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REGIONAL FISHERIES MANAGEMENT INVESTIGATIONS

Job No. 1-b[1]. Region 1 Coeur d'Alene Lake Investigations

By

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TABLE OF CONTENTS

Page

ABSTRACT 1

INTRODUCTION 2

OBJECTIVES 2

DESCRIPTION OF STUDY AREA 3

METHODS 3

Kokanee 3
Trawling 3
Trawl Evaluations 5
Length at Spawning 7
Fecundity 7
Population Modeling 7
Chinook 7
Stocking 7
Spawning 8
Wolf Lodge Creek 8
Coeur d'Alene River 8
Ageing 8
Natural Chinook Salmon Abundance 11
Redd Counts 11
Creel Survey 11

RESULTS 12

Kokanee 12
Trawling 12
Population Estimates 12
Density 12
Maturity 12
Age 12
Length at Spawning 12
Fecundity 15
Population Modeling 15
Trawl Evaluation 15
Chinook 15
Stocking 15
Spawning 19
Wolf Lodge Creek 19
Coeur d'Alene River 19
Age and Growth 19
Natural Chinook Salmon Abundance 19
Redd Counts 27
Creel Survey 27

DISCUSSION 27

Kokanee 27
Abundance 27
Survival 33

Page

Length at Spawning 37
Length at Age 37
Fecundity 37
Chinook 41
Stocking 41
Spawning 41
Natural Reproduction 45
Wolf Lodge Creek 45
Coeur d'Alene River 45
St. Joe River 47
Natural Chinook Abundance 47
Chinook Salmon Fishery 47

RECOMMENDATIONS 48

LITERATURE CITED 49

APPENDICES 50

LIST OF TABLES

Table 1. Kokanee population estimates (in millions) and 90% confidence intervals for each age class in each section of Coeur d'Alene Lake, Idaho, on August 14 to 16, 1990 16

Table 2. Kokanee density (fish/ha) estimates for each age class in each section of Coeur d'Alene Lake, Idaho on August 14 to 16, 1990 16

Table 3. Estimates of kokanee available for chinook consumption (yield), amount of kokanee that 1,000 stocked chinook would consume, and maximum chinook stocking level that a year class of kokanee could support for Coeur d'Alene Lake, Idaho 16

Table 4. Number, kilograms, and lengths of fall chinook salmon released into Coeur d'Alene Lake, Idaho, 1982-1990 . . . 18

Table 5. Summary of fall chinook salmon spawntaking operations in Wolf Lodge Creek, Coeur d'Alene Lake, Idaho, 1984-1990 20

Table 6. Composition of the spawning run of fall chinook salmon in Wolf Lodge Creek, Coeur d'Alene Lake, Idaho, 1984-1990 21

Table 7. Mean lengths of aged fall chinook salmon, Coeur d'Alene Lake, Idaho, 1990 25

Page

Table 8. Number of hatchery and naturally produced chinook salmon in the Wolf Lodge Creek spawning run, tributary to Coeur d'Alene Lake, Idaho. Year class denotes the year eggs were laid. Estimate of age 0 natural chinook was derived by the proportion of hatchery to natural fish . . 25

Table 9. Fall chinook salmon redd counts, Coeur d'Alene Lake drainage, Idaho, September 29, 1989 and November 10, 1990 28

Table 10. List of Coeur d'Alene Lake, Idaho, tributaries surveyed October 31 to November 1, 1990 for chinook redds . 30

Table 11. Summary of creel information relating to fall chinook salmon on Coeur d'Alene Lake, Idaho, 1984-1990 31

Table 12. Number and percentage of hatchery (fin-clipped) and natural fall chinook salmon caught during the 1990 "Big One Derby" on Coeur d'Alene Lake, Idaho, that were weighed-in or checked during angler interviews 31

Table 13. Estimates of kokanee year classes (1975-1989) made by midwater trawl in Coeur d'Alene Lake, Idaho, 1979-1990. Estimates are in millions of kokanee 32

Table 14. Estimates of female kokanee spawning escapement, potential egg deposition, fall abundance of wild kokanee fry, and their subsequent survival rates in Coeur d'Alene Lake, Idaho, 1978 to 1990 40

Table 15. Number of fall chinook salmon eggs taken from natural and hatchery fall chinook salmon and sent to Mackay Hatchery 44

Table 16. Summary of spawning run of fall chinook salmon in Wolf Lodge Creek, Coeur d'Alene Lake, Idaho, 1988-1990 . . . 44

Table 17. Percent of each marked group of fall chinook salmon stocked into Coeur d'Alene Lake, Idaho that returned to Wolf Lodge Creek trap, 1987-1990. (The number of adults from the 1984 year class that returned in 1987 is a combined total for both fin clips based on the percent of age 2 fish that returned.) 46

LIST OF FIGURES

Figure 1. Map of Coeur d'Alene Lake, Idaho 4

Figure 2. Location of 17 trawling stations on Coeur d'Alene Lake, Idaho, and the 3 sections used in stratified sampling . 6

LIST OF FIGURES (Cont.)

Page

Figure 3. Map of Wolf Lodge Bay and Wolf Creek, Coeur d'Alene Lake, Idaho, showing present and former fall chinook weir locations 9

Figure 4. Fall chinook salmon redd counting sections, locations of groups of redds, and location of the weir in Coeur d'Alene River, Idaho, 1990 10

Figure 5. Percent maturity of various size classes of kokanee sampled from Coeur d'Alene Lake, Idaho, 1990 13

Figure 6. Lengths of kokanee age classes in Coeur d'Alene Lake, Idaho, August 14, 15, and 16, 1990 14

Figure 7. Kokanee density estimates made by four trawlers which sampled the northern end of Coeur d'Alene Lake, July 25-26, 1990. Bar on north Idaho trawler estimate denotes 95* confidence limits 17

Figure 8. Number and date of spawning fall chinook salmon in Wolf Lodge Creek, Coeur d'Alene Lake, Idaho, 1990 22

Figure 9. Age-length relationship of fall chinook salmon in Coeur d'Alene Lake, Idaho, 1990. (Points [+] represent the mean length of approximately 25 fish 23

Figure 10. Age-weight relationship of fall chinook salmon in Coeur d'Alene Lake, Idaho, 1990. (r = .98) (Points [*] represent the mean weight of approximately 25 chinook 24

Figure 11. Numbers of chinook salmon stocked from hatcheries and produced naturally in tributaries to Coeur d'Alene Lake, Idaho (top). Trend of age 0 natural chinook abundance in Coeur d'Alene Lake, Idaho (bottom). Data for natural chinook salmon in 1989 and 1990 not yet available 26

Figure 12. Map of the St. Joe River fall chinook salmon redd count sections and locations of groups of redds, 1990 29

Figure 13. Relationship between the number of fall chinook salmon stocked two years previous (and wild production) and the

Figure 15. Relative survival between different age classes of kokanee in Coeur d'Alene Lake, Idaho, 1980 to 1990 36

CONTENTS

LIST OF FIGURES (Cont.)

Page

Figure 16. Lengths of spawning kokanee in Coeur d'Alene Lake, Idaho, 1954 to 1990 38

Figure 17. Lengths of kokanee of different age classes in Coeur d'Alene Lake, Idaho, corrected to September 39

Figure 18. Timing of natural and hatchery fall chinook salmon spawning runs entering Wolf Lodge Creek trap, Coeur d'Alene Lake, Idaho, 1988 to 1990 42

LIST OF APPENDICES

Appendix A. Kokanee catch by age class for each of the 17 trawls in Coeur d'Alene Lake, Idaho, August 14, 15, and 16, **1990** 51

Appendix B. Total length of kokanee in Coeur d'Alene Lake, Idaho, 1978 to 1990. Lengths were corrected to estimated length in September of each year (Rieman 1990) 52

Appendix C. Description of chinook weir and trap on Wolf Lodge Creek and Coeur d'Alene River 53

ABSTRACT

From 10,500 to 60,100 fall chinook salmon Oncorhynchus tshawytscha have been stocked annually into Coeur d'Alene Lake, Idaho, since 1982. In addition, chinook salmon straying into the lake's tributaries have spawned an estimated 13,500 to 43,800 additional fingerlings. This level of chinook salmon abundance has caused several changes in the kokanee population, their main forage. Survival of age 0 to age 1 kokanee O. perka kennerlyi has dropped from 90% to 20%, and survival of age 2 to age 3 kokanee has dropped from 60% to 30%. Abundance of age 1 kokanee correlated quite closely (r=0.94) and negatively with the amount of chinook stocking. When an estimated 90,000 chinook entered the lake, age 1 kokanee abundance dropped 75%.

To date, the abundance of age 3 kokanee, however, remained largely unchanged due to increased number of eggs deposited, improved fry survival, and improved age 1 to age 2 survival. This indicated a considerable capacity of the population to compensate for losses due to predation. In recent years, the expansion of naturally spawning chinook appears to have exceeded the kokanee's compensatory ability.

The Lake Michigan stock and the Bonneville stock of chinook salmon were found to have different migration times and different ages at maturity. The 1985 year class of Bonneville stock matured at 36% age 2 and 64% age 3 instead of the expected 6% age 1, 58% age 2, and 35% age 3. The Lake Michigan stock matured at 51% and 49% age 2 and 3, respectively, instead of 35% age 2, 55% age 3, and some age 4 as expected from parental stock.

Long-term management goals for the chinook salmon/kokanee program in Coeur d'Alene Lake will require some degree of control of natural chinook salmon production. The public perceived "wild salmon" as something special and has attempted to exert their perceptions through encouraging natural production.

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INTRODUCTION

Coeur d'Alene Lake is located in north Idaho adjacent to the town of Coeur d'Alene and only 50 km from the major population center of Spokane, Washington. It **is**, therefore, an urban fishery and has the potential for a large amount of use. It currently supports approximately 200,000 angler hours, or 20 hours per hectare.

Historically, the two sport fish in the lake were westslope cutthroat trout Oncorhynchus clarki lewisi and bull trout Salvelinus confluentus. Kokanee O. nerka kennerlyi were stocked into Coeur d'Alene Lake from 1937 to 1974 and caused the development of an extremely popular fishery. Harvest of kokanee was as high as half **a** million fish annually (Mauser and Horner 1982), with catch rates in the handline fishery up to 3 fish/h. During the 1970s, the population became self-sustaining, largely due to enhanced spawning success on road fills in Wolf Lodge Bay. Size of kokanee declined to only 24 cm at maturity because of the increased kokanee abundance.

Managers introduced fall chinook salmon O. tshawytscha (a large piscivor) to reduce the kokanee population and promote better growth. A very dedicated trophy fishery developed for chinook salmon which reached 19 kg. The program was considered quite successful since anglers had the opportunity for trophy or harvest fisheries.

Continued intensive management of the lake is necessary to maintain the predator-prey balance. Current goals for the program include providing a consistent chinook fishery with the opportunity to catch large fish. Kokanee goals include improving kokanee size in the fishery to 25 cm, and most importantly, maintaining an abundant kokanee population that can perpetuate itself even with fluctuations in kokanee and chinook salmon year class strength.

OBJECTIVES

1. To determine kokanee stock status in Coeur d'Alene Lake.

2. To evaluate changes in the kokanee population caused by stocking chinook.

3. To make predictions about future kokanee fisheries based on year class strengths and potential egg deposition.

4. To evaluate our trawling gear and determine if representative samples were being collected.

5. To evaluate the chinook salmon stocking program based on mathematical models of their consumption rates.

6. To determine the status of the natural chinook salmon population in Coeur d'Alene Lake.

7. To determine the status of the chinook salmon run in the Coeur d'Alene River and its implications to management.

8. To investigate methods to control chinook salmon abundance should that become necessary.

DESCRIPTION OF STUDY AREA

Coeur d'Alene Lake is Idaho's third largest natural lake (Figure 1). It is located in the Spokane River drainage, which ranges in elevation from 648 m (lake level) to 2,086 m. Most of the drainage is covered by coniferous forest. This area receives some of the largest quantities of precipitation in Idaho, averaging over 76 cm per year, and 70% is snow. Winter temperatures are often below freezing, but Coeur d'Alene Lake's surface does not normally freeze completely.

The lake has a surface area of 12,950 ha and has a volume of 2.75 billion m^3. The mean and maximum depths are 21.2 m and 61 m, respectively. The major tributaries are the Coeur d'Alene and St. Joe rivers; there are many minor tributaries as well. Coeur d'Alene Lake is the source of the Spokane River which drains into the Columbia River. Flows are regulated at the Post Falls Dam for hydroelectric power production.

Land use activities within the Spokane River drainage include recreation, logging, agriculture, mining, and ore processing. Coeur d'Alene Lake has become a prime recreational and summer home site. Over 80% of the 1,950 km of shoreline has been developed.

Rapid residential and commercial development of the shoreline and increasing recreational use of Coeur d'Alene Lake have created considerable potential for nutrient enrichment of the lake. Coeur d'Alene Lake has been classified as mesotrophic based on nutrient content (Anonymous 1977).

A major water quality problem in Coeur d'Alene Lake is the amount of heavy metals, including cadmium, lead, zinc, copper, and arsenic, that have been introduced into the lake from over 100 years of mining and ore processing in the basin. Over 104 billion kg of contaminated tailings have been produced within the South Fork Coeur d'Alene River drainage; 65 billion kg were discharged directly into the river. The delta that has formed at the mouth of the Coeur d'Alene River has the same amount of contamination as the tailings in the South Fork. Lake sediments had levels of the heavy metals, arsenic, copper, lead, and zinc in excess of the upper 95% confidence limit for sediments nationwide (Woods 1989).

Native game fish in Coeur d'Alene Lake and lake system include westslope cutthroat trout bull trout, and mountain whitefish Prosopium williamsoni. Introduced species include kokanee, chinook salmon, rainbow trout O. mykiss, brook trout Salvelinus fontinalis, largemouth bass Micropterus salmoides, smallmouth bass Micropterus dolomieu, black crappie Pomoxis nigromaculatus, pumpkinseed Lepomis gibbosus, yellow perch Perca flavescens, brown bullhead Ameiurus nebulosus, black bullhead A. melas, and northern pike Esox lucius.

METHODS

Kokanee

Trawling

Midwater trawling was used to obtain density estimates of kokanee and representative samples of fish. An 8.5-m, 140-horsepower diesel engine boat towed the midwater trawl net. This net was 13.7 m long with a 3 m by 3 m mouth. Mesh sizes (stretch measure) graduated from 32 mm to 25 mm to 19 mm to 13 mm in

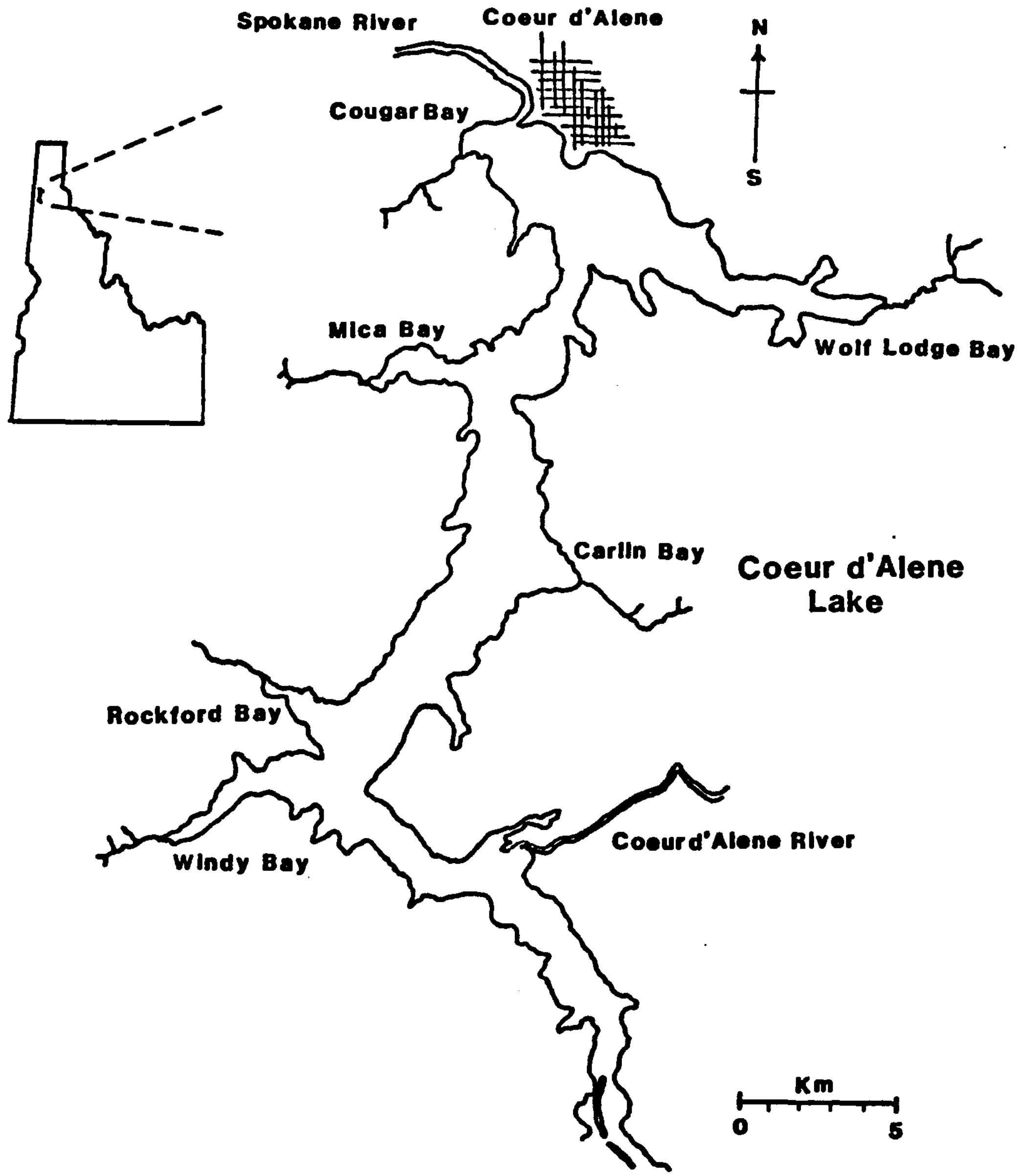

Figure 1. Map of Coeur d'Alene Lake, Idaho.

the body of the net and terminated in a 6 mm mesh cod end. The net was pulled at 1.5 m/s.

All trawling was conducted after dark during the new moon phase to optimize capture efficiency (Bowler et al. 1979). During 1990, the trawling dates were August 14, 15, and 16. The layer of kokanee distribution was delineated using a Ross 200 depth sounder with two hull-mounted transducers (22° and 8° beam angles). The vertical distribution of kokanee was divided into 3.5 m sublayers; usually 3 to 5 sublayers encompassed the vertical distribution. A step-wise oblique net tow was made through the kokanee layer. Net was pulled for 3.5 min in each sublayer, sampling 2,832 m^3 of water over a distance of 315 m. A total of 8,496 to 14,160 m^3 of water was sampled during each haul depending on the width of the kokanee distribution.

A stratified random sampling scheme was used in sampling kokanee. Coeur d'Alene Lake was divided into three sections. Five trawl locations were chosen in the northern section of the lake, seven in the middle section, and five in the southern section (Figure 2). The same trawling locations were used annually, and trawling methodology was standardized from 1979 to 1990 to make comparisons between years possible.

The number of kokanee of a specific age class collected in each haul was divided by the volume of water sampled to obtain age specific density estimates. These densities were then multiplied by the thickness of the kokanee layer (in m) at the trawling site and then multiplied by 10,000 to obtain the number of kokanee per hectare at that site. Mean densities in each section were multiplied by the area of the section to obtain population estimates and summed to make whole-lake population estimates. Parametric statistics were then applied to the density estimates to calculate 90% confidence limit.

Kokanee scales were removed from trawl-caught fish and impressed in clear plastic laminate sheeting using a Carver Model C laboratory press. We exerted 364 kg/cm' for approximately 10 s in making the impressions. Plastic impressions were then read on an Eberback scale reader.

Trawl Evaluations

Kokanee population estimates in Coeur d'Alene Lake were used as a relative population index (comparing our trawl catch in one year to our catch in another), but also as an absolute population estimate (comparing the kokanee population in Coeur d'Alene Lake to other lakes). We attempted to validate our absolute density estimates by comparing our sampling methodology with that of other types of sampling gear during the summer of 1990.

Four trawling boats were used; all sampled the same section of the lake, staying as close together as feasible. Sampling depths were standardized for all boats. Fishing was done during the new moon phase on the nights of July 23-24, 24-25, and 25-26.

Our boat (the north Idaho trawler) sampled kokanee as previously discussed. The Dworshak trawler had the same size and mesh net as ours and trawled at the same speed (1.5 m/s). It, however, used four 4.6 kg weights as depressors on the net mouth whereas the North Idaho trawler used a weighted and inverted hydrofoil. The portable trawler, again, used the same size net but it trawled at a speed of 0.98 m/s. Lastly, the Canadian trawler used a 5.2 m by 5 m net with a single tow cable, operating at a speed of 0.9 m/s.

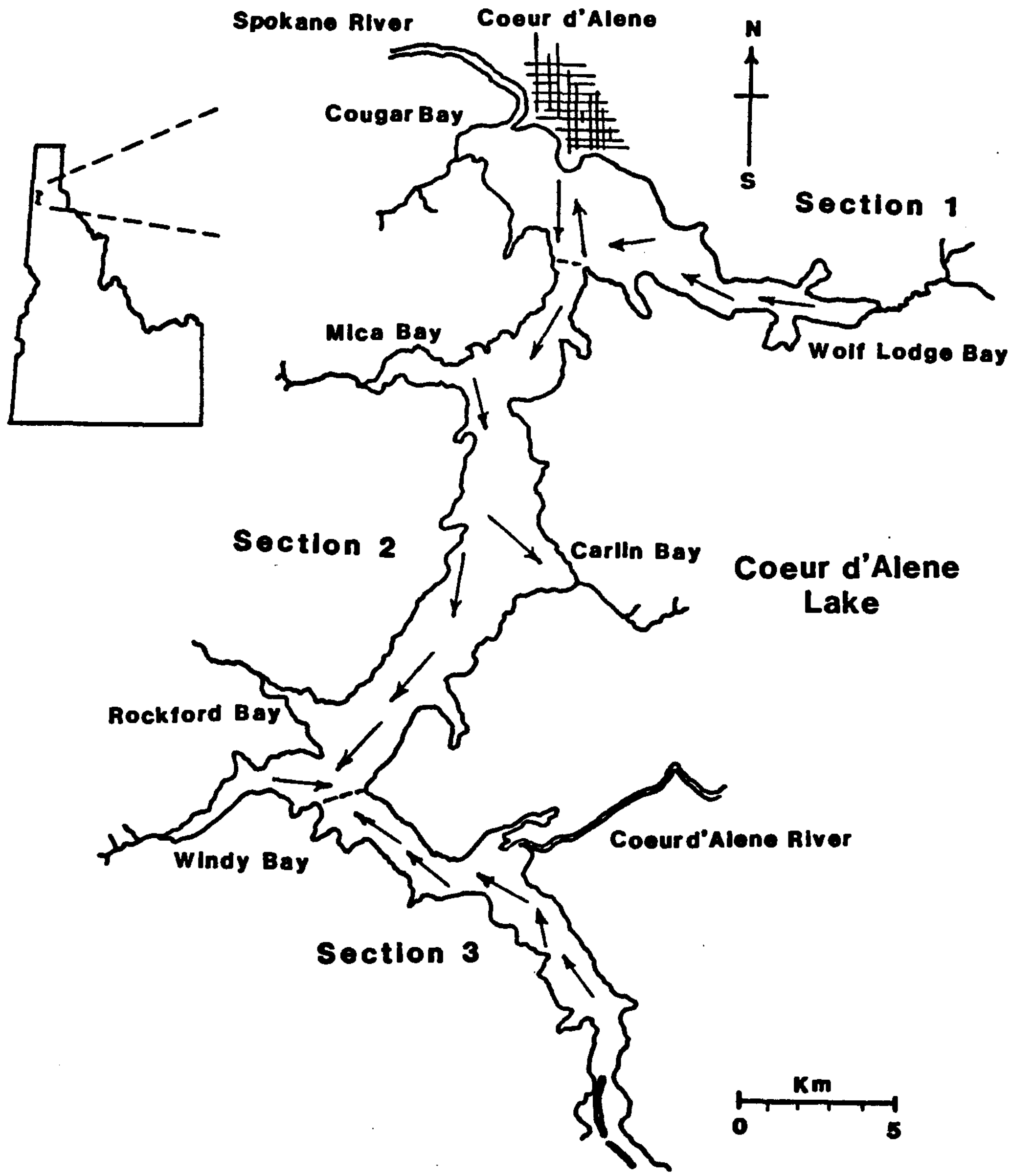

Figure 2. Location of 17 trawling stations on Coeur d'Alene Lake, Idaho, and the 3 sections used in stratified sampling.

Length at Spawning

Total length of kokanee spawners was measured most years since 1953 from fish collected by a variety of methods. In recent years, kokanee were collected in Lake Merwin trap nets during the beginning, middle, and end of the spawning run (November 20, December 4, and December 13, 1990). Total length of 142 fish were measured in 1990.

Fecundity

Number of eggs produced by a known number of females was recorded during the spawntaking operation. In addition, the number of eggs left in the body cavity after spawning was enumerated. Potential egg deposition was then calculated by dividing the number of eggs taken in the spawning operation by the number of females that were spawned, adding the mean number of eggs left in the body cavity, and multiplying by the population estimate of mature female kokanee.

Eggs/female was also calculated by the formula $y = -947+5.26x$, where x = kokanee length in mm, and y = total eggs produced by a female ($r^2 = 0.84$)(B. Rieman, personal communication, IDFG Eagle Fish Lab).

Population Modeling

We used the Bioenergetics Model of Fish Growth from the University of Wisconsin Sea Grant Institute (Hewett and Johnson 1987) to gain a better understanding of chinook predation on kokanee. The monthly temperature regime of Coeur d'Alene Lake was added to the model, as was the present growth rate curve for Coeur d'Alene chinook. For the model, we assumed chinook fed only on kokanee and that the caloric content of kokanee was equal to that of sockeye salmon O. nerka. Data for chinook respiration and excretion were provided by the model.

A kokanee yield model was then used to interpret what effects chinook consumption would have on the kokanee population (B. Rieman, personal communication, IDFG Eagle Fish Lab). Kokanee growth (in grams), kokanee mortality, and conversion efficiency of chinook were added to this model. Total kokanee mortality was set so that the kokanee population would be in equilibrium (just replace itself from one generation to the next). Kokanee mortality, attributed to predation, was partitioned among the various year classes to maximize the yield of kokanee to chinook. Egg to fall fry survival was set at 4%, which was consistent with survival rates for large lakes in north Idaho. Other forms of natural mortality and fishing mortality were reduced to zero. (Under these assumptions the model's output represented a maximum weight of kokanee that could be available for chinook to feed on without causing declines in the kokanee population.)

Chinook

Stocking

Fall chinook salmon eggs were obtained from the Washougal State Fish Hatchery, Washington (Bonneville stock) and stocked into Coeur d'Alene Lake in 1982 and 1983. From 1983-1986, chinook salmon eggs from Lake Michigan stock were obtained from various state hatcheries in Wisconsin, Indiana, and Illinois and stocked into Coeur d'Alene Lake from 1984 to 1987. Since 1987, eggs have been obtained from spawners that enter Wolf Lodge Creek, a tributary to Coeur d'Alene Lake. The eyed eggs were sent to Idaho state hatcheries; Hagerman in 1982, Mullan in 1984 and 1985, and Mackay in 1983 to 1990. Chinook salmon were raised to fingerling size and stocked as age 0 fish in Coeur d'Alene Lake after they had passed the smolting stage. The number, size, time, and location of stocked fish varied considerably. In general, chinook salmon fingerlings were reared to a size and released after they had passed the smolting stage to insure minimal emigration from the lake. They were released in the Wolf Lodge Bay area of Coeur d'Alene Lake, where 90% of the kokanee spawn, to insure maximum potential predatory impact on kokanee. The number of chinook salmon stocked has varied from 10,500 to 60,100 in order to meet management goals without overshooting their carrying capacity.

Spawning

Wolf Lodge Creek-In 1984, the first weir was installed in Wolf Lodge Creek 0.6 km above the I-90 bridge (Figure 3). As the program developed, the location and design of the weir changed. In 1988, the present location of the weir was established under the I-90 bridge (Figure 3).

Trapped chinook were netted and spawned twice weekly in 1990. All fish were measured, sexed, examined for fin clips, and scale samples were taken from all natural fish and five of each cohort of fin-clipped hatchery fish. A minimum of 50 pairs of salmon were spawned to maintain genetic diversity. An attempt was made to increase the percentage of larger fish by spawning large males with large females. We attempted to control run timing (selecting for early spawners) by spawning fish that had entered the trap from mid-September to mid-October. Some eggs were heat-shocked to produce sterile triploid progeny to experiment with longevity and growth potential. After the spawning operation ended, the upstream block weir was left in place until mid-November to suppress natural reproduction from late-migrating salmon.

Coeur d'Alene River-In 1990, a weir was built on the Coeur d'Alene River 200 m below the I-90 bridge at Cataldo, Idaho (Figure 4). Trapped salmon were removed to a holding area, spawned when ripe, measured, examined for fin clips, and scale samples were taken. Every third male salmon trapped was released immediately and each male was released after being spawned once. A trap tender was hired to keep the weir free of debris, protect the trapped salmon, and collect information on the downstream fishery that developed as a result of the weir.

Ageing

Scale samples that were collected during the spawning operation were aged and checked by two people. Impressions were made using a Carver Model C laboratory press. Scales were placed on a 75 mm x 25 mm laminate plastic strip and inserted between two metal plates and placed into the press. Pressure was increased to 364 kg/cm (20,000 psi) for 10 s. The impressions were then read using an Eberbach Scale Reader. The number of annuli were recorded. Length at age relationship and weight at age relationship were developed.

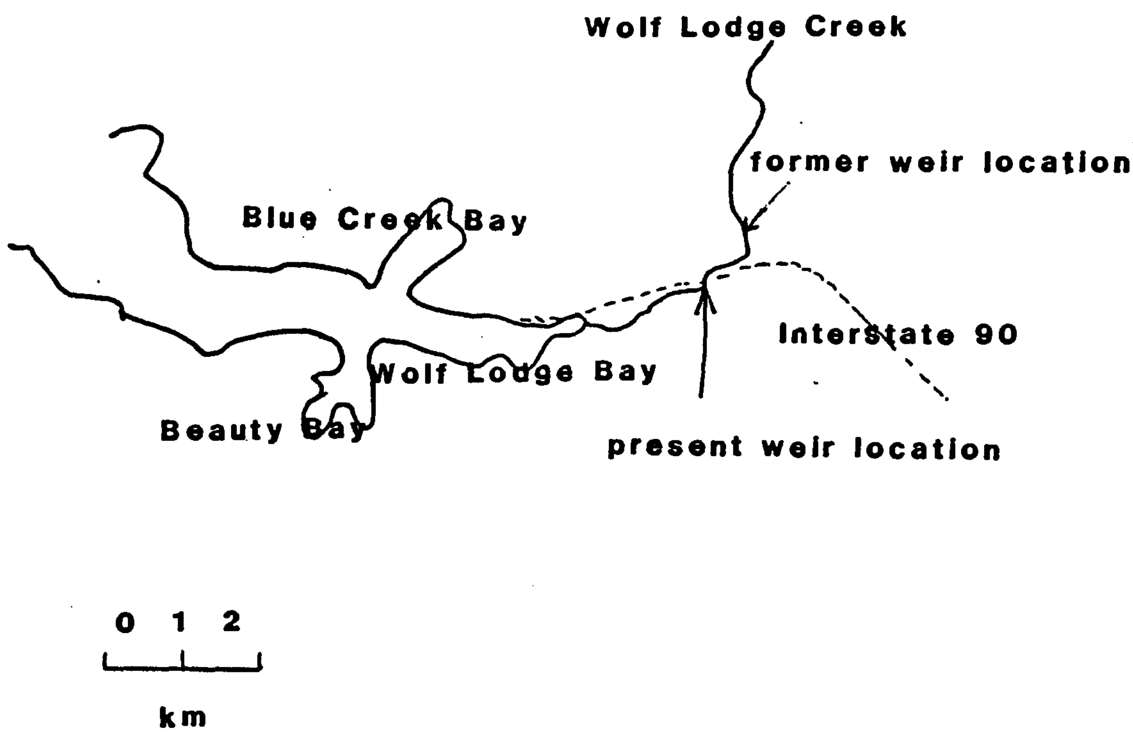

Figure 3. Map of Wolf Lodge Bay and Wolf Creek, Coeur d'Alene Lake, Idaho, showing present and former fall chinook weir locations.

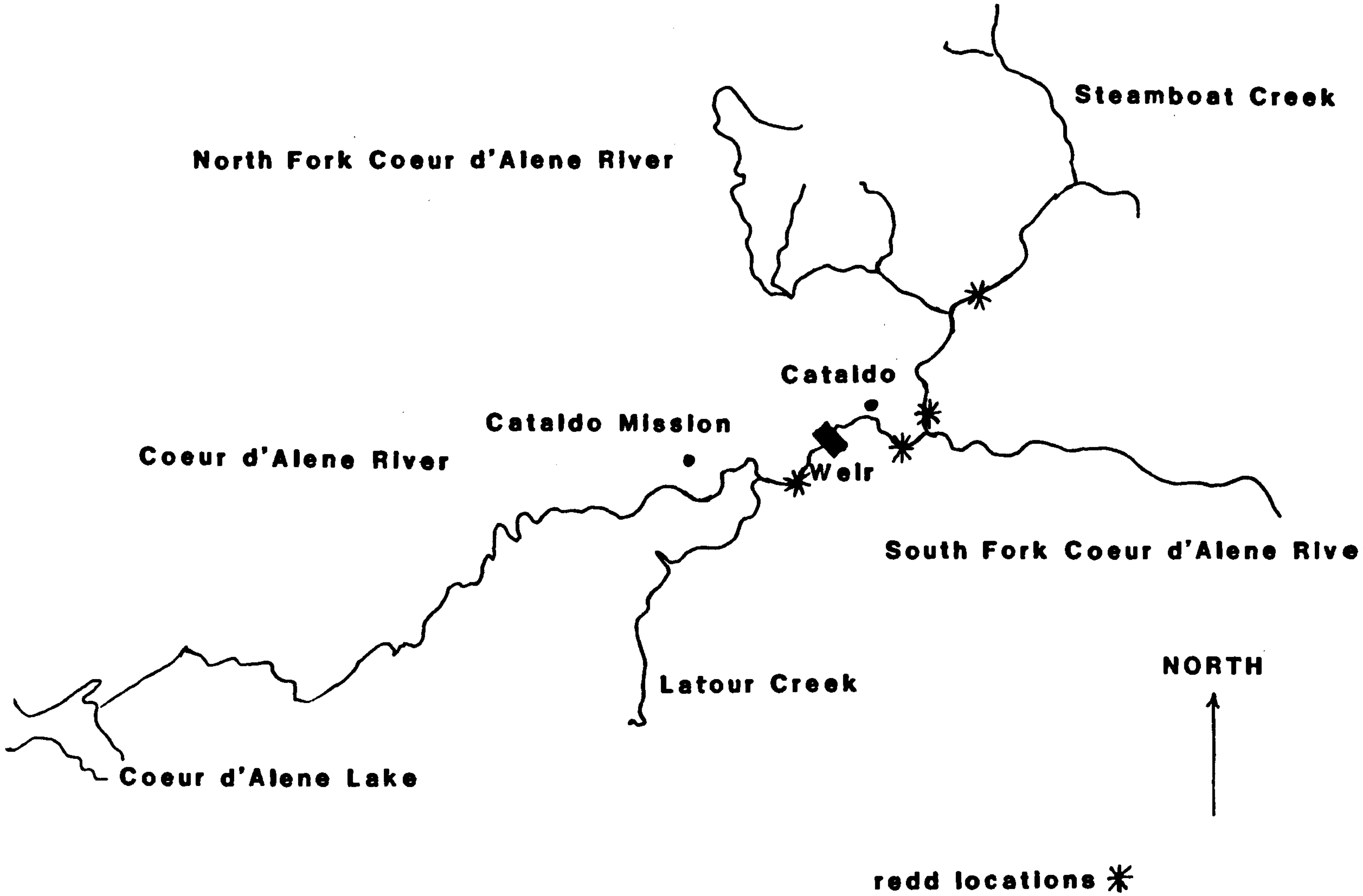

Figure 4. Fall chinook salmon redd counting sections, locations of groups of redds, and location of the weir in Coeur d'Alene River, Idaho, 1990.

Natural Chinook Salmon Abundance

Starting in 1985, all hatchery chinook salmon were fin-clipped before release. Numbers of fin-clipped (hatchery) and non-fin-clipped (natural) chinook salmon were recorded by age class as the chinook matured and were subsequently trapped in Wolf Lodge Creek. The proportion of natural to hatchery fish was used to estimate wild chinook age 0 production by the equation:

$$N_{age0} = (H)\ ((W_{age2} + (W_{age3})\ /\ (\ C_{age2} + C_{age3})\ )$$

Where: N equals the number of natural chinook salmon at age 0 of year class x, H equals the number of hatchery chinook salmon stocked of year class x, W equals the number of natural chinook salmon in the spawning run of year class x maturing at age;, and C equals the number of hatchery chinook salmon in the spawning run of year class x maturing at age;.

The 1984 natural chinook salmon year class estimate was derived by a different means since return of fin-clipped salmon was poorly documented. It was calculated as a proportion of what was stocked to estimates of wild production by the formula:

$$\frac{0.5\ S_{82} + 0.5\ S_{83}}{N_{85}} = \frac{0.5\ S_{82}}{N_{84}}$$

where: N_{84} = estimate of wild production in 1984
N_{85} = estimate of wild production in 1985

S_{82} number of chinook salmon stocked in 1982

S_{83} = number of chinook salmon stocked in 1983

The constant, 0.5, was used to correct for half of the fish maturing at age 2 and half maturing at age 3.

Redd Counts

Aerial redd counts were made on the Coeur d'Alene, South Fork Coeur d'Alene, and St. Joe rivers on November 11, 1990 using a Cessna 182 fixed-wing aircraft. Ground counts were also made on the Coeur d'Alene River below the weir on September 18, 1990 and on several small tributaries to Coeur d'Alene Lake on October 31 and November 1, 1990.

Creel Survey

A creel survey was conducted August 18-26, 1990 on Coeur d'Alene Lake during the Big One Chinook Derby. Boat patrol was used to get incomplete trip angler information. Completed trip information was collected at the Third Street boat ramp. At least one of these methods was used each day of the derby. Collected information included the number of anglers in each party, hours fished, and number of fish caught. Harvested fish were measured for length and weight, sexed if possible, and checked for fin clips. All data was summarized and compared to previous data. In addition to the creel survey, data on length, weight, sex, fin clips, and hours fished were collected at weigh-in locations.

RESULTS

Kokanee Trawling

Population Estimates-From the trawling on August 14, 15, and 16, 1990, we estimated the kokanee population at 7.39 million fish (+ 18%, 90% error bounds). The number of kokanee within each lake section and within each age class are shown in Table 1. An estimated 82% of all young-of-the-year (YOY) kokanee were found in the northern section of the lake, and only an estimated 1.4% were found in the southern section. Population estimates of age 0, 1, 2, and 3 kokanee were 3.00 million, 0.59 million, 2.78 million, and 1.31 million, respectively.

Density-Estimates of kokanee density (fish/ha) were also calculated (Table 2). Age 1, 2, and 3 kokanee were almost equally distributed in the northern and middle sections of the lake. The southern section had much lower densities of all age classes of kokanee. Density of age 0 kokanee was much higher in the northern section of the lake (1,147 kokanee/ha) than in the southern section (12 kokanee/ha).

Maturity-All kokanee under 200 mm in the trawl samples appeared immature, and all kokanee over 220 mm were mature (Figure 5). At 200 to 209 mm, females and males were 79% and 67% immature, respectively. Immature females and males dropped to 7% of the fish sampled in the 210 to 219 mm size group. No age 4 kokanee were collected. The 200 mm length at which maturity occurred corresponds to the size of age 3 kokanee. Thus, nearly all spawners were thought to be age 3.

Aqe-Age 0 and age 1 kokanee were defined by peaks in the size frequency distribution and had a modal size of 45 mm and 135 mm, respectively. Age 2 and age 3 kokanee were defined by aging 53 scale samples. Some overlapping of sizes was noted for age 2 and age 3 kokanee (Figure 6). Twenty-two percent of the 200 mm to 209 mm size group was age 2 (78% age 3), and 8% of the 210 mm to 219 mm size group was age 2 (92% were age 3) (Figure 6). Modal size of age 2 and age 3 kokanee were 195 and 215 mm, respectively.

Length at Spawning

A total of 142 kokanee were measured on three dates throughout the spawning run. On November 20, 1990, males and females averaged 252 mm and 247 mm, respectively. On December 4, mean lengths of males and females declined to 248 mm and 239 mm. On December 13, the mean length of male kokanee was 247 mm and mean length of females was 233 mm. Overall average for all fish collected was 244.7 mm (249.1 mm for males and 240.2 mm for females). The change in size throughout the spawning run indicates the need for multiple sampling in future years.

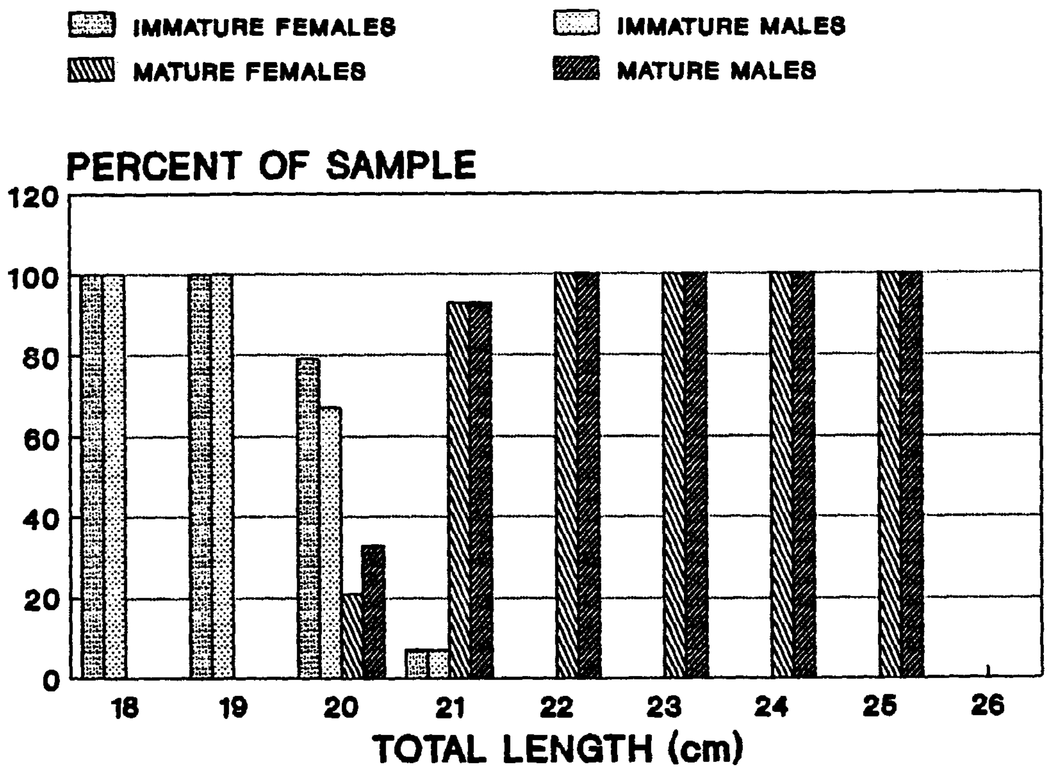

Figure 5. Percent maturity of various size classes of kokanee sampled from Coeur d'Alene Lake, Idaho, 1990.

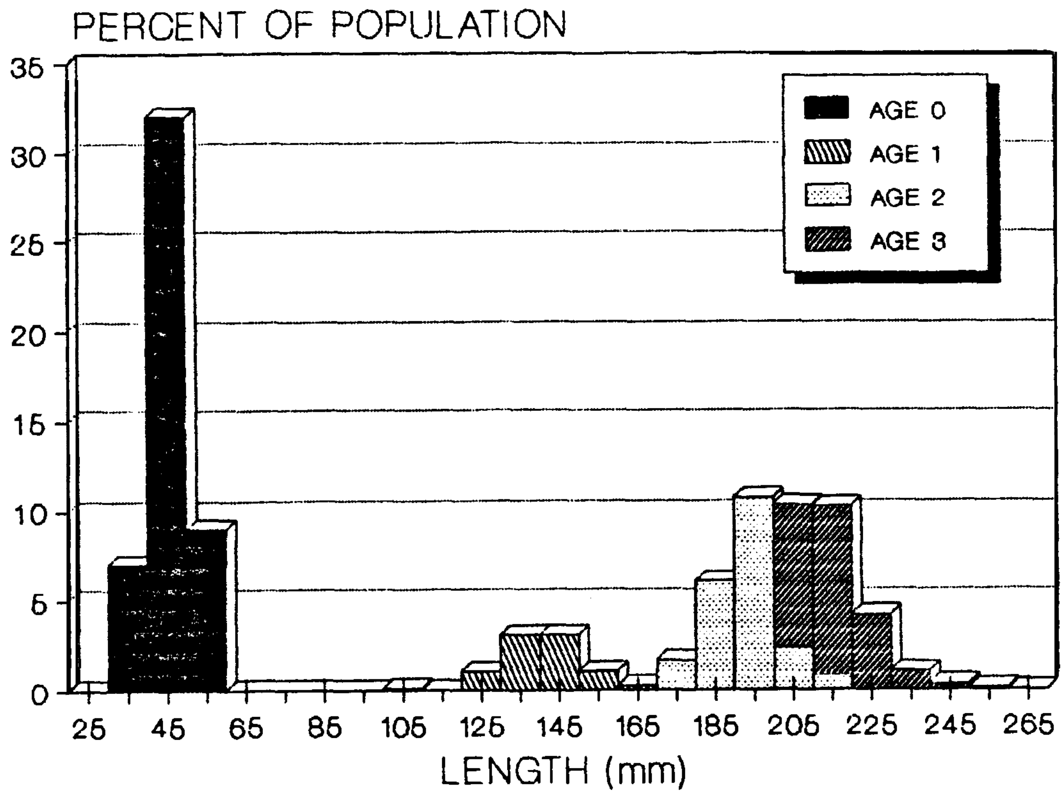

Figure 6. Lengths of kokanee age classes in Coeur d'Alene Lake, Idaho, August 14, 15, and 16, 1990.

Fecundity

During the spawntaking operation, 1,114 female kokanee produced 326,105 eggs for a mean of 293 eggs/female. In addition, a mean of 16 eggs were left in each spawned-out female for a total of 309 eggs produced/female. Number of eggs/female as calculated by the regression equation was y= -947+5.26(240.2) or 316 eggs/female. The former value was probably more accurate since it was site and time specific. Since total number of mature kokanee was 1.32 million, potential egg deposition in 1990 was estimated at 203.94 million eggs (309 x 0.5 x 1.32 million).

Population Modeling

Results of the Bioenergetics modeling indicated 1,000 stocked chinook would consume 816 kg of kokanee their first year of life, 1,799 kg of kokanee their second year, 808 kg their third year, and 280 kg in their fourth year (Table 3). This yielded a total consumption of 3,749 kg of kokanee per 1,000 chinook stocked, or 150 metric tons of kokanee to feed a stocking of 40,000 chinook throughout their life.

Modeling of the "idealized" kokanee population, with the assigned values for chinook related kokanee mortality, was used to estimate kg of kokanee available for chinook consumption without causing the population to numerically decline between generations. By their first fall, kokanee could provide 51,270 kg for consumption. During the next three years they could provide 77,177, 32,119, and 25,277 kg (Table 3).

Dividing kokanee yield by the amount consumed by a single chinook gave an estimate of about 40,000 chinook that could be stocked. At this stocking level, kokanee in age class 1 and 2 would be depleted to the point where the population could just maintain itself (with no fishing or other natural mortality for kokanee).

Trawl Evaluation

The Canadian trawler significantly underestimated kokanee abundance relative to the north Idaho trawler (95W confidence level) (Figure 5). These differences occurred in all age classes of kokanee. The north Idaho trawler, the portable trawler, and Dworshak trawler were fairly consistent in estimating age 0, 1, and 2 kokanee densities. The north Idaho trawler, however, caught significantly less age 3 kokanee than the Dworshak boat, but significantly more than the portable trawler or Canadian boats (Figure 7).

Chinook

Stocking

In 1990, 36,350 chinook salmon averaging 123 mm in total length and 17.5 g were stocked into Wolf Lodge Bay on July 10 from the Mineral Ridge boat ramp (Table 4; Figure 1). A portion of the plant, 650 fish, were from the sterilized (heat-shocked) eggs that produced 75% triploidy. In the past, annual plants of 10,500 to 60,100 have taken place in July, August, or October at the I-90 boat ramp or the Mineral Ridge boat ramp (Table 4).

Table 1. Kokanee population estimates (in millions) and 90% confidence intervals for each age class in each section of Coeur d'Alene Lake, Idaho, on August 14 to 16, 1990

Section	Age 0	Age 1	Age 2	Age 3	Total
1	2.452	0.206	0.685	0.399	3.742
	±39%	±44%	±43%	±325	±25%
2	0.528	0.352	1.770	0.891	3.541
	±65%	±60%	±38%	±30%	±26%
3	0.022	0.036	0.021	0.026	0.105
	±76%	±117%	±122%	±105%	±94%
Total	3.002	0.594	2.476	1.316	7.388
	±34%	±39%	±30%	±22%	±18%

Table 2. Kokanee density (fish/ha) estimates for each age class in each section of Coeur d'Alene Lake, Idaho on August 14 to 16, 1990.

Section	Age 0	Age 1	Age 2	Age 3	Total
1	1,147	96	321	187	1,751
2	92	61	307	155	614
3	12	21	12	15	60
Whole lake density	311	62	257	136	766

Table 3. Estimates of kokanee available for chinook consumption (yield), amount of kokanee that 1,000 stocked chinook would consume, and maximum chinook stocking level that a year class of kokanee could support for Coeur d'Alene Lake, Idaho.

Cohort number	Month	Kokanee yield (kg/150 million eggs laid)	Chinook consumption (kg/1,000 chinook stocked)	Maximum stocking level
1	Jun-Nov	51,270	861	59,542
2	Dec-Nov	77,180	1,799	**42,899**
3	Dec-Nov	32,119	808	39,745
4	Dec-Nov	25,277	280	90,022

TABLES

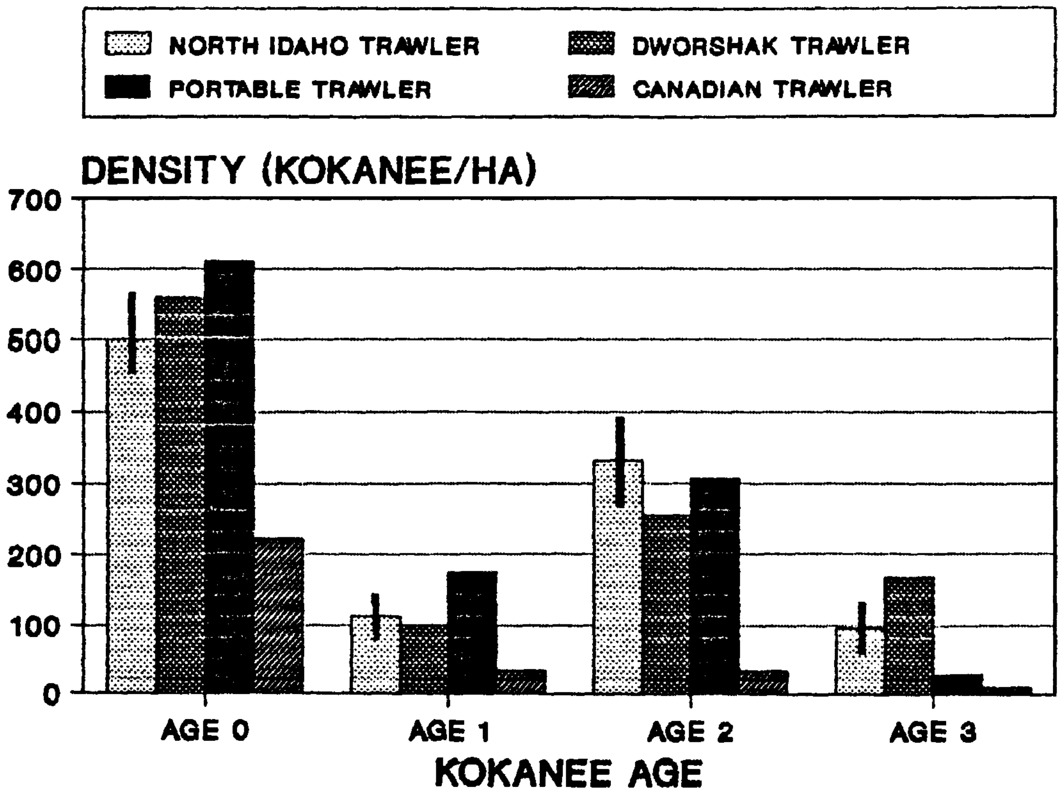

Figure 7. Kokanee density estimates made by four trawlers which sampled the northern end of Coeur d'Alene Lake, July 25-26, 1990. Bar on north Idaho trawler estimate denotes 95% confidence limits.

Table 4. Number, kilograms, and lengths of fall chinook salmon released into Coeur d'Alene Lake, Idaho, 1982-1990.

Release date	Release site	Number released	kg released	Lengths mean	Lengths range	Rearing hatchery	Stock of fish	Mark
07-19-82	MR	28,700	767	137	125-150	Hagerman	Bonneville	None
10-05-82	I-90	5,700	273	150	130-170	Hagerman	Bonneville	None
Total 82		34,400	1,040					
08-09-83	I-90	30,100	289	109	80-130	Mackay	Bonneville	None
10-26-83	I-90	30,000	637	124	80-150	Mackay	Bonneville	None
Total 83		60,100	926					
10-29-84	I-90	10,500	373	150	80-190	Mackay & Mullan	Lake Michigan	None
10-16-85	I-90	11,100	409	136	100-110	Mackay & Mullan	Lake Michigan	LV
10-17-85	I-90	7,400	273	143			Lake Michigan	Adipose
Total 85		18,500	682					
07-02-86	I-90	29,500	375	1,144	81-145	Mackay	Lake Michigan	RV
07-01-87	I-90	59,400	900	119	62-155	Mackay	Lake Michigan	Adipose
07-16-88	I-90	44,600	977	133	95-180	Mackay	Lake C d'Alene	LV
07-06-89	I-90	35,000	636	126	100-165	Mackay	Lake C d'Alene	RV
07-10-90	MR	35,700	626	123	80-145	Mackay	Lake C d'Alene	Adipose
07-10-90	MR	650	11	123	80-145	Mackay	Lake C d'Alene	Adipose & RV
Total 90		36,350	637					

MR = Mineral Ridge boat ramp.

Spawning

Wolf Lodge Creek-The 1990 spawning run into Wolf Lodge Creek totaled 172 fish trapped, 160 fish spawned, and 297,340 eggs collected (Table 5). The percentage of males and females in the run was 49 and 51, respectively. Natural chinook (natural chinook salmon are fish that have been raised in the hatchery at some time in their background) comprised 49% and hatchery chinook comprised 51% of the trapped fish (Table 6). The spawning run consisted of age 2 and age 3 adults. The spawning operation began September 10, 1990 and ended October 16, 1990. Natural fish migrated during the first weeks followed by the hatchery fish; there was a short period of overlap in the middle of the run (Figure 8).

Coeur d'Alene River-Only 23 chinook were trapped, and 6 of the 18 females were spawned providing 12,000 eggs (several thousand eggs were overripe). One male was released upstream after spawning. The remaining chinook died or were illegally removed from the trap or holding area.

The same general migration pattern was apparent in the Coeur d'Alene River as in Wolf Lodge Creek. The first natural chinook salmon entered the trap on August 26, 1990; the first hatchery fish entered the trap on September 25, 1990. Increased flows caused the weir to collapse on October 27, 1990. When the weir failed, several fish were observed passing upstream; one of these fish was identified as hatchery because of the missing adipose fin. Two days of rain and failure to clean the debris from the pickets led to the collapse of the weir.

Age and Growth

A total of 100 scale samples were collected during the 1990 spawning operation. Mean length of age 1, 2, and 3 year old chinook were 44.8 cm (n=5), 73.7 cm (n=23), and 88.4 cm (n=62), respectively (Table 7). The age at length relationship was described by the equation Y=9.lx + 21.8 (Figure 9).

Age 0 chinook are usually stocked at 12.7 to 22.8 g in July. At the end of the second, third, and fourth summer in the lake, chinook weighed an average of 2.0, 4.5, and 8.5 kg, respectively. The weight at age relationship was described by y=-2.56 + (0.27)x (r=.098) (Figure 10).

Natural Chinook Salmon Abundance

Naturally produced chinook salmon were estimated to have increased from 13,500 fish in 1984 to 43,800 fish in 1987 (Table 8; Figure 11). No estimates were yet available for the 1988 or 1989 year classes since they have not yet entered the spawning runs. The 1987 year class estimate was based on actual number of age 2 chinook in the spawning run and projections for the number of age 3 chinook that will run in 1991.

A second method was used in estimating natural chinook abundance for the 1984 year class. The 1985 year class of natural chinook (N_{85}) was estimated at 37,086 fish (Table 8). This year class originated from stockings of 34,400 hatchery fish, some of which matured at age 3 (Sn), and 60,100 stocked hatchery fish, some of which matured at age 2 (S_{83}). The 1984 natural chinook year class

Table S. Summary of fall chinook salmon spawntaking operations in Wolf Lodge Creek, Coeur d'Alene Lake, Idaho, 1984-1990.

Year	Total fish trapped	Number spawned	Number females spawned	Number eggs taken	Eggs per female
1984	80	28	13	50,000	3,846
1985	0	0	0	0	0
1986	60	46	19	[a]8,700	NA
1987	50	34	27	105,000	3,880
1988	130	106	58	210,000	3,627
1989	143	143	72	'53,280	NA
1990[b]	178	166	79	297,340	3,498

[a]Number of eggs shipped or survived-not total eggs taken.
[b]Total includes totals from Wolf Lodge Creek trap and Coeur d'Alene River trap.

Table 6. Composition of the spawning run of fall chinook salmon in Wolf Lodge Creek, Coeur d'Alene Lake, Idaho, 1984-1990.

	Natural fish trapped						Hatchery fish trapped							
	M		F		Total		M		F		Total			
Year Trapped	No.	%	No.		No.	%	No.		No.		No.		Year fish stocked	Fin clip
1984	No natural fish return yet.						22	63	13	37	35	100	1982	--
1985	No natural fish return yet.									--	--	--	1982	--
								--		--	--	--	1983	--
1986	Unknown natural run.						19	41	27	59	46	100	1983	--
	Hatchery fish were not clipped.												1984	--
1987	3-year-old fish from 1984 release were not						27	79	7	21	34	100	1984	--
	marked.												1985	AD & LV
1988	28	56	20	44	45	42	15	29	37	71	52	--	1985	AD
							3	100	0	0	3	--	1985	LV
							5	83	1	17	6	--	1986	RV
					Totals		23	38	38	62	61	58	--	--
1989	22	42	31	58	53	40	3	33	6	67	9	--	1986	RV
							46	64	26	36	72	--	1987	AD
					Totals		49	60	32	40	81	60	--	--
1990	40	46	45	54	85	49	17	28	43	72	60	--	1987	AD
							20	80	5	20	25	--	1988	LV
					Totals		38	44	49	56	87	51	--	--

TABH

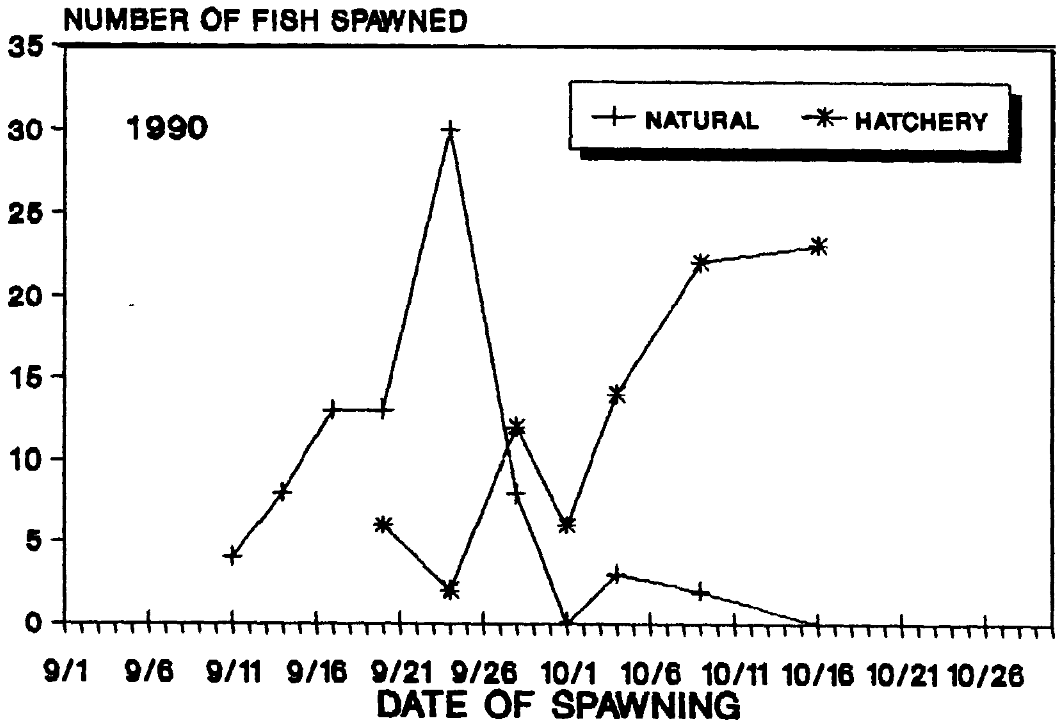

Figure 8. Number and date of spawning fall chinook salmon in Wolf Lodge Creek, Coeur d'Alene Lake, Idaho, 1990.

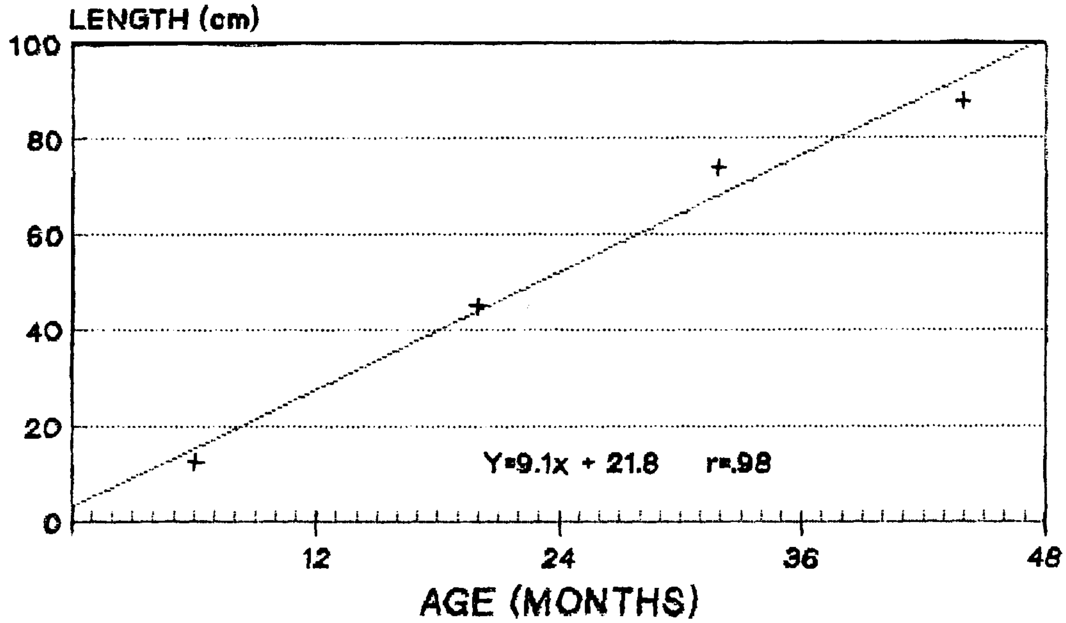

Figure 9. Age-length relationship of fall chinook salmon in Coeur d'Alene Lake, Idaho, 1990. (Points [+] represent the mean length of approximately 25 fish.)

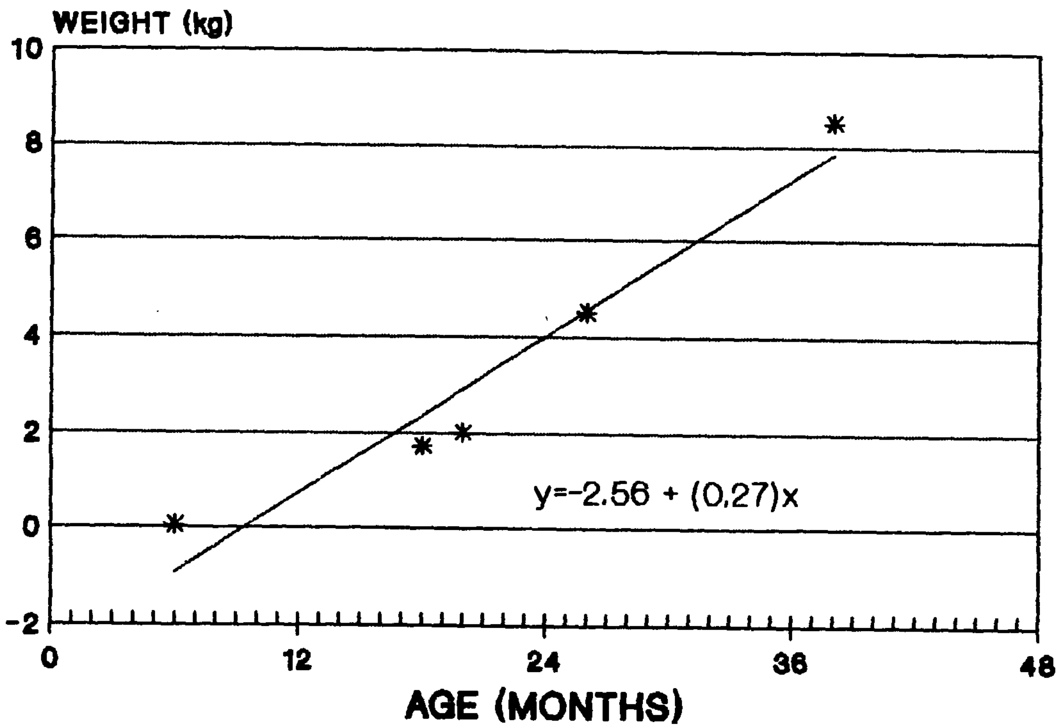

Figure 10. Age-weight relationship of fall chinook salmon in Coeur d'Alene Lake, Idaho, 1990. (r = .98) (Points (*) represent the mean weight of approximately 25 chinook.)

Table 7. Mean lengths of aged fall chinook salmon, Coeur d'Alene Lake, Idaho, 1990.

Age	Number	Mean length (mm)
age 1 males	4	45.8
age 1 all	5	44.8
age 2 females	7	73.1
age 2 males	8	74.1
age 2 all	23	73.7
age 3 females	42	87.5
age 3 males	19	89.8
age 3 all	62	88.4

Table 8. Number of hatchery and naturally produced chinook salmon in the Wolf Lodge Creek spawning run, tributary to Coeur d'Alene Lake, Idaho. Year class denotes the year eggs were laid. Estimate of age 0 natural chinook was derived by the proportion of hatchery to natural fish.

		Hatchery		Wild		
Year class	Hatchery release	age 2	age 3	age 2	age 3	Estimated age 0 natural chinook salmon
1984	18,500	--	--	--	--	13,500
1985	29,500	18	17	16	28	37,086
1986	59,400	64	55	25	54	39,434
1987	44,600	29	29[a]	19	38[a]	43,831

'Estimated value.

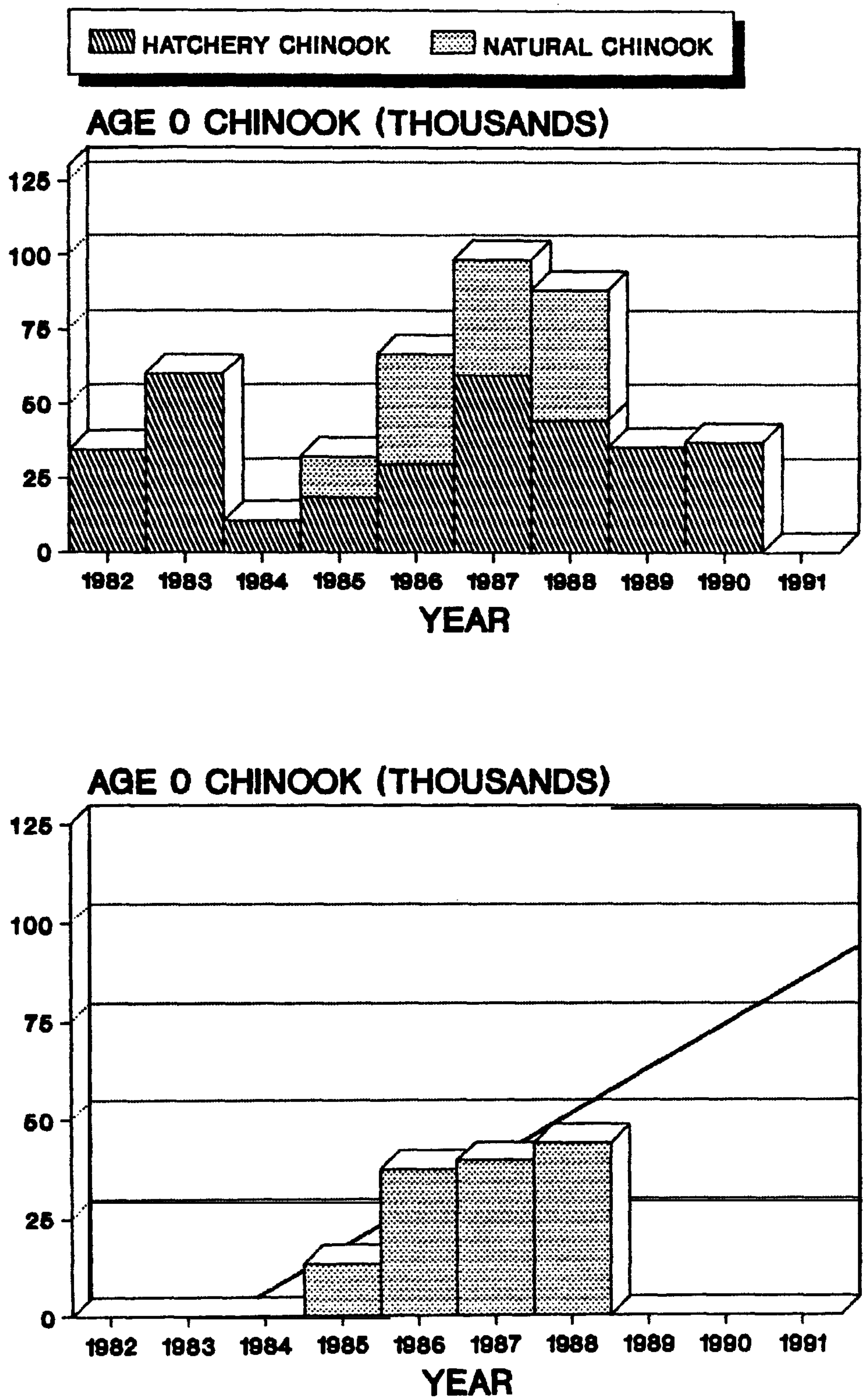

Figure 11. Numbers of chinook salmon stocked from hatcheries and produced naturally in tributaries to Coeur d'Alene Lake, Idaho (top). Trend of age 0 natural chinook abundance in Coeur d'Alene Lake, Idaho (bottom). Data for natural chinook salmon in 1989 and 1990 not yet available.

originated only from age 2 fish stocked in 1982. The proportion specified in the methods section therefore became:

$$\frac{17,200 + 30,050}{37,086} = \frac{17,200}{N_{84}}$$

Natural chinook salmon production in 1984 (Nu) was therefore estimated at 13,500 salmon.

Redd Counts

A total of 55 fall chinook salmon redds were counted in the Coeur d'Alene River (Table 9; Figure 4). Thirty-five redds were located below the weir at Cataldo, Idaho, and 75% of the total were located below the confluence of the South Fork Coeur d'Alene River. Ten redds were counted in the St. Joe River (Figure 12). Several smaller tributaries to the lake were surveyed October 31 through November 1, 1990 (Table 10). Five redds were found in Lake Creek (Table 10).

Creel Survey

The catch rate for the "Big One Chinook Derby" was 146 hours per fish; the lowest catch rate since 1986 (Table 11). A total of 1,037 anglers spent 4,416 hours to catch 31 chinook (Table 11). Hatchery fish comprised 78% of the catch (Table 12). Data collected at the weigh-in sites indicated that 69% of the fish harvested were hatchery chinook (Table 12). Combining all the data, 70% of all harvested fish were hatchery and 30% were natural (Table 12).

Anglers fishing below the weir were interviewed, and a minimum of 42 fall chinook salmon were estimated to be caught on the Coeur d'Alene River. No data was available on the percentage of natural and hatchery composition.

DISCUSSION

Kokanee

Abundance

Kokanee population estimates show some marked changes over the past 12 years (Table 13). The total population of 7.38 million in 1990 was down significantly ($P< 0.1$) from the last three years, indicating that chinook salmon are having an effect on the population.

More significant changes occurred within each age class of kokanee. Age 0 kokanee abundance (3 million fish) was nearly identical to last year. We were not able to detect a decline in the abundance of YOY kokanee despite Interstate 90 construction activities and fill in of the spawning areas during the kokanee spawning and egg incubation period. Age 0 kokanee were, however, the most variable segment of the population, and impacts of the construction may become more detectable as this cohort matures.

Table 9. Fall chinook salmon redd counts, Couer d'Alene Lake drainage, Idaho, September 29, 1989 and November 10, 1990.

Location		Year 1989	1990
Coeur d'Alene River (CdA River)			
Cataldo Mission to South Fork (SF) CdA River			41
SF CdA River to North Fork (NF) CdA River			10
NF CdA River			4
	Total	52	55
St. Joe River			
St. Joe City to Calder			4
Calder to Huckleberry Campground			3
Huckleberry Campground to Avery			3
	Total	0	10
	Grand Total	52	65

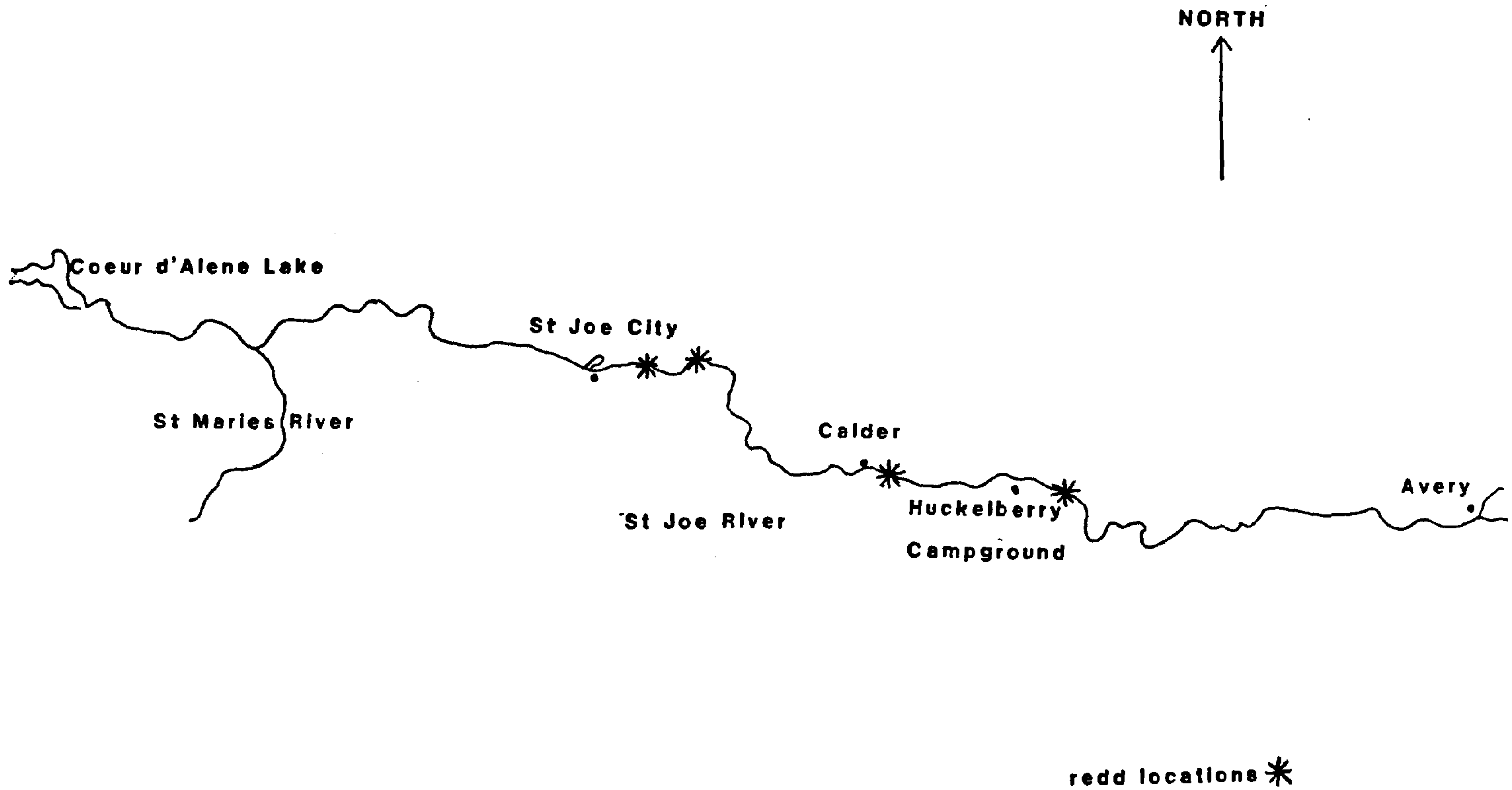

Figure 12. Map of the St. Joe River fall chinook salmon redd count sections and locations of groups of redds, 1990.

Table 10. List of Coeur d'Alene Lake, Idaho, tributaries surveyed October 31 to November 1, 1990 for chinook redds.

Location	Number of redds
Beauty Creek	0
Benewah Creek	0
Blue Creek	0
Carlin Creek	0
Cougar Creek	0
Fighting Creek	0
Lake Creek	5
Mica Creek	0
Plummer Creek	0
Squaw Creek (north end of lake)	0
Turner Creek	0

Table 11. Summary of creel information relating to fall chinook salmon on Coeur d'Alene Lake, Idaho, 1984-1990.

Year		Number	Percent total hours			Number fish caught			Catch rates fish/hour		
			kok	ck	ct	kok	ck	ct	kok	Ck[a]	ct
1984	811	13,248	60	15	25	14,474	94	7	1.1	100	0.1
1985	121	79,000	52	43	15	103,870	240	--	1.3	333	--
1986	584	37,800	57	42	NA	--	76	NA	--	497	NA
1987	1,287	239,581 67,943[b]	89	7	NA	212,807	350	NA	0.9	38[c]	NA
1988	--	--	--	--	NA	--	106	NA	--	93[c]	NA
1989	604	37,363			NA	--	843	NA	--	44[c]	NA
1990	1,037	4,416			NA	--	31	NA	--	143[c]	NA

[a]Catch rate, hours per fish.
[b]Estimated angling hours for derby only.
[c]Catch rate for derby only.
[d]Data not expanded, creel data summary only.
kok = kokanee salmon
ck = fall chinook salmon
ct = westslope cutthroat trout

Table 12. Number and percentage of hatchery (fin-clipped) and natural fall chinook salmon caught during the 1990 "Big One Derby" on Coeur d'Alene Lake, Idaho, that were weighed-in or checked during angler interviews.

	Adipose		Left ventral		Right ventral		Total Hatch		Natural		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.
Creel survey	9	39	6	26	3	13	18	78	5	22	23
Weigh-in	48	37	38	29	3	2	89	69	40	31	129
Total	57	38	44	29	6	4	107	70	45	30	152

Table 13. Estimates of kokanee year-classes (1975-1989) made by midwater trawl in Coeur d'Alene Lake, Idaho, 1979-1990. Estimates are in millions of kokanee.

	Year estimated											
Year class[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
1989	3.00											
1988	0.59	3.04										
1987	2.48	0.75	3.42									
1986	1.32	3.95	3.06	6.88								
1985		0.94	3.81	2.38	2.17							
1984			0.61	2.92	2.59	4.13						
1983				0.89	1.83	0.86	0.70					
1982					0.72	1.86	1.17	1.51				
1981						2.53	1.89	1.91	4.53			
1980							0.80	2.25	2.36	2.43		
1979								0.81	1.38	1.75	1.86	
1978									0.93	1.71	1.68	1.50
1977										1.06	1.95	2.29
1976											1.06	1.79
1975												0.45
Total	7.39	8.68	10.9	13.07	7.31	9.37	4.56	6.48	9.20	6.94	6.55	6.04
Number/ha	766	900	1,123	1,353	757	970	472	671	953	719	678	625

[a]Year eggs were deposited.

TABH

The most profound affect of chinook predation on kokanee appeared to occur when kokanee were age 1. During 1985, 1989, and 1990, kokanee abundance at age 1 was severely depressed. This corresponds to high chinook stockings two years previous. During 1990, age 1 kokanee abundance was at its lowest point on record. This corresponds to a chinook stocking of 44,600 in 1988 and an estimated natural chinook production of an additional 43,831 fish (natural chinook production estimated by the proportion of fin-clipped to non-fin-clipped chinook sampled in spawning runs). The low number of age 1 kokanee in 1990 did not appear to be an artifact of our trawling methodology, since very similar density estimates were made by two other trawlers during the trawl evaluation tests in July. If this estimate proves accurate, the reduction of this year class to 0.6 million was below the level needed for the population to sustain itself at levels typical of the last 10 years. Even if all 0.6 million kokanee survive to age 3, which is unlikely since chinook continue to prey on them, and 50% are females laying 309 eggs each (as determined in 1990), then only 93 million eggs would be produced (less than one-half the potential egg deposition of 1990). The relationship between age 1 kokanee and the number of chinook stocked two years previously fit the equation $y = 1{,}432.97\, x^{'\bullet 67}$ ($r^2 = 0.81$), where x was the number of chinook stocked plus an estimate of wild production, and y = kokanee abundance at age 1 (Figure 13). This relationship could be used to predict the affects of various chinook stockings on the abundance of age 1 kokanee. Predictions from this relationship assumes that chinook salmon harvest is a constant proportion of the population.

The number of age 2 kokanee remained stable from 1979 to 1985, but dropped to a low point in 1986 (Figure 14). This low point corresponded to a high stocking of chinook three years previous. They then increased from 1987 to 1989 to a point about 200% of their historic levels. During the sampling in 1990, densities were found to have dropped significantly to a point closer to historic levels.

Fluctuations of age 3 kokanee were less pronounced. They reached a low point in 1986, but abundance has been increasing from 1988 to 1990 (Figure 14). No clear mechanism appeared responsible for the increases in some age classes above the historic levels. One possible hypothesis was that a reduction of young kokanee caused a rebounding effect in older age classes. However, interspecific competition between older and younger age classes was thought to be minor (Rieman and Meyers 1990).

Survival

Annual survival rates of kokanee have also had some pronounced changes. These rates remained relatively stable before the introduction of chinook, 1980 to 1982 (Figure 15). The most sensitive group to chinook predation appeared to be the younger kokanee. Within one year of stocking chinook in 1982, survival estimates of kokanee between age 0 and age 1 dropped from about 100% to about 40%. (Survival values may appear in excess of 100% since they become more vulnerable to our trawling gear as they get larger.) During 1989 and 1990, age 0 to age 1 survival has further declined to approximately 20%. Survival of age 2 to age 3 kokanee followed a similar pattern to that of younger kokanee. Their survival dropped from 60% (before introducing chinook) to about 30% during 1988, 1989, and 1990. These changes in survival would indicate that chinook were preying quite heavily on these age classes.

Survival of kokanee from age 1 to age 2 has shown a quite different trend. Their relative survival increased from about 90% (before chinook were introduced) to about 130% in the late 1980s, to a high of 300% in 1990 (Figure 15). Why chinook salmon predation would not be affecting this age group is currently unknown. One of the compensatory responses that we expected to see was that if

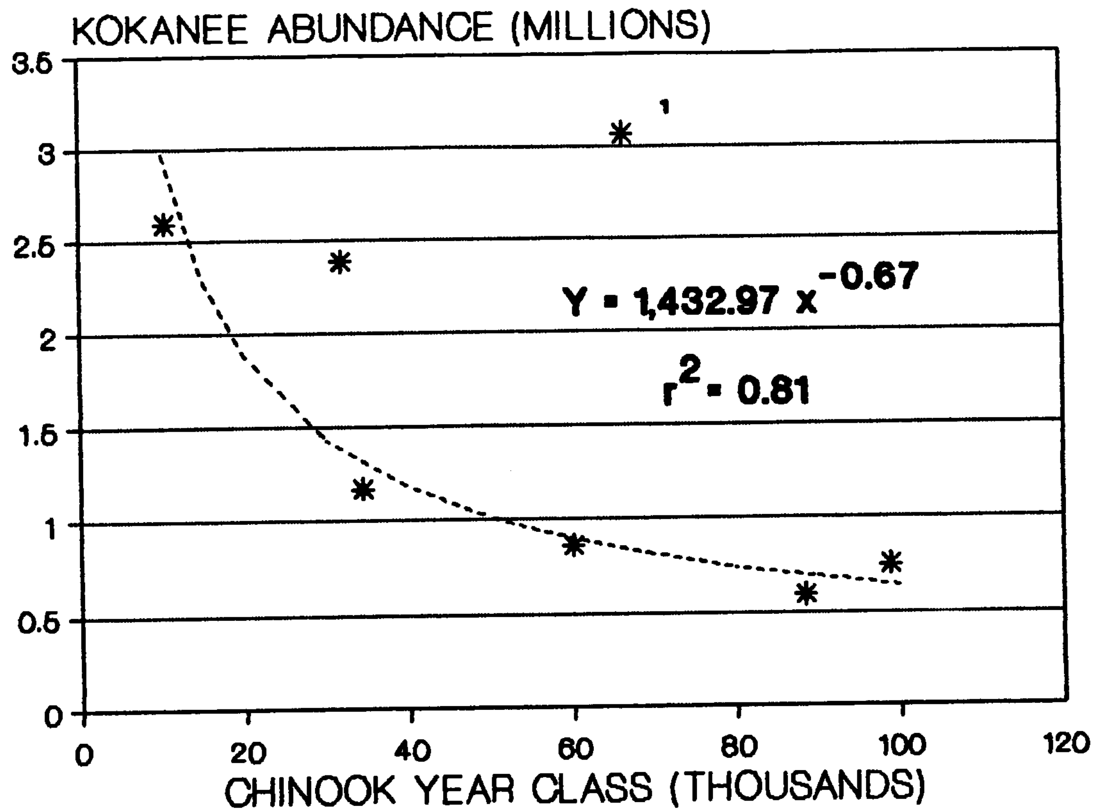

Figure 13. Relationship between the number of fall chinook salmon stocked two years previous (and wild production) and the number of age 1 kokanee estimated in Coeur d'Alene Lake, Idaho. ([1]One point, a record strong year class, was deleted from regression equation.)

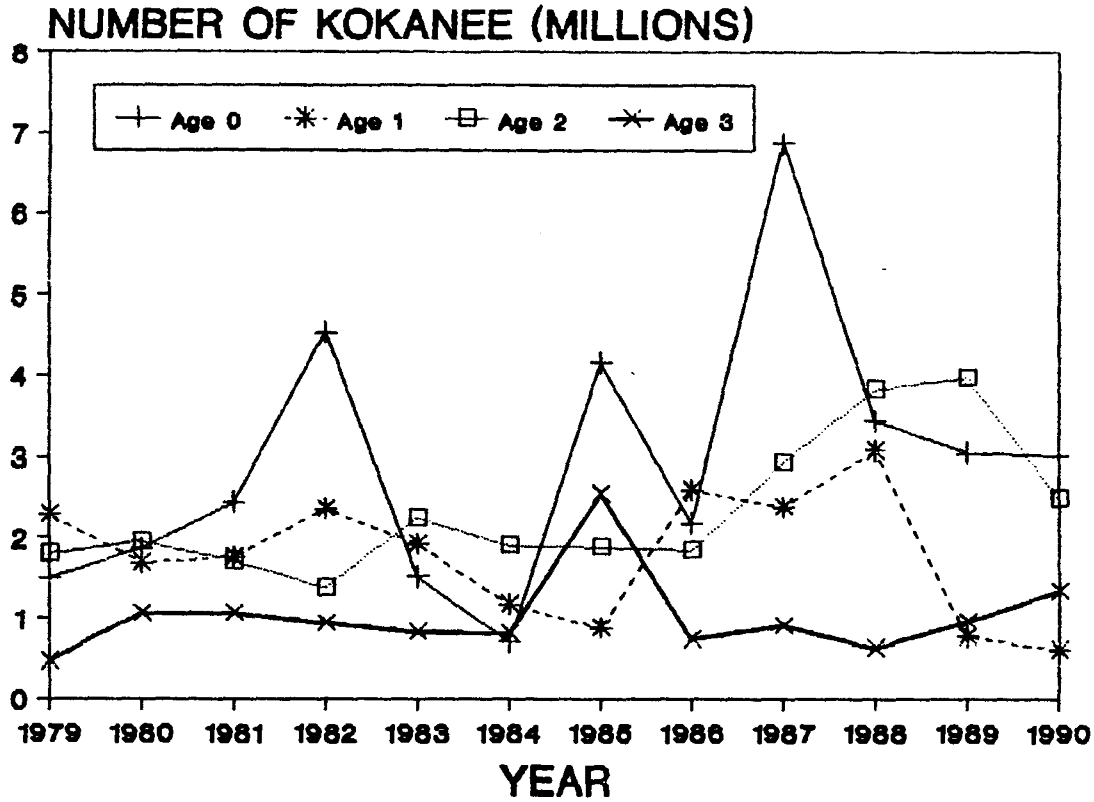

Figure 14. Kokanee abundance by age class in Coeur d'Alene Lake, Idaho, 1979 to 1990.

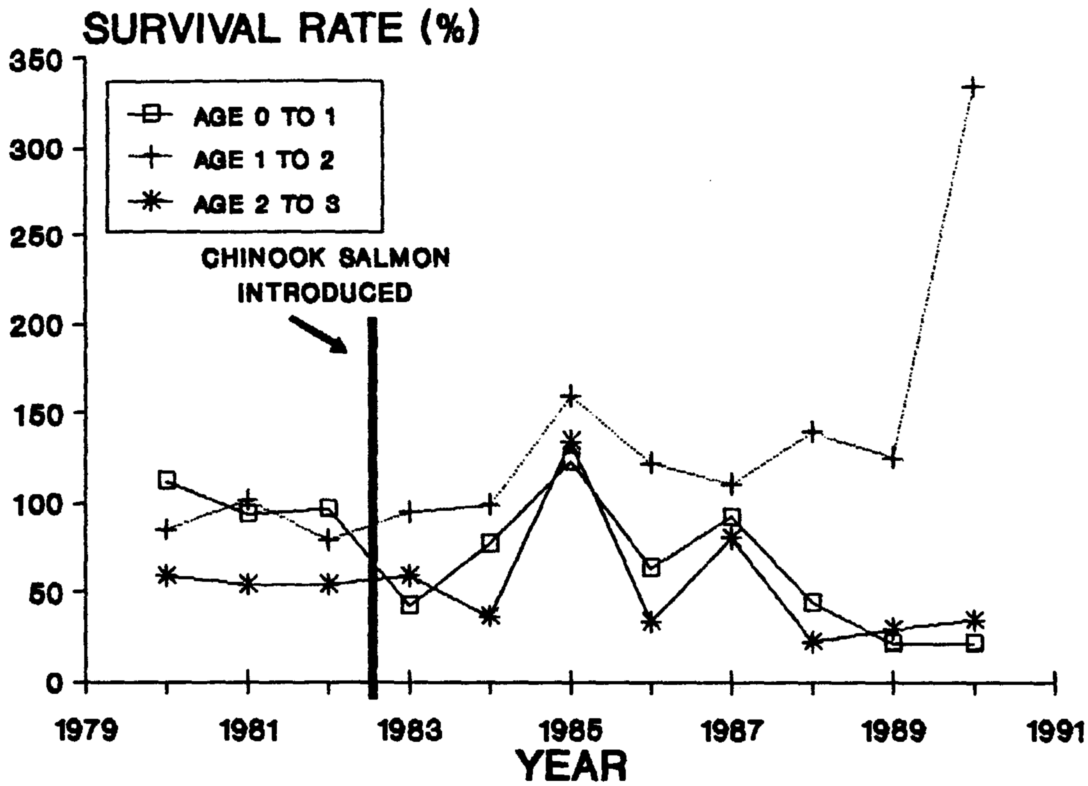

Figure 15. Relative survival between different age classes of kokanee in Coeur d'Alene Lake, Idaho, 1980 to 1990.

one kokanee age group were reduced through predation, then natural mortality might decline in other age groups, hence the increasing survival of age 1 to age 2 kokanee. To date, the compensatory changes in mortality have kept the kokanee population in equilibrium; enough age 3 kokanee were left to produce enough eggs to start the next generation at an equal level of density. As mentioned earlier, reducing age 1 kokanee to 0.6 million may be exceeding this level unless survival rates are extremely high in forthcoming years.

Length at Spawning

The initial reason for stocking chinook in 1982, was to reduce kokanee abundance and thus increase their length (Mauser and Horner 1982). In the last nine years, no appreciable increase in kokanee length at maturity was found (Figure 16). In 1983, kokanee matured at their smallest length on record (212 mm). Size improved in 1985 (257 mm), but then declined to its current mean of 245 mm. For most of the last 11 years, kokanee length remained fairly constant. Therefore, the stocking of chinook from 1982 to 1986 (plus natural chinook production) apparently was too low to cause the needed changes in kokanee density. (Kokanee maturing in 1990 would have had the 1985 year class of chinook salmon as their primary predator.) However, the big growth in chinook salmon population came after 1986 (Figure 11), and the effects were only recently becoming apparent in the younger age classes of kokanee. With the severe reduction in age 1 kokanee abundance, their length at maturity may increase.

Length at Age

We also looked at changes in kokanee length by each age class since 1978 to attempt to document improved lengths. Since trawling was conducted on different dates, all lengths were corrected to late September length estimates by formulas presented by Rieman and Meyers (1990). Again, no great improvement in kokanee length was apparent after the chinook were stocked in 1982 (Figure 17). Age 2 kokanee during 1990 were the largest they had been since 1978, but the change was slight. Other age classes were close to average length.

Fecundity

The potential egg deposition estimated in 1990 of 204 million eggs was the highest estimate ever recorded (Table 14). This increase in the number of eggs resulted from a very dominant 1986 year class of kokanee. In 1986, an estimated 103 million eggs were laid; a relatively low amount. They had the best egg to fall fry survival on record (6.681) and produced a record high of 6.89 million age 0 kokanee in 1987. The 1986 year class produced record numbers of age 1 and age 2 kokanee and the second best year class of age 3 kokanee. Initial survival of this year class may have been improved by the low stocking of chinook in 1984 (10,500 chinook), 1985 (18,500 chinook), and 1986 (29,500 stocked plus an estimated 37,091 naturally-spawned chinook). Thus, there were relatively few chinook in the older age classes to prey on this dominant kokanee year class. This strong kokanee cohort was apparently unaffected by the high chinook stocking of 59,400 hatchery chinook salmon (and an estimated 39,600 naturally-produced chinook salmon) in 1987.

This dominant cohort illustrated another important point; that year class strength was not determined by potential egg deposition, but rather by survival of kokanee their first year in the lake. Survival at this stage may be largely weather-related.

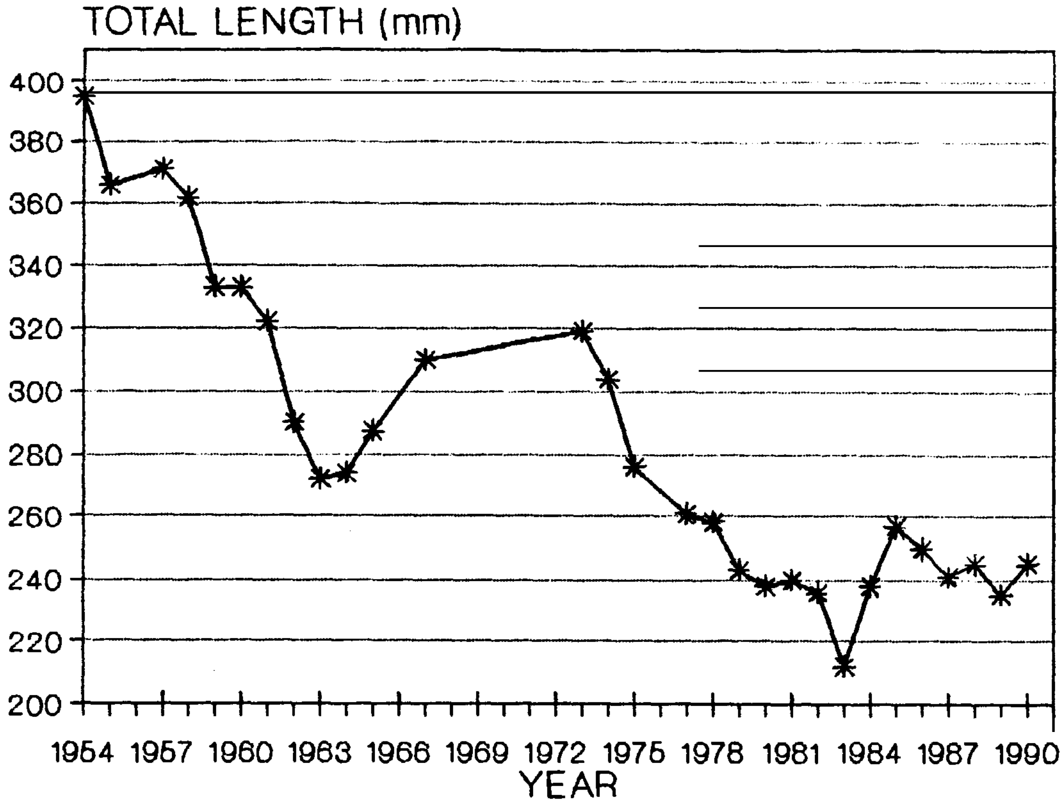

Figure 16. Lengths of spawning kokanee in Coeur d'Alene Lake, Idaho, 1954 to 1990.

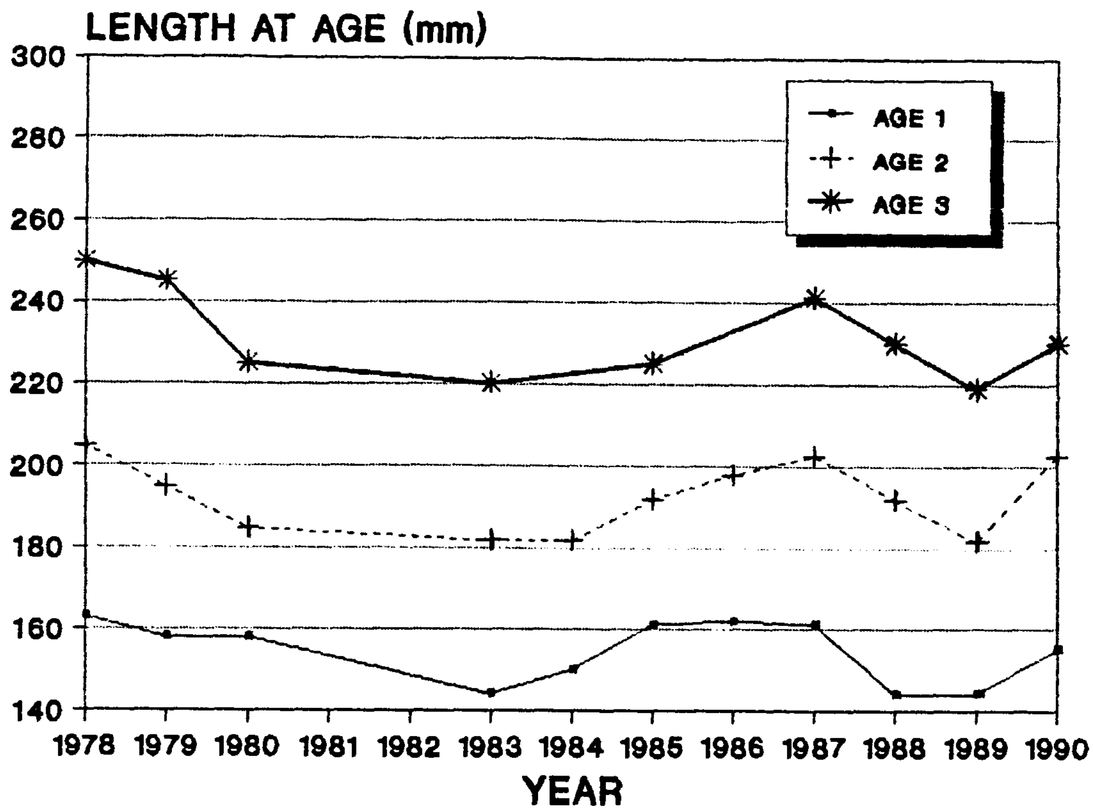

Figure 17. Lengths of kokanee of different age classes in Coeur d'Alene Lake, Idaho, corrected to September.

Table 14. Estimates of female kokanee spawning escapement, potential egg deposition, fall abundance of wild kokanee fry, and their subsequent survival rates in Coeur d'Alene Lake, Idaho, 1978 to 1990.

Year	Female spawning escapement	Potential number of eggs ($x10^6$)	Fall fry from previous year escapement ($x10^6$)	Wild survival (%)
1979	256,716	86	--	--
1980	501,492	168	1.86	2.20
1981	550,000	184	2.43	1.45
1982	358,200	120	4.54	2.46
1983	441,376	99	1.51	1.25
1984	316,829	106	0.70	0.71
1985	530,631	167	4.13	3.90
1986	368,633	103	2.17	1.29
1987	377,746	126	6.89	6.68
1988	362,000	119	3.42	2.71
1989	516,845	155	3.04	2.55
1990	657,777	204	3.00	1.94

Indications were that chinook salmon fed on kokanee a year younger than themselves; i.e., age 2 chinook salmon prey on age 1 kokanee. If this is true, it would be too late to stock high numbers of chinook once a dominant year class of kokanee is detected at age 0. Chinook stocking could only be matched to kokanee abundance if year class strength could be predicted a year in advance.

Chinook

Stocking

Fall chinook salmon were obtained from the Washugal State Fish Hatchery in Washington in 1982 and 1983 when the program was just beginning. This stock of fish matured predominately at age 2 (58$) and age 3 (35%) (Harold Hauser, personal communication, Oregon Department of Fish and Wildlife). They also tended to weigh approximately 9 kg at age 3. In Coeur d'Alene Lake, this stock spawned between late August and late September. These fish generally entered Wolf Lodge Creek in an already deteriorated state and very ripe, characteristic of downriver "tule" fall chinook salmon.

In 1984, the chinook stock came from Lake Michigan and were used through 1987. Most of these fish matured predominately at age 3 (55%) with 35$ maturing at age 2 and some at age 4. This stock tended to be larger than the Bonneville stock, averaging 11.8 to 14.5 kg at age 3. In Coeur d'Alene Lake, these fish entered spawning streams in late September and spawned primarily in mid-October and persisted into early November. This stock tended to appear much "brighter" than the Bonneville stock fish and took longer to ripen in the trap.

Spawning

The spawning program utilizing fish from Coeur d'Alene Lake developed for two reasons. First, the sources for fall chinook salmon eggs could not be guaranteed due to priority concerns in other states. Second, Idaho adopted a new fish disease policy that precluded stocking diseased fish into "clean" drainages. Chinook eggs from the Great Lakes are no longer available due to the presence of EED (epizootic epitrophic disease) a devastating viral disease found in Great Lakes salmonids. Wolf Lodge Creek provided an egg source to maintain the option of rearing and stocking hatchery chinook salmon.

Mature chinook salmon were first seen in Wolf Lodge Creek in 1983. In 1984, a weir was built 0.6 km above slack water to prevent fish from spawning in lower Wolf Lodge Creek (Figure 3). However, chinook salmon were observed spawning successfully below the weir. A few fish were collected, but spawntaking was unsuccessful due to warm water temperatures and poor egg condition. Techniques improved, and in 1987, enough eggs were collected to meet the program needs the following year. Beginning in 1988, all fall chinook salmon stocked into Coeur d'Alene Lake originated from "Coeur d'Alene stock," a mixture of the original Bonneville and Lake Michigan stocks.

During the past three years, 1988 to 1990, the spawning run has shown two peaks (Figure 18). The first peak consisted of natural chinook salmon (Bonneville stock). This run developed during the first years of trapping chinook salmon in Wolf Lodge Creek (1984-1987) when the weir was placed well above slack water and chinook salmon spawned successfully. The second peak was dominated by hatchery fish (Lake Michigan stock) and were identified by fin clips (hatchery stocking during 1985-1987). Placement of the weir at the beginning of

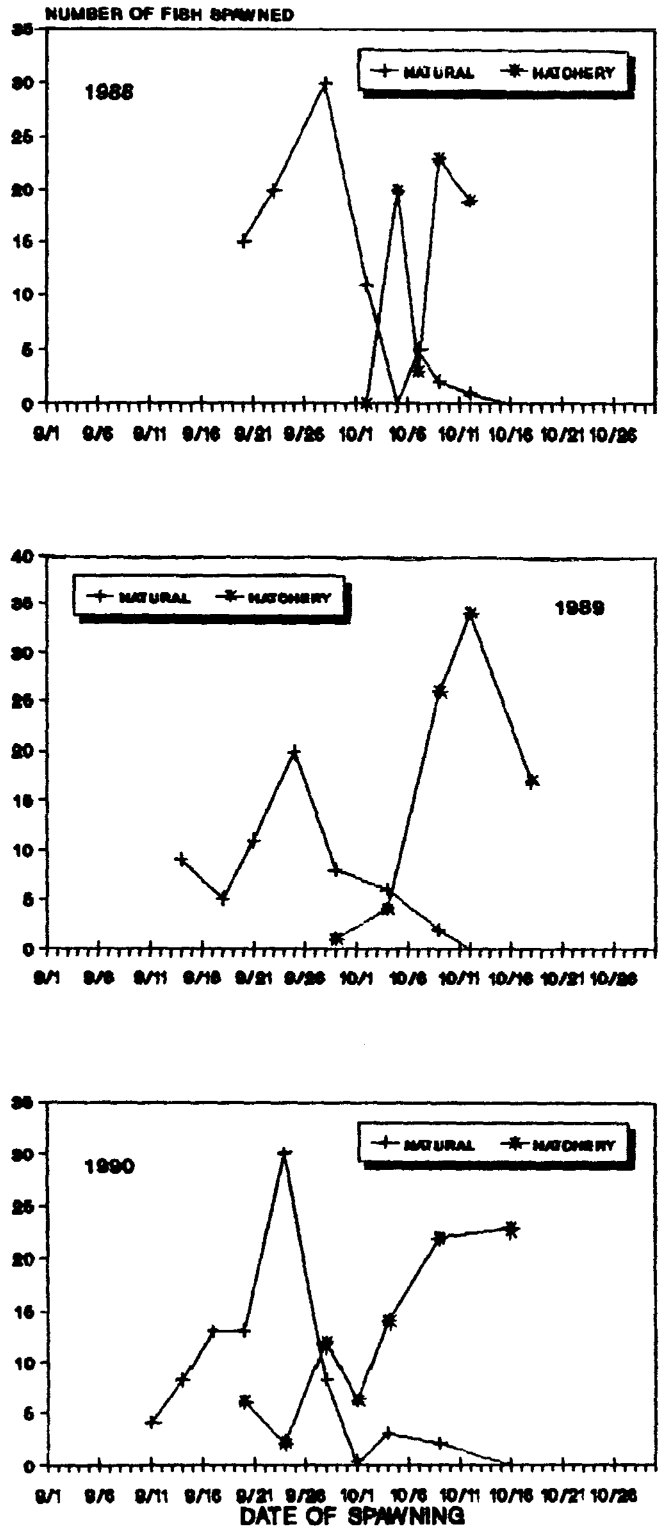

Figure 18. Timing of natural and hatchery fall chinook salmon spawning runs entering Wolf Lodge Creek trap, Coeur d'Alene Lake, Idaho, 1988 to 1990.

slack water in 1988 should have eliminated natural reproduction in Wolf Lodge Creek.

The differentiation of the early and late spawning runs provides an opportunity to select the most advantageous stock of chinook salmon for Coeur d'Alene Lake. The run timing of each stock of chinook salmon has influenced its ability to establish spawning runs in other tributaries of Coeur d'Alene Lake. The early run (Bonneville stock) has been able to establish spawning runs into Wolf Lodge Creek and the Coeur d'Alene River,but not the St. Joe River as evidenced in 1989 when no redds were seen on September 19 (Table 9). There are two possible hypotheses. First, the southern end of Coeur d'Alene Lake and impounded portions of the St.Joe River are relatively shallow (less than 9 m) and, therefore, becomes quite warm (>21°C) at the time the early run is ready to spawn. This thermal condition may be too warm and too long (46 km) for early chinook salmon to successfully migrate up the St. Joe River to spawn. Second, the Coeur d'Alene River is the first major tributary that the chinook salmon encounter in the southern end of the lake. This entrance to the river is about 9 m deep and also becomes warm, but is probably cooler than the St. Joe River. However, the main body of the lake near the mouth of the river varies in depth from 15 m to 26 m and provides cold water habitat. The distance to spawning habitat is also less than in the St. Joe River (38 km in the Coeur d'Alene River versus 46 km in the St. Joe River). When the early chinook are ripe, they swim up the Coeur d'Alene River to spawn instead of the St. Joe River.

This was not the case for the later running Lake Michigan stock. They have successfully spawned in the St. Joe River and Lake Creek, as well as the Coeur d'Alene River. These fish ripen in early October, and in most years, the southern area near the St. Joe River and the back waters of Windy Bay have cooled sufficiently so the chinook salmon could successfully reach spawning habitat. This kind of spawning behavior of the Lake Michigan stock has made it undesirable in Coeur d'Alene Lake. Controlling the number of age 0 chinook salmon entering the lake on an annual basis (natural production and stocking) is essential in maintaining the predator/prey balance. We, therefore, recommend eliminating the Lake Michigan stock from our spawning program in Wolf Lodge Creek. Their spawning behavior makes this a relatively easy task. Eggs could be taken from adult chinook salmon that enter the Wolf Lodge Creek trap prior to October 1. Control of the already established runs in the St. Joe and Coeur d'Alene rivers will be more difficult.

Chinook salmon eggs have been taken from both stocks of chinook salmon for the past three years, 1988 to 1990 (Table 15). The 1988 year class (eggs taken in 1988 and smolts stocked in 1989) were dominated by late running chinook salmon (68%). The 1989 and 1990 year classes were dominated by early running chinook salmon 80% and 56%, respectively (Table 15). We should be able to eliminate late running chinook salmon from Wolf Lodge Creek by 1994 (1993 would be the last of the late running fish returning to Wolf Lodge Creek).

The age composition of the spawning run in Wolf Lodge Creek was different from the original information. Early running Bonneville stock was expected to return as predominately age 2 and age 3, 58% and 35%, respectively. In Coeur d'Alene Lake, the 1985 year class of natural chinook (early running Bonneville stock) returned to Wolf Lodge Creek at 36% and 64% age 2 and age 3, respectively (Table 16). The 1986 year class had similar returns with 32% and 68% age 2 and age 3, respectively.

The Lake Michigan stock (late running fin clipped hatchery fish) was expected to return as 35% and 55% age 2 and age 3, respectively, and some age 4. The 1985 year class returned as 51% age 2, 49% age 3, and no age 4 (Table 16). The 1986 year class returned as 54% age 2 and 46% age 3 and no age 4 adults (Table 16). Return of each marked group to Wolf Lodge Creek was shown in Table

Table 15. Number of fall chinook salmon eggs taken from natural and hatchery fall chinook salmon and sent to Mackay Hatchery.

	Natural (early)		Hatchery (late)		
Year class	No.	o	No.	%	Total
1988	25,224	32	54,604	68	79,828
1989	39,644	80	10,756	20	50,400
1990	31,592	56	23,894	44	55,486

Table 16. Summary of spawning run of fall chinook salmon in Wolf Lodge Creek, Coeur d'Alene Lake, Idaho, 1988-1990.

	Year class									
	1985				1986				1987	
	Hatchery		Natural		Hatchery		Natural		Hatchery	Natural
Spawning year	No.	%	No.		No.	%	No.	%	No.	No.
1988	18	5	16	36						
1989	17	49	28	64	64	54	25	32		
1990					55	46	54	68	29	19
Totals										
#	35		44		119		79			
%	44		56		60		40		60	40

Year class denotes the year eggs were laid.

17. It is unclear as to the cause, but accelerated growth in the hatchery may have altered the timing of maturity of the Lake Michigan stock.

Natural Reproduction

Wolf Lodge Creek-As discussed in another section of this report, the total number of chinook salmon entering the lake on a yearly basis must be controlled to maintain the predator/prey balance in Coeur d'Alene Lake. Controlling the number of natural chinook produced is critical to the success of the program.

The development of **a** natural population of fall chinook salmon was not entirely expected. It was believed that natural fish would behave as normal anadromous chinook salmon by smolting and emigrating from the lake (Mauser and Horner 1982). Once below the Post Falls Dam, they could never return to the lake. Although some of the juvenile chinook salmon may behave as their anadromous counterparts, there have been a substantial number that have residualized in the lake. Flows through Coeur d'Alene Lake have apparently not been sufficient during the smolting phase to give all juvenile fish the needed stimulus or direction to migrate through the lake to the ocean. Production of natural chinook salmon in the system **is** likely to be highly variable due to both the success of spawning and egg incubation and the percent of residualization of smolts in the lake.

The chinook salmon that have been stocked into Coeur d'Alene Lake have strayed and started natural populations in several tributaries. The stocking location may be one factor that has increased the potential for straying. Normally, adult chinook salmon return to their natal stream and only a small percentage of straying occurs. The chinook salmon stocked in Wolf Lodge Bay do not have an opportunity to imprint on a stream. The chinook salmon were stocked into Wolf Lodge Bay to achieve maximum predation pressure on kokanee fry, but recent data indicated that age 1 chinook salmon were the primary predators on kokanee fry. Therefore, stocking chinook salmon fry into Wolf Lodge Bay may not be necessary to achieve the needed reduction in kokanee fry abundance. The one major factor limiting the use of Wolf Lodge Creek as a stocking site could be water temperatures at the time of stocking and this should be investigated. If the water temperature **is** adequate for stocking in Wolf Lodge Creek, the amount of straying could be reduced.

Coeur d'Alene River-The 1990 spawning run in the Coeur d'Alene River was comprised of early running natural chinook salmon and late running hatchery chinook salmon. Apparently, the early migrating chinook salmon could withstand the warm water temperature in the lower section of the Coeur d'Alene River. The first reports of chinook salmon in the river occurred in 1984 and 1985. The reports of fish in the river increased during the following years, and a river fishery developed. The adult salmon that spawned in 1990 were the hatchery chinook salmon stocked in 1987 and 1988 and the F2 progeny of the 1986 and 1987 adult salmon that spawned in the Coeur d'Alene River. The number of redds has increased to over 50 in two generations and will probably continue to increase during the next few years.

One of the main objectives of the weir in the Coeur d'Alene River was to determine the number and composition of the adult chinook salmon migrating upstream to spawn. The run was composed of early running natural stock and late running hatchery stock. The number of chinook salmon in the run could only be estimated. A limited creel survey accounted for a minimum of 42 harvested salmon. A total of 23 salmon were caught in the trap. Most of the fish did not enter the trap because of the design or ripeness of the fish. The fish then dropped downstream and spawned, as evidenced by the 40 redds that were observed

Table 17. Percent of each marked group of fall chinook salmon stocked into Coeur d'Alene Lake, Idaho that returned to Wolf Lodge Creek trap 1987-1990. (The number of adults from the 1984 year class that returned in 1987 is a combined total for both fin clips based on the percent of age 2 fish that returned.)

Year class	Fin clips	Return year			
		1987	1988	1989	1990
1983	None	53			
1984	LV	47	11.3		
	Adipose		69		
1985	RV		43.8	56.2	
1986	Adipose			55	45

below the weir. There were 55 redds counted in the Coeur d'Alene River in 1990. Bjornn (1978) and Kiefer and Forrester (1991) estimated one female per redd. If we assume 1 male per redd, then 110 adult salmon spawned. The minimum number of adult chinook salmon in the Coeur d'Alene River spawning migration in 1990 was 175 fish.

St. Joe River-The population of chinook salmon in the St. Joe River is just beginning to increase. In 1989, no chinook redds were counted because of the early date, September 29. In 1990, 10 redds were counted on November 10 after the late running chinook salmon had spawned in the St. Joe River. The adults that spawned this year could be a combination of 1987 and 1988 hatchery stocked chinook salmon and natural chinook salmon that were spawned in 1986 and 1987.

Natural Chinook Abundance

In 1984, chinook salmon stocking was reduced to 10,500 fish from the previous year's stocking of 60,100 fish. The reduction was made because chinook salmon predation appeared to be reducing kokanee abundance below the desired level. An immediate response occurred in the kokanee population as age 0 kokanee abundance soared from 0.70 million to 4.13 million. More importantly, age 1 kokanee abundance jumped from 0.86 million in 1985 to 2.59 million in 1986 with the reduced abundance of chinook salmon. This illustrated that the kokanee population could respond quite quickly to changes in chinook salmon stocking. From 1987 to 1990, we reduced chinook salmon stocking from 60,000 to 37,000, but have not seen similar rebounds in the kokanee population. The obvious reason was that natural chinook production was increasing and effectively offset declines in stocking levels. For example, stocking was reduced to 44,600 chinook salmon in 1988, but an additional 43,800 chinook were produced by natural spawning bringing the total to 88,400.

If the increasing trend in natural chinook spawning continues, then further reductions in chinook salmon stocking are advised. It is doubtful that the kokanee prey base can support a chinook salmon population of 80,000 to 100,000 fish on a sustained basis. Bioenergetics modeling indicated the lake could sustain only half of this amount, and past stocking of 60,000 chinook salmon precipitated sharp declines in kokanee abundance. Based on the current trend, natural chinook salmon abundance will be in excess of 80,000 fish by 1991. Therefore, the time for corrective measures appeared limited.

Chinook Salmon Fishery

The chinook salmon fishery in Coeur d'Alene Lake has been highly variable to date. Catch rates (h/fish) have varied from a high of 497 h/fish in 1986 to 38 h/fish in 1987 during the "Big One Chinook Derby" in August. Chinook salmon, age 2 and older, were the most desirable component of the fishery. A weak relationship existed between the catch rate and the number of chinook salmon stocked 2 and 3 years earlier. (This relationship applied to the August derby which is 14 days long.) It appeared that as the number of fish stocked increased, the hours/fish caught decreased. However, setting a goal of 100 h/fish caught or less during this August period would not be realistic. There is a finite number of chinook salmon that the kokanee production can support (population modeling section of this report). Increasing the number of chinook salmon to achieve such a goal would exceed the carrying capacity of the lake and the prey base would collapse. This relationship spans a short period of time where prizes may influence the number of anglers that participate. Plus, angler expertise, weather, or the state of chinook salmon sexual maturity may also influence catch rates. Reports from anglers indicate that catch rates are substantially better during other times of the year (e.g. winter), so that these catch rates were not representative of the fishery as a whole.

RECOMMENDATIONS

1. Stock Coeur d'Alene Lake so that the combined total of hatchery and natural chinook salmon does not exceed 40,000 to 50,000 age 0 fish annually. This stocking level should be maintained for several years, evaluated, and adjusted accordingly. Hatchery chinook salmon stocking should remain above 10,000 fish to evaluate the contribution of natural reproduction in the spawning run. The most definitive and consistent way to meet this recommendation would be to eliminate natural chinook salmon reproduction and stock 50,000 hatchery chinook salmon.

2. Immediately take control of natural chinook salmon spawning so that chinook salmon numbers can be regulated.

3. If natural spawning of chinook salmon cannot be controlled in 1991, reduce stocking to 10,000 chinook salmon to break the increasing trend in abundance and document natural production.

4. Continue annual midwater trawling to assess kokanee population dynamics. Factors which need to be monitored include length and age at maturity, size-frequency of the population, fecundity, and population estimates by age class.

5. Educate the public to the finite limits of kokanee production (and thus chinook production) in Coeur d'Alene Lake.

6. Make any future hatchery plants in Wolf Lodge Creek to minimize straying into other spawning tributaries.

7. Eliminate the Lake Michigan stock from the spawning operations.

8. Determine the number of adult chinook salmon in the spawning runs in Wolf Lodge Creek, Coeur d'Alene River, St Joe River and Lake Creek.

9. Continue to monitor the fishery for natural and hatchery composition.

10. Determine the annual harvest of chinook salmon in the sport fishery.

11. Investigate methods and effectiveness of destroying chinook salmon redds as a means to control natural reproduction. Evaluate cost-effectiveness of redd destruction versus weir building as a control measure.

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APPENDICES

Appendix A. Kokanee catch by age class for each of the 17 trawls in Coeur d'Alene Lake, Idaho, August 14, 15, and 16, 1990.

Site	Height (m)	Steps	Age 0	Age 1	Age 2	Age 3/4	Total
1.1	16.76	5	116	2	19	16	153
1.2	13.72	4	72	6	19	12	109
1.3	13.72	4	90	10	12	7	119
1.4	13.72	4	169	15	30	17	231
1.5	16.76	5	30	7	54	26	117
2.1	16.76	5	0	16	10	16	42
2.2	13.72	4	1	4	7	4	16
2.3	16.76	5	2	6	31	16	55
2.4	16.76	5	11	4	53	20	88
2.5	13.72	4	9	1	21	14	45
2.6	16.76	5	7	4	40	17	68
2.7	16.80	5	24	1	19	4	48
3.1	--	--	--	--	--	--	--
3.2	--	--	--	--	--	--	--
3.3	8.23	3	1	8	5	5	19
3.4	10.97	3	2	0	0	0	2
3.5	10.97	3	2	2	1	2	7

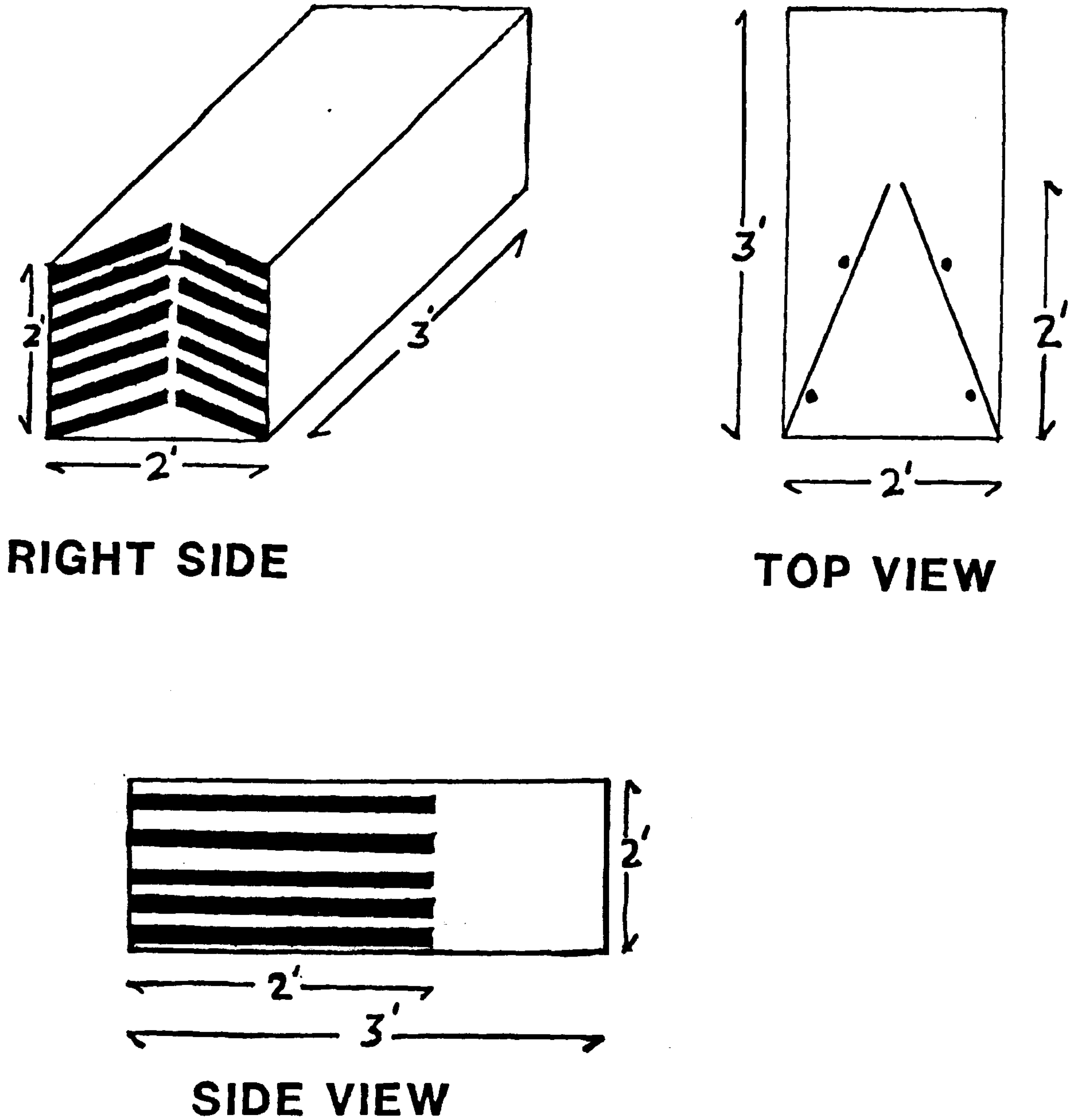
Appendix B. Total length of kokanee in Coeur d'Alene Lake, Idaho, 1978 to 1990. Lengths were corrected to estimated length in September of each year (Rieman 1990).

Year of observation	Age 1	Age 2	Age 3
1978	163	205	250
1979	158	195	245
1980	158	185	225
1983	144	182	220
1984	150	182	--
1985	161	192	225
1986	162	198	--
1987	161	203	241
1988	144	192	230
1989	144	182	219
1990	155	203	230

Appendix C. Description of chinook weir and trap on Wolf Lodge Creek and Coeur d'Alene River.

The weir consisted of welded metal frames with two horizontal pieces 3 m long and two vertical pieces 0.6 m long. The frame work was made from 5 cm x 5 cm angle iron. Holes 2.5 cm in diameter were drilled 1.9 cm apart in the horizontal pieces of the frame. Metal pickets, electrical conduit 2.2 cm outside diameter by 1.5 m long, were inserted through the holes to create a picket fence. The metal frames were held in place by 2 m metal fence posts driven into the substrate and secured with bailing wire. The present design consisted of an upstream block weir and a downstream block weir with an entrance (Figure C-1). The entrance was a 0.6 m x 0.6 m opening with a "V"-shaped gate. The gate was made with redwood slats 2.5 cm x 1.5 m x 0.6 cm thick; six slats to a side. The slats were secured to the downstream end of the opening in a horizontal position. The upstream ends were suspended and the size of the opening was controlled by two verticle poles per side. One pole was located about midway along the redwood slats and the other pole was located near the opening. In 1990, the metal fence posts were replaced with steel tripods. The tripods were constructed of steel pipe 2 m long and 5 cm in diameter. A three-way hinged coupler was used to secure the three legs at one end. A "T" was made from two pieces of the same pipe, 90 cm long and 120 cm long, to keep the legs separated. Three single hinged couplers were used to secure the ends of the "T" to the legs of the tripod and a "T" coupler was used to secure the two smaller pipes together to form the "T" (Figure C-2).

The weir was 80 m long and was built using the same materials as described above. There were 14 tripods, 40 10 cm x 10 cm x 5 m wood stringers, and a trap box. The weir was a single fence across the river shaped to direct the upstream migrating salmon into the trap. The tripods were spaced approximately 4 m apart, two rows of stringers were wired to the tripods and the metal frames were wired to the upstream side of the wood stringers. The trap box was located at the apex of the "V"-shaped weir. The trap was a 2 m x 2 m x 1.2 m box made of marine grade plywood, conduit, and 5 cm x 5 cm fir (2 in x4 in). The trap entrance was similar in design to Wolf Lodge Creek trap entrance. The opening was 1.2 m high and 1 m wide. The sides of the trap were electrical conduit spaced 2.5 cm apart. Threaded rods were used to hold the trap together. Trap doors were cut into the top of the box to allow access to the trapped salmon (Figure C-3).



ENTRANCE TO WOLF LODGE CREEK CHINOOK SALMON WEIR

Figure C-1.

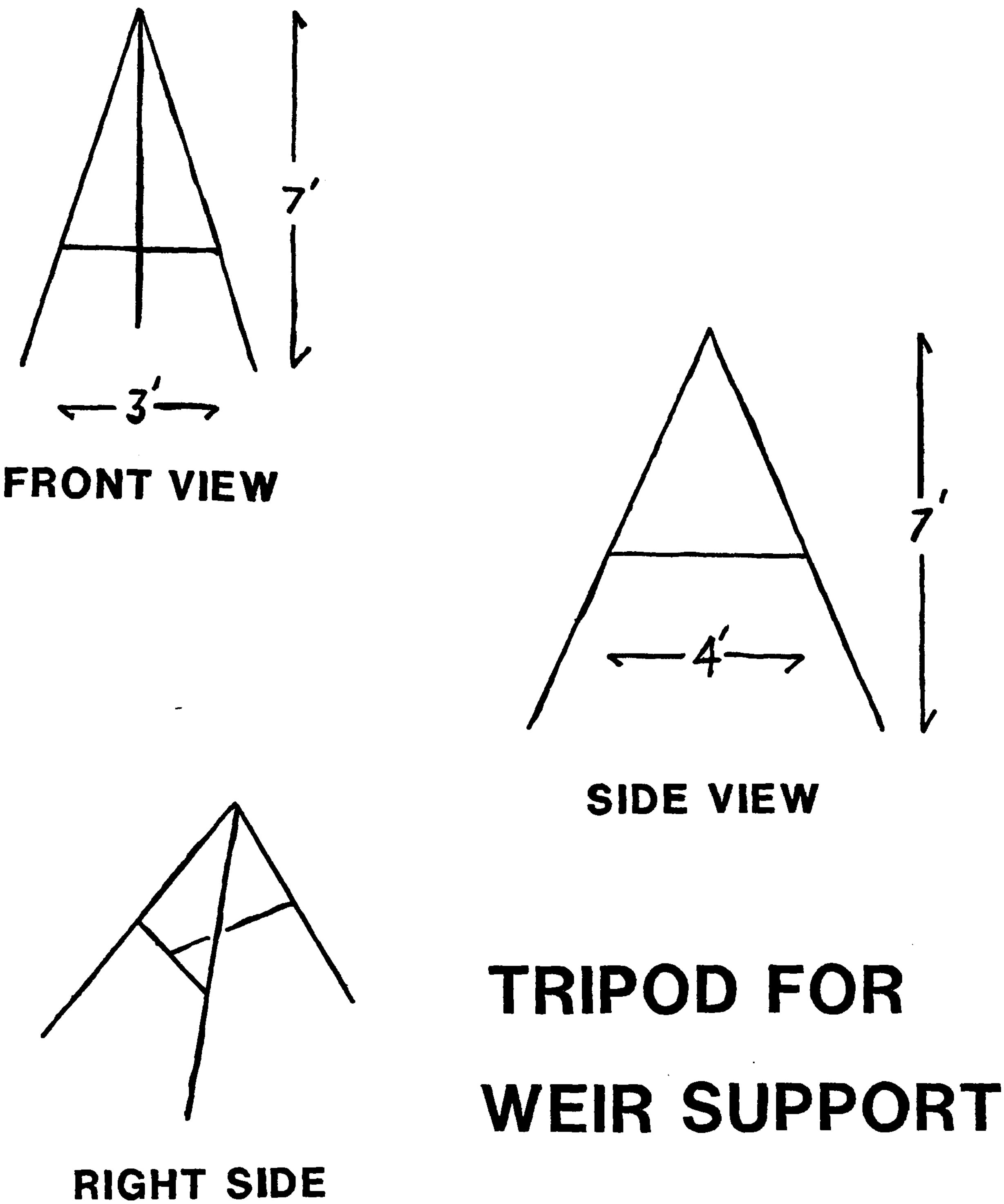
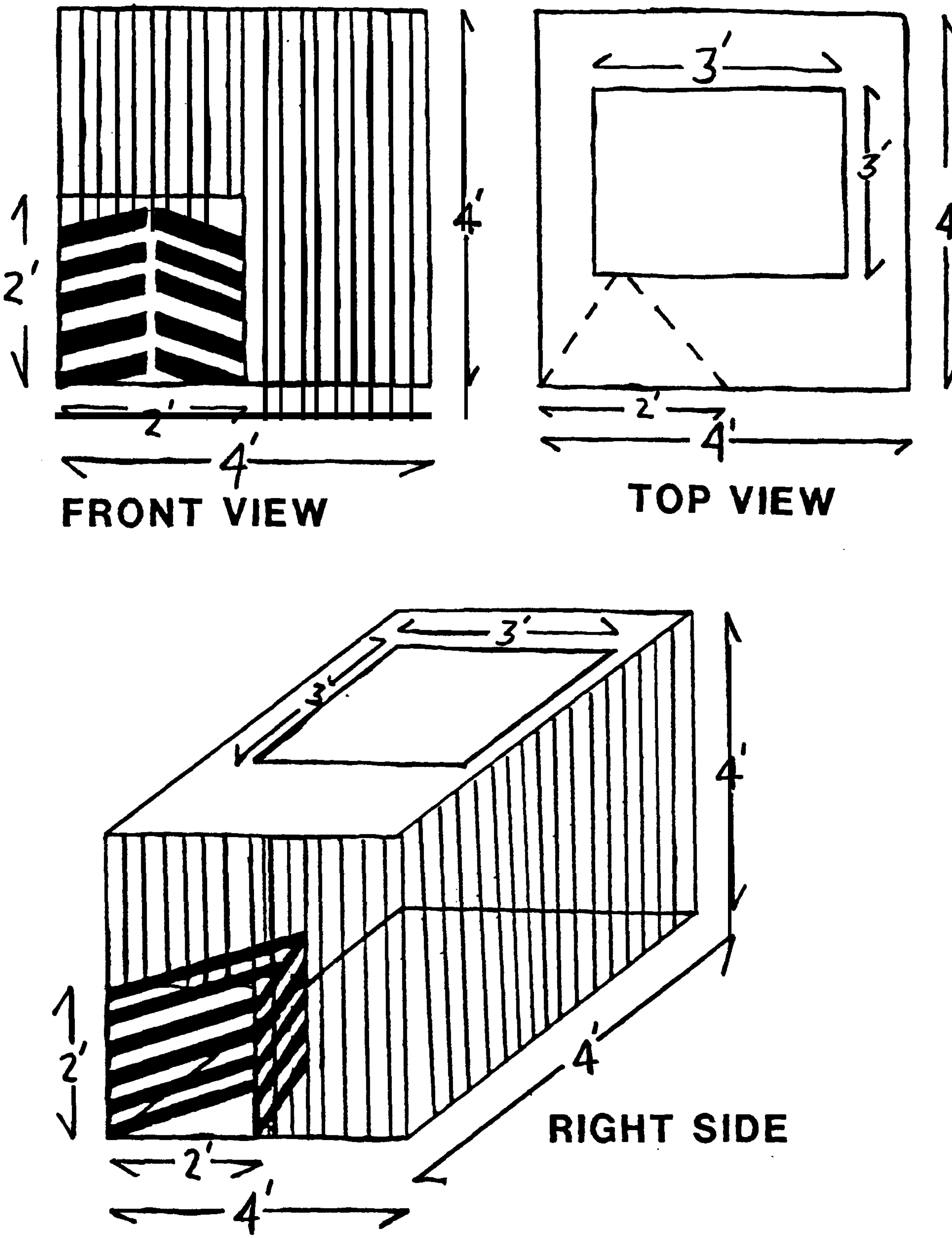

7'
3'
FRONT VIEW
7'
4'
SIDE VIEW
RIGHT SIDE
TRIPOD FOR
WEIR SUPPORT

Figure C-2.



COEUR D'ALENE RIVER CHINOOK SALMON TRAP

Figure C-3.

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