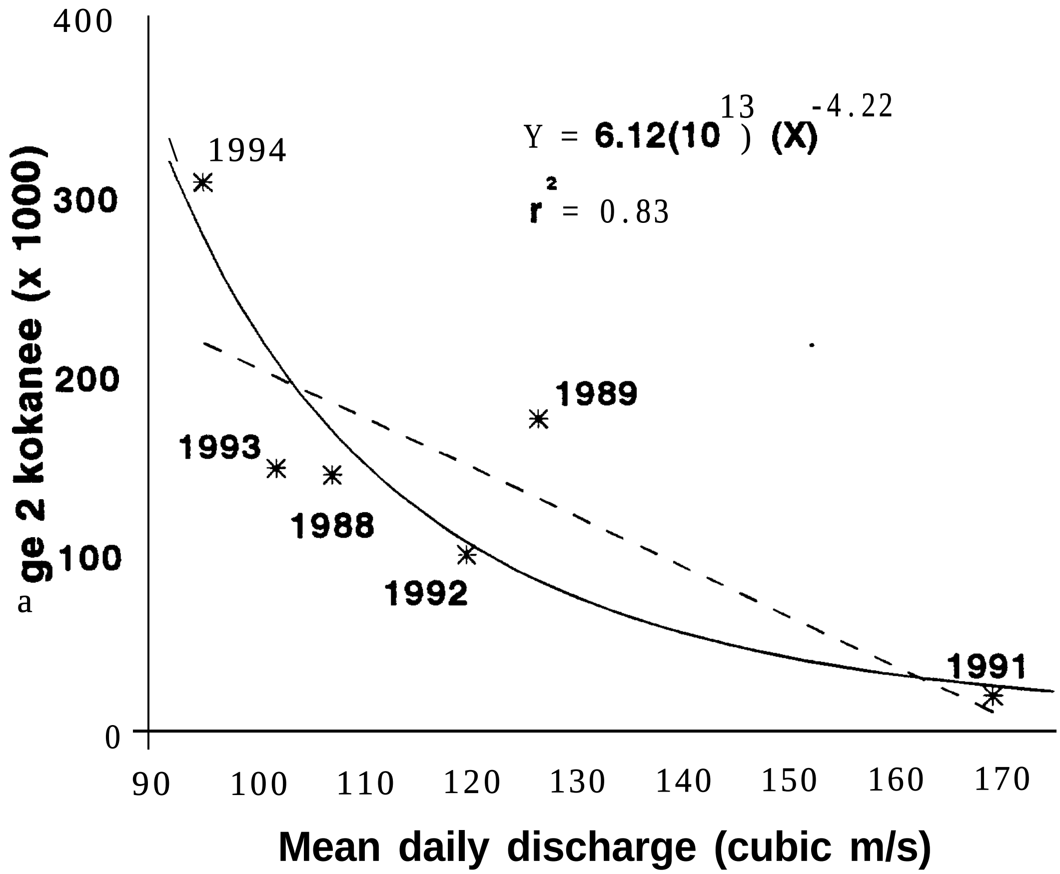

Figure 6. **Relationship between amount of water discharged from Dworshak Dam from July 1 to June 30, and the estimated population of age 2+ kokanee based on July trawling. A linear relationship (dashed line) shows the age 2+ kokanee population in 1994 was higher than expected and suggests the use of selector gates was effective. Model and r^2 values are for non-linear model.**

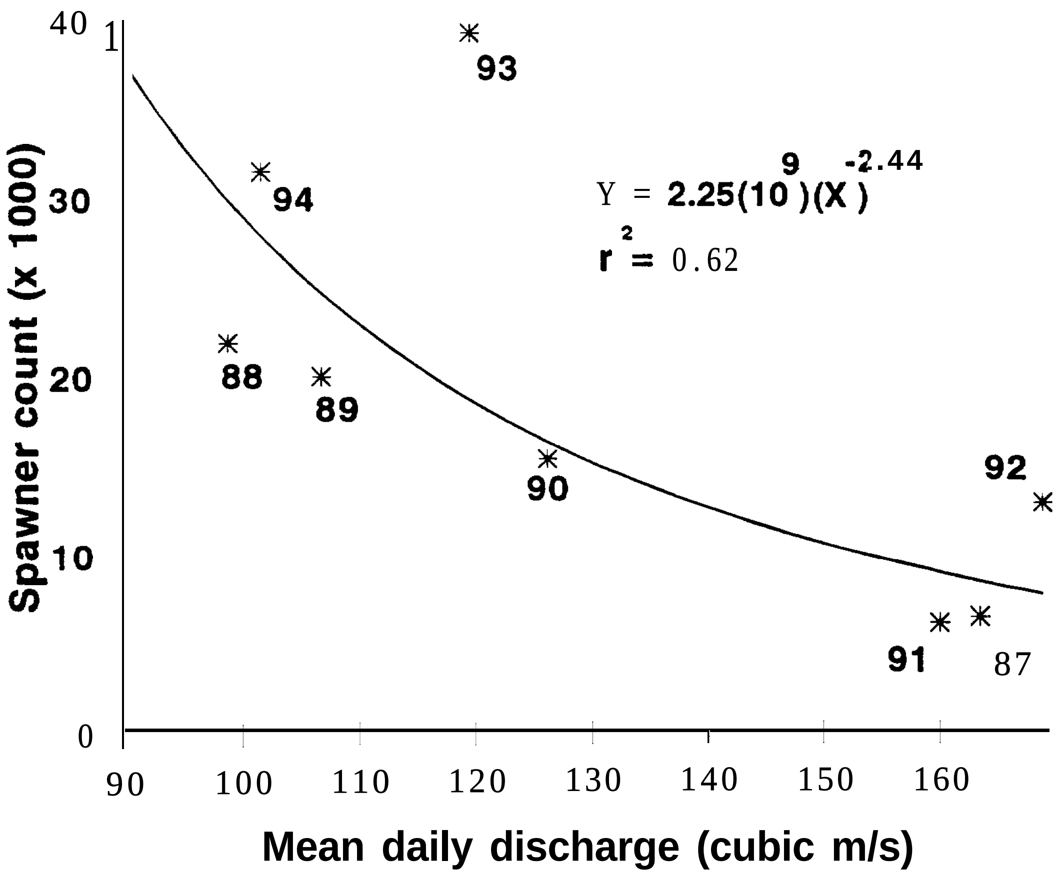

Figure 7. **Relationship between amount of water discharged from Dworshak Dam from July 1 to June 30, and the number of kokanee spawners** the **following year in Isabella, Quartz, and Skull creeks.**

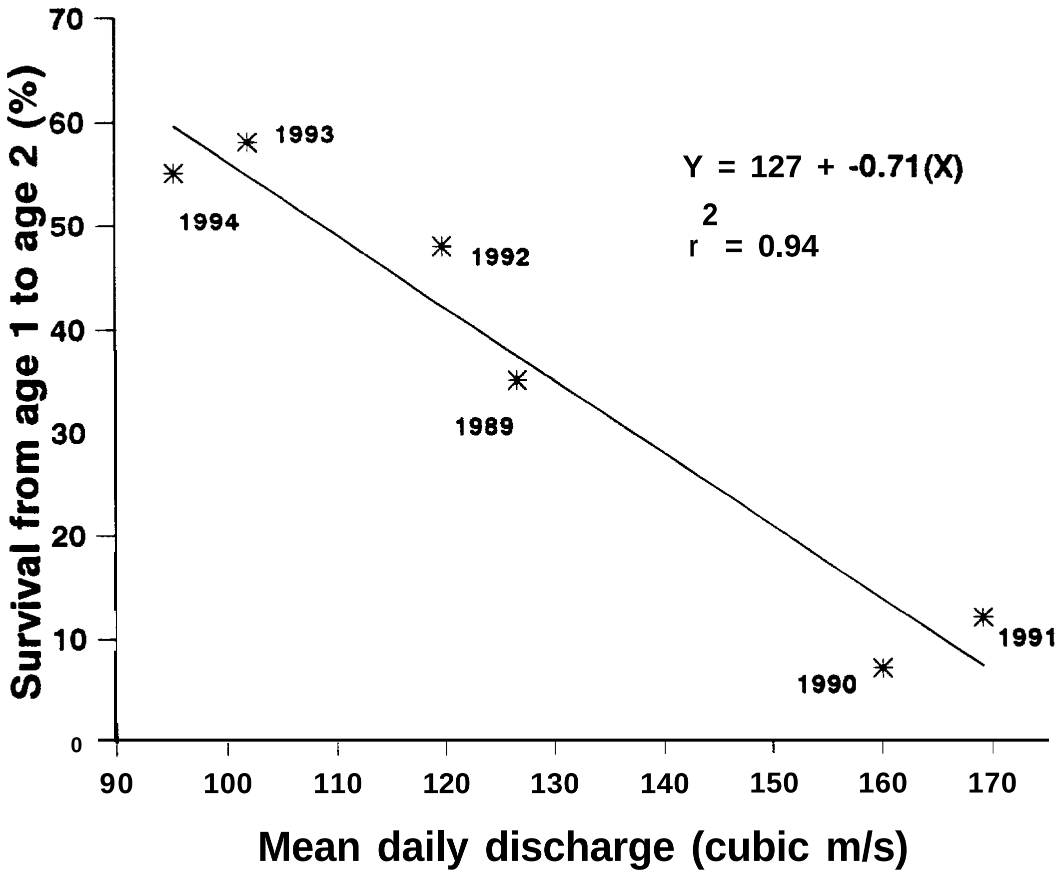

Figure 8. Relationship between amount of water discharged from Dworshak Dam from July 1 to June 30, and the estimated survival from age 1 + to age 2 + kokanee based on July trawling.

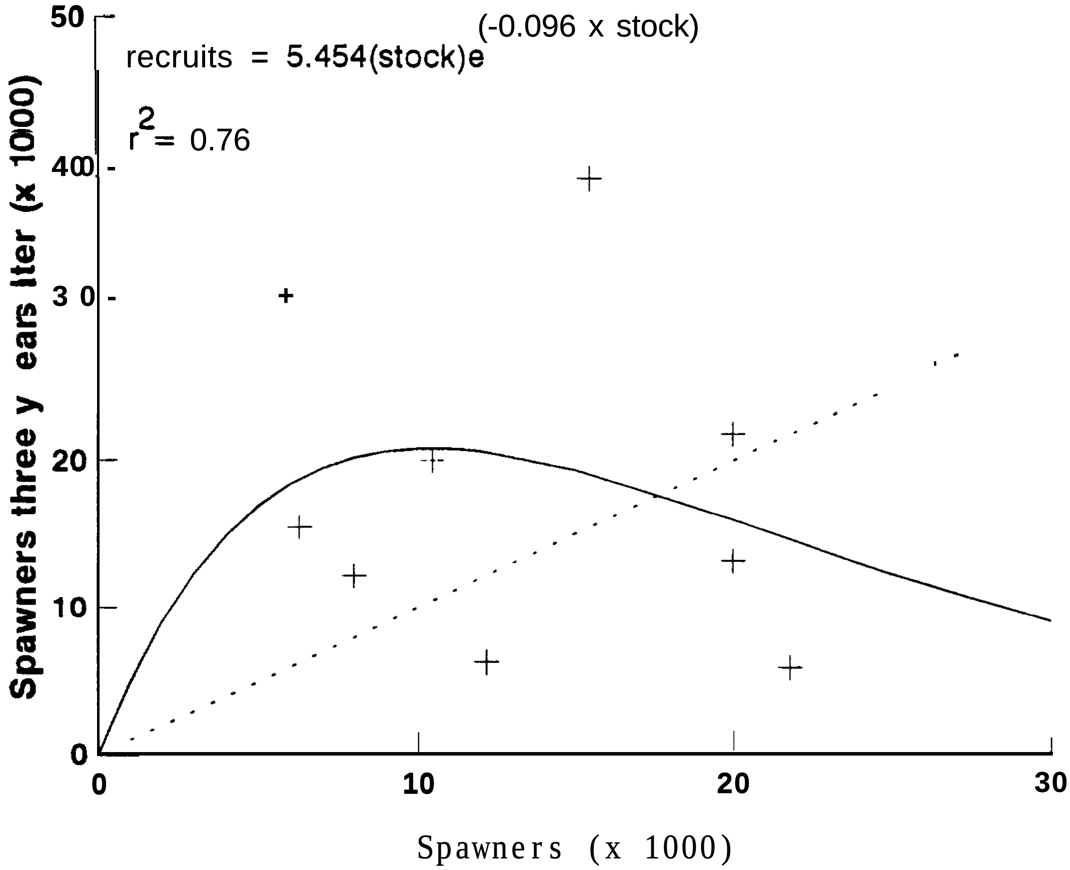

Figure 9. **Abundance of kokanee spawners in Isabella, Quartz, and Skull creeks (recruits) as a function of spawner abundance three years earlier (stock).**

Kokanee Size

Greater densities in 1994 again resulted in smaller size kokanee in both the trawl (Figure 10) and the spawner run (Figure 1 1). This year, kokanee were the smallest modal size since estimates began in 1981. Because the population of age 2 + and 3 + kokanee was the highest recorded, the small size of the spawners was expected; however, the modal size (238 mm) was even below the predicted low of 270 mm. This may be the result of the abundance of age 1 + kokanee in the spawner run, which varies from year to year and may complicate the relationship between size of spawners and number of spawners. For this reason, abundance and length of age 2 + kokanee determined by trawling in July may be a better indicator of the relationship between kokanee density and size than kokanee collected in the spawner run.

The smaller size of kokanee may indicate that density of adult kokanee in 1994 (nearly 70 fish/ha) is higher than desirable. Maiolie et al. (1993) recommended managing the Dworshak Reservoir stock for densities of 30 to 40 adults/ha, and Rieman and Meyers (1990) reported little benefit in yield in fisheries where kokanee densities exceeded 40 to 50 adults/ha. This was the first year we've seen kokanee density undesirably high. We expect densities will decline after the current drought cycle. If entrainment losses of kokanee could be reduced during normal and high precipitation years, then the addition of predators could utilize excess kokanee production and provide an additional fishery. This is not currently recommended.

RECOMMENDATIONS

1. We recommend the Corps of Engineers continue to use selector gates during winter to minimize kokanee entrainment losses. Testing the use of the gates in a normal water year through continued kokanee population monitoring will greatly benefit our understanding of kokanee losses.

2. We recommend a creel survey be conducted to 1) assess angler satisfaction regarding the large numbers of smaller kokanee, 2) estimate annual kokanee harvest, and 3) determine the success of the Gerrard rainbow trout 0. mykiss introductions.

3. We recommend future sampling efforts be conducted to compare between hydroacoustic and midwater trawl estimates of kokanee density.

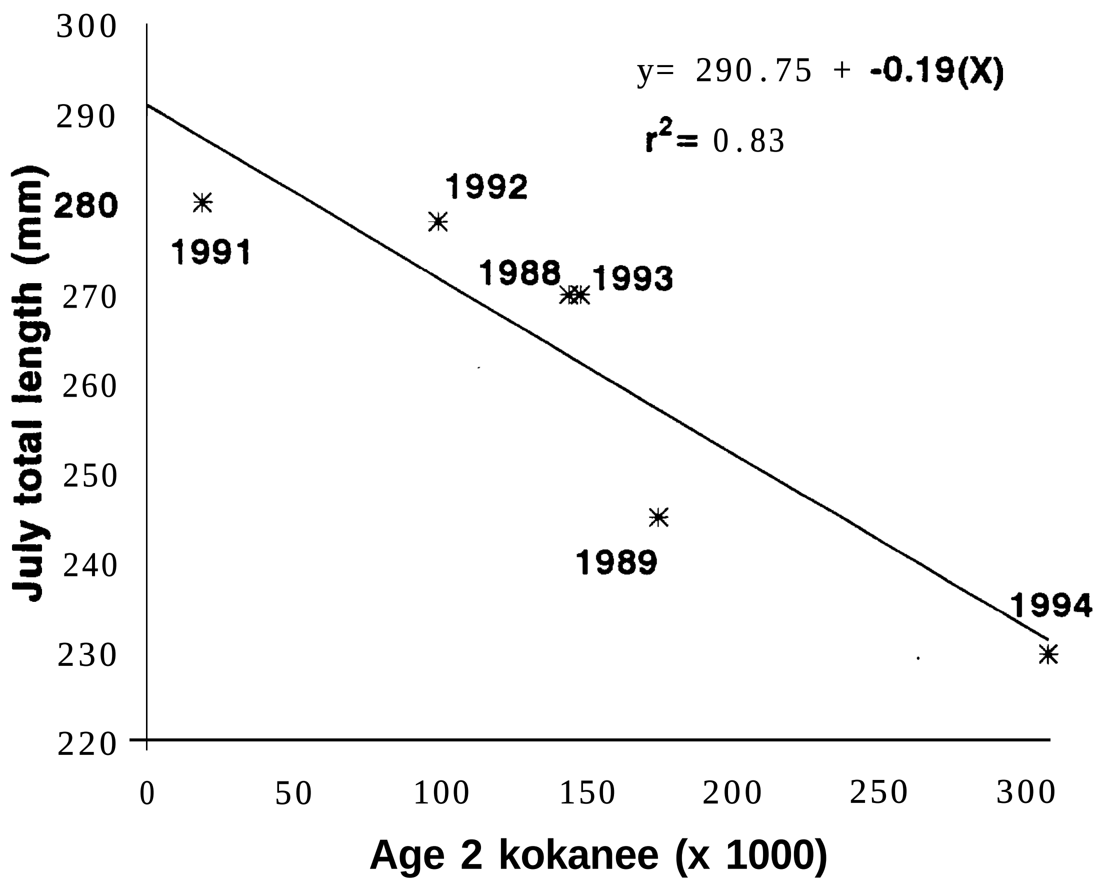

Figure 10. **Abundance of age 2 + and 3 + kokanee and their modal length estimated from the July trawling effort.**

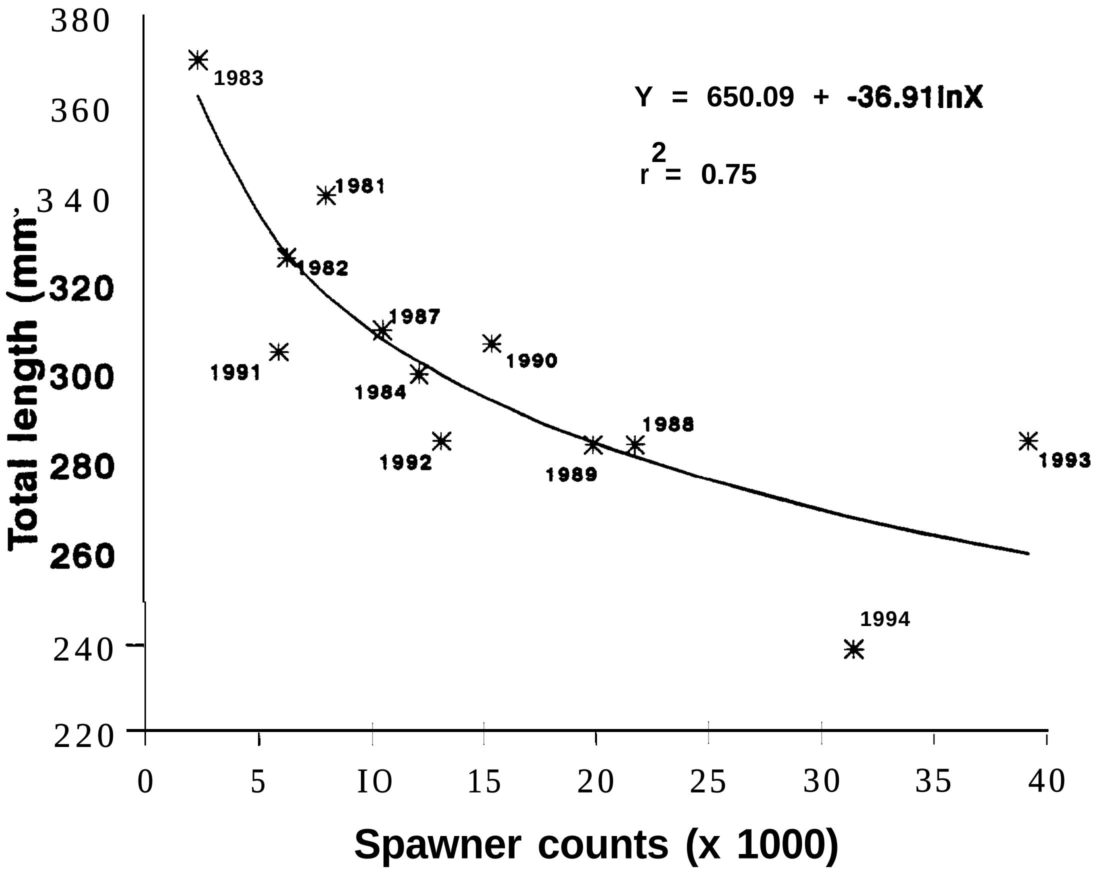

Figure 1 1. **The number of spawning kokanee in Isabella, Quartz, and Skull creeks since 1981 and their modal length.**

ACKNOWLEDGEMENTS

Kokanee monitoring in Dworshak Reservoir in 1994 was the result of contributions by many people. Ric Downing and Steve Dove assisted with the midwater trawling. Howard Holmes, Steve Dove, Pete Russell, and Charlie Anderson helped count kokanee spawners in Dworshak Reservoir tributaries. Ralph Roseburg of the U.S. Fish and Wildlife Service collected spawner lengths.

LITERATURE CITED

Falter, C.M. 1982. Limnology of Dworshak Reservoir in a low flow year. U.S. Army Corps of Engineers. Walla Walla, Washington.

Maiolie, M.A., D.P. Statler, and S. Elam. 1993. Dworshak Dam impact assessment and fishery investigation and trout, bass, and forage species. Combined Project Completion Report. U.S. Department of Energy, Bonneville Power Administration, Project Nos. 87-99 and 87-407. Portland, Oregon.

Maiolie, M.A., and S. Elam. 1993. Dworshak Dam impacts assessment and fisheries investigation. U.S. Department of Energy, Bonneville Power Administration, Project No. 87-99. Portland, Oregon.

Rieman, B.E. 1992. Kokanee salmon population dynamics-kokanee salmon monitoring guidelines. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-14, Subproject II, Study II, Boise.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, No. 119.

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