Kokanee Entrainment Losses at Dworshak Reservoir

Dworshak Dam Impacts Assessment and Fisheries Investigation Project

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Kokanee Entrainment Losses at Dworshak Reservoir

DWORSHAK DAM IMPACTS ASSESSMENT AND FISHERIES INVESTIGATION PROJECT

Annual Progress Report
Period Covered: January - December 1996

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ABSTRACT

We used split-beam hydroacoustics to monitor kokanee *Oncorhynchus nerka kennerlyi* abundance in Dworshak Reservoir from 1995 to 1996 in order to quantify the impacts of water releases from Dworshak Dam. The kokanee population was at a record high level of 1.9 million age-1 and age-2 fish (350 fish/ha) during June 1995. Large discharges of water during July and August of 1995 did not result in major losses of kokanee. Mid-winter flooding in February, March, and April of 1996: however, caused entrainment losses of 90% of all kokanee in the reservoir. The population declined to 140,000 kokanee. High flows during spring run-off caused another 50% of the kokanee to be lost, further reducing the population to 71,000 fish (13 fish/ha). Entrainment losses were partially explainable by the distribution of kokanee in the reservoir. During winter, all age-classes of kokanee congregated near the dam making them susceptible to high releases of water. Kokanee appeared to be less susceptible to entrainment during summer and early fall because most kokanee were in other parts of the reservoir: adults were in the upper reservoir staging to spawn, fry were in the upper reservoir having emerged from tributary streams, and juvenile kokanee were spread throughout the reservoir.

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INTRODUCTION

Kokanee *Oncorhynchus nerka kennedyl* provide very popular fisheries in many lakes and reservoirs in the Pacific Northwest (Wydoski and Bennett 1981). Sport harvest for kokanee may exceed several hundred thousand fish annually in some lakes and reservoirs. They are a pelagic zooplanktivore, which can reach relatively high densities even in oligotrophic waters (Rieman and Maiolie 1995). Kokanee can be well adapted to life in fluctuating reservoirs since they rely on the pelagic environment, feed on zooplankton, and some strains spawn in tributary streams.

One negative aspect for kokanee in any body of water with a short retention time is their vulnerability to entrainment. Entrainment losses of kokanee have been documented at Libby Dam (Skaar et al. 1996), Banks Lake, Washington (Stober et. at. 1979), and Dworshak Reservoir (Maiolie et at. 1992). Although losses of kokanee have been reported, the effects of losses on the population are not well documented. In addition, the environmental conditions which precipitate high entrainment losses are not well understood.

In this study, we monitored the population of kokanee in Dworshak Reservoir from 1995 through 1996. We estimated the entire population of kokanee in the reservoir, by age-class, both before and after water releases due to winter flooding, spring run-off, and water releases to benefit anadromous fish migration. Our intent was to quantify the impacts of these water releases on the kokanee population and to determine the conditions, which lead to high entrainment losses.

OBJECTIVE

To maintain densities of 30 to 50 adult kokanee/ha in Dworshak Reservoir by reducing entrainment losses. This range of densities was shown by Rieman and Maiolie (1995) to optimize the sport fishery.

DESCRIPTION OF STUDY AREA

Dworshak Dam is located on the North Fork of the Clearwater River in northern Idaho. At 219 m tall, it is the largest straight-axis concrete dam in the United States. It was built in 1971 for power production and flood control. Three turbines within the dam have a total operating capacity of 450 megawatts. The dam can discharge up to 380 m^3/s (10,000 cfs) through the turbines and another 420 m^3/s (15,000 cfs) through reservoir outlets and the spillway.

The reservoir behind the dam is 86 km long at full pool (Figure 1). Maximum and mean depths are 194 m and 56 m, respectively. Surface area at full pool is 6,644 ha with 5,400 ha of kokanee habitat (defined as the area over 15 m deep). Drawdowns for flood control may lower the surface elevation 47 m and reduce surface area by as much as 52%. The reservoir has a mean retention time of 10.2 months and a mean annual discharge of 162 m^3/s (Falter 1982). High

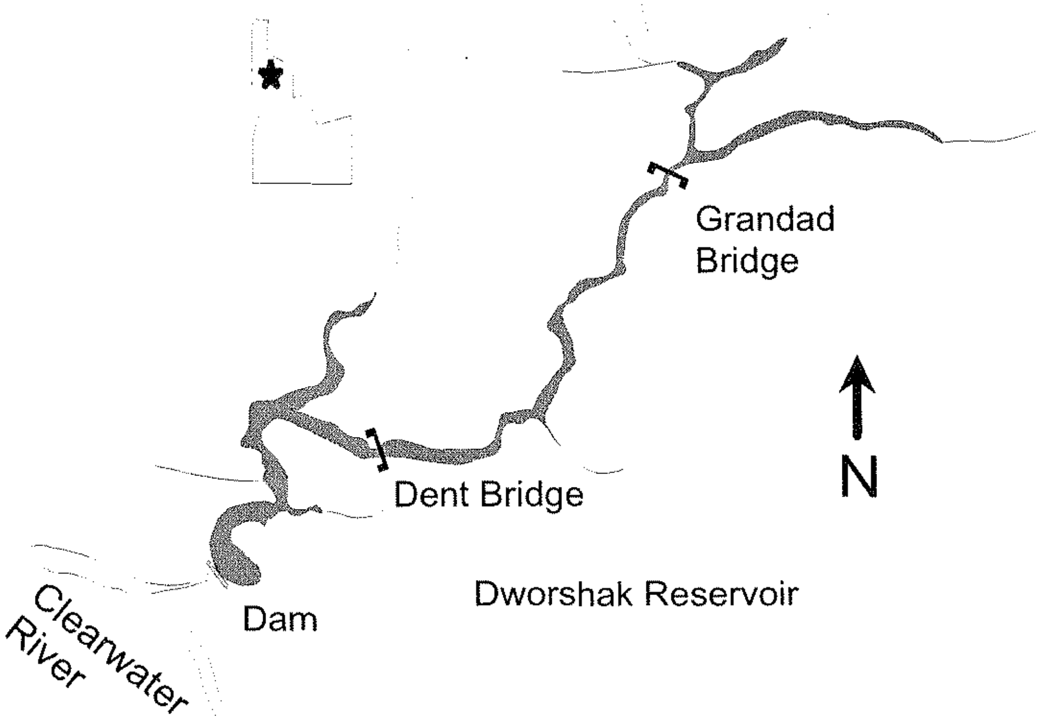

Figure 1. Map of Dworshak Reservoir and its major tributaries, North Fork Clearwater River, Idaho.

releases from the reservoir occur during spring run-off, during the tall when the reservoir is lowered for flood control, and during late summer when water is released for anadromous fish flows.

Kokanee were first stocked into Dworshak Reservoir in 1972 (Horton 1981). Four sources of fish were initially used, but the early spawning strain from Anderson Ranch Reservoir, Idaho now populates the reservoir (Winans et al. 1996). These fish spawned during September in tributary streams as far as 140 km above the reservoir. They reached maturity primarily at age-2, although age-1 and age-3 spawners were occasionally found. Adults ranged in size from 200 to 400 mm in total length depending on density in the reservoir, but generally averaged 300-mm during spawning (Maiolie and Elam 1995).

METHODS

We used a Simrad EY500 split-beam scientific echosounder with a 120 kHz transducer to document the abundance and distribution of kokanee. Boat speed was 1.5 to 2.3 m/s and all surveys were conducted at night. The echosounder was set to ping at 0.7 s intervals, with a pulse width of 0.3 milliseconds. Data were collected with a time varied gain constant of 20 log r (range).
We calibrated the echosounder at the beginning of the year using a 23-mm copper calibration sphere with a target strength of -40.4 dB (decibels) (at 23°C). We checked the calibration of the echosounder prior to each monthly survey, and adjusted the transducer gains if needed.

We configured the echosounder so that only echos meeting certain criteria would be regarded as a fish. First, the returned echo had to be greater than -60 dB. The length of the returned echo had to be between 0.8 and 1.8 times the length of the echosounder's ping. The echo could not require more than 4.0 dB compensation for being off the acoustic axis, and the target had to be within a 7.1° cone. Echos meeting these criteria were classified as a fish "trace" (a single returned echo from a single fish).

Fish density estimates were calculated using EP-500 software, version 4.5. Densities were based on echo integration techniques to account for fish within schools that could not be distinguished as single targets. We analyzed only the pelagic region of each echogram, generally from depths of 5 m to 50 m.

Kokanee age-classes were separated by graphing a frequency distribution of the fish's target strengths. We then examined the frequency distribution to define the three peaks, which corresponded to the three age-classes of kokanee. We defined age-0 kokanee as fish between -60 dB and -48 dB during surveys conducted after June each year. Age-1 kokanee were defined as fish between –48 dB and -42 dB in April, and –48 dB and -39 dB during the remainder of the year. Age-2 kokanee were defined as fish between –41 dB and -33 dB in April and -38 dB and -33 dB the remainder of the year. Our analysis ended at -33 dB since few fish were detected over this size. We placed confidence limits only on the combined estimate of age-1 and age-2 fish since target strengths of these two groups overlapped. This was particularly true when kokanee densities were high and size differences were small. For the purpose of mapping kokanee distributions in the reservoir, we defined age-0 kokanee as fish between –60 dB and -54 dB in June and August. These conservatively small targets were used to eliminate the chance that age-1 fish were included in the distribution of fry.

Reservoir-wide hydroacoustic surveys were conducted to estimate kokanee abundance before and after the large releases of water. We used a systematic, stratified survey design (Scheaffer et al. 1990). The reservoir was stratified into three sections: from the dam to Dent Bridge, Dent Bridge to Grandad Bridge, and Grandad Bridge to the headwaters (Figure 1). Mean fish densities in each reservoir section were multiplied by the area of that section then totaled to obtain population estimates. Ninety-percent confidence limits were placed on the total kokanee population estimates by formula for stratified systematic designs (Scheaffer et al. 1990).

Survey transects were spaced at 3.2 km intervals throughout the length of the reservoir using Global Positioning System (GPS) locations. Surveys were conducted in 1995 on April 10 and 11, June 13 and 14, and August 15 and 16. In 1996, surveys were conducted on February 14 and 15, April 15 and 16, July 8 and 9, and October 17 and 18. These dates were selected so we could monitor the population before and after spring run-off (May and June) and discharges for anadromous fish migrations (July and August).

We felt confident that nearly all-pelagic fish in Dworshak Reservoir were kokanee based on mid-water trawling at night from 1987 to 1994. Trawl catch was composed of >99.5% kokanee with an occasional Pacific lamprey *Entosphenus tridentatus*, smallmouth bass *Micropterus dolomieui*, or black crappie *Pomoxis nigromaculatus* in the trawl samples (Idaho Department of Fish and Game data files).

We counted kokanee in three tributaries to Dworshak Reservoir to serve as an additional relative index of the adult population. Counts of spawning kokanee were performed in Isabella

Creek, Skull Creek, and Quartz Creek. We walked these streams from mouth to the furthest upstream reaches utilized by kokanee. These tributaries were surveyed annually from 1981 to 1997 on or near September 25, which was the peak of kokanee spawning (Horton 1980).

Data on discharge from the dam were obtained from the U.S. Army Corps of Engineers.

RESULTS

Population estimates of age-1 and age-2 kokanee in the reservoir remained high during all of 1995. Estimates were as high as 1.9 million fish during June of 1995 (Table 1 and Figure 2). By August 1995, the mean population estimate was still 1.6 million kokanee, which is a large population for Dworshak Reservoir.

Table 1. Population estimates of kokanee in Dworshak Reservoir, 1995 to 1996, based on hydroacoustic surveys. Kokanee enter next age group on January 1 each year, and all age-2 fish were assumed to spawn and die during September of each year.

Date	Number of age-0 kokanee	Number of age-1 kokanee	Number of age-2 kokanee	Population estimate of age-1 and age-2 (+/- 90% C.I.)
April 1995	-	908,000	790,000	1,698,000 (+/- 289,000)
June 1995	1,635,000	1,309,000	595,000	1,904,000 (+/- 362,000)
August 1995	1,560,000	977,000	610,000	1,587,000 (+/-397,000)
February 1996	-	433,000	1,010,000	1,443,000 (+/- 1,082,000)
April 1996	-	37,800	111,000	148,000 (+/- 90,500)
July 1996	231,000	42,600	28,900	71,500 (+/- 24,300)
October 1996	235,000	37,425		37,400 (+/- 26,700)

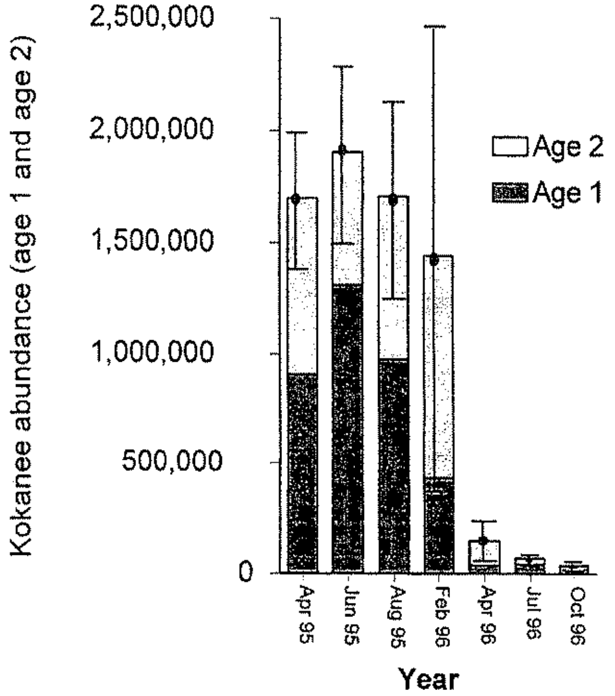

Figure 2. Population estimates of age-1 and age-2 kokanee during seven hydroacoustic surveys of Dworshak Reservoir, Idaho during 1995 and 1996. Ninety-percent confidence limits on the total population estimates are shown

Between our surveys in August 1995 and February 1996, most of the age-2 kokanee matured and died, the age-1 fish became age-2, and the age-0 fish from 1995 became age-1. Even with these changes, the population of age-1 and age-2 fish remained at a high level of 1.4 million fish (Figure 2).

Very large declines in kokanee abundance occurred between February and April 1996 as the population dropped from 1.4 million to 148,000. These two age groups of kokanee declined further to 71,000 kokanee during July. The population dropped to 37,000 fish by October 1996 as the age-2 kokanee matured and died in September (Figure 2).

We split the age-1 and age-2 population estimates on the basis of fish target strengths to determine how each age group was affected. We noted large declines occurred in age-1 kokanee between February and April 1996 (91% decline). For the remainder of 1996, the population of age-1 fish remained stable (Table 1 and Figure 2). Similarly, age-2 kokanee also showed large declines between February and April 1996 (89% decline), but they also showed a second decline between April and July 1996 (74% decline) (Table 1 and Figure 2).

We found that kokanee changed their distribution throughout the reservoir during the year. *During surveys in April 1995, and February and April 1996, kokanee of all age-classes were found* in the lower end of the reservoir near the dam (Figure 3). Surveys during June 1995 and July 1996 indicated age-1 and age-2 kokanee were spread throughout the reservoir. During August 1995 kokanee of age-1 and age-2 were found in much higher densities at the upper end of the reservoir.

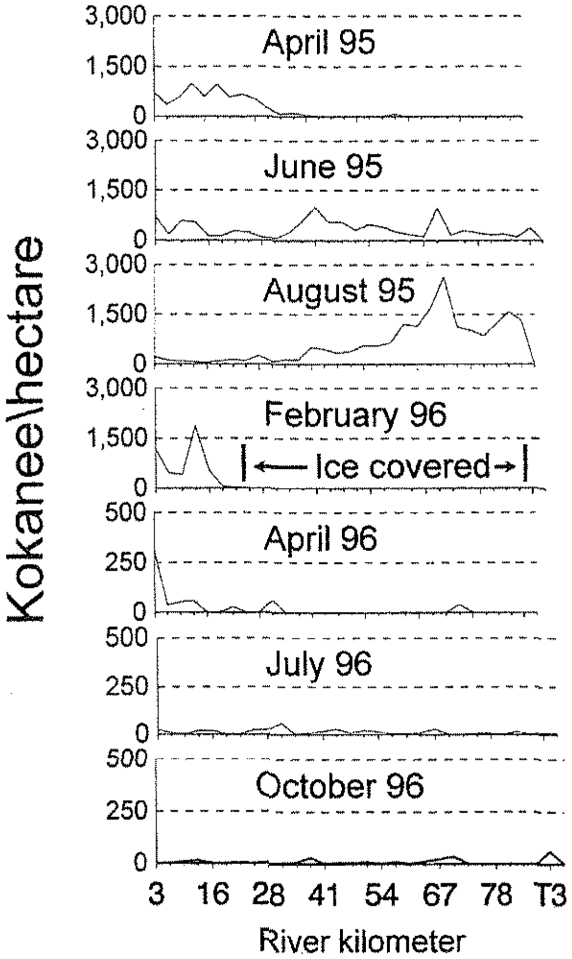

Figure 3. Distribution of age-1 and age-2 kokanee throughout Dworshak Reservoir, Idaho, April 1995 to October 1996. Dam is located at river kilometer 3 and T3 is 3 km up the Little North Fork Arm near the headwaters of the reservoir.

The distribution of kokanee fry in the reservoir was different from other age groups. Most tributaries suitable for kokanee spawning are located at the upper end of the reservoir. Understandably, we documented high densities of fry in the upper reaches of the reservoir between June and August as fry moved out of tributary streams (Figure 4). Surveys conducted in October 1996 indicated that kokanee fry had spread throughout the reservoir by this time (Figure 4). Fry then appeared to move down the reservoir and congregate near the dam during February 1996 (fry become age-1 on January 1) (Figure 3).

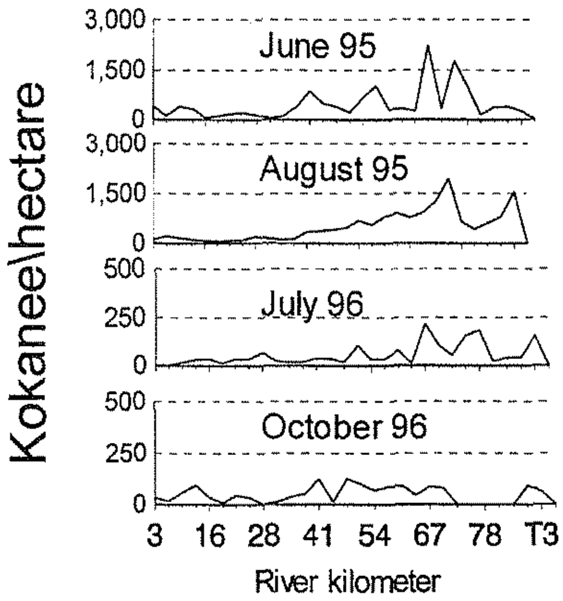

Figure 4. Distribution of kokanee fry throughout Dworshak Reservoir, Idaho, 1995 and 1996. Dam is located at river kilometer 3 and T3 is 3 km up the Little North Fork Arm near the headwaters of the reservoir.

Estimates of fry abundance in 1996 (230,891 fry in July) were much lower than fry estimates in 1995 (1.6 million fry in June) (Table 1). The fry in 1996 would have been eggs buried in the gravel of tributary streams during the winter flooding of 1995-96.

Declines in counts of spawning kokanee were consistent with declines based on hydroacoustics estimates (Figure 5). During 1996, only 2,570 kokanee were counted in the three tributaries that were surveyed. This was a 93% decline from the 36,480 kokanee counted in 1995. Spawner counts in 1997 dropped further to only 144 fish, which was an all time low count for the population. These counts also indicated that large declines in kokanee abundance occurred during 1983, 1987, and 1991 (Figure 5).

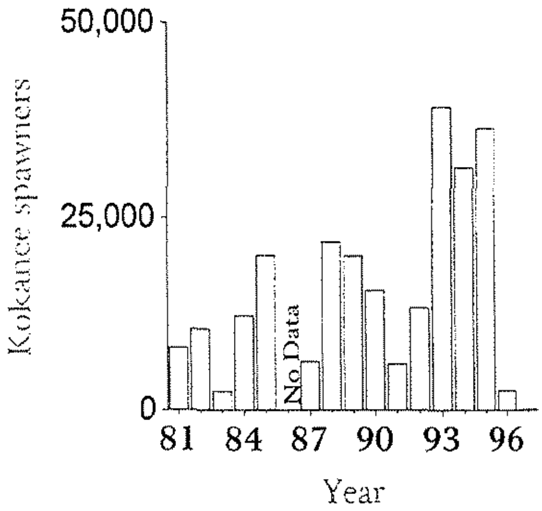

Figure 5. Counts of spawning kokanee in three tributaries (Isabella, Skull, and Quartz creeks) to Dworshak Reservoir, Idaho, from 1981 to 1997

Mean monthly flows from Dworshak Dam varied from a low of 30 m^3/s to a high of 610 m^3/s during 1995 and 1996 (Figure 6). High flows occurred during spring run-off of 1995 and 1996 with flows reaching 280 m^3/s and 260 m^3/s, respectively. High releases from the dam also occurred during July and August of each year to aid anadromous fish below the dam. These discharges averaged 380 m^3/s in August 1995 and 400 m^3/s in August 1996. The highest discharge recorded in these two years was during the winter flooding in March 1996 when flows averaged 610 m^3/s (Figure 6); which coincided with the large declines in kokanee abundance. This was in sharp contrast to the previous year's flow of only 30 m^3/s during January, February, and March 1995.

DISCUSSION

Very high losses of kokanee occurred from Dworshak Reservoir during the late winter and early spring of 1996. We estimated that 95% of the age-1 and age-2 kokanee disappeared from the 86 km long reservoir in a period of five months. Two conditions were present during these high losses. First, discharge through the dam was very high (610 m^3/s for a mean monthly discharge during March 1996). Secondly, the high discharges occurred during late winter and spring when kokanee were concentrated near the dam (nearly the entire population was within 13 km of the dam during February 1996). The concentration of all age-classes of kokanee near the dam explains how a high percentage of the population could be lost from a long reservoir in such a short period of time.

The loss of nearly 1.4 million kokanee was well beyond the population's ability to compensate within this generation of fish. Reductions in other forms of natural mortality could not compensate for a 95% mortality due to entrainment, thus entrainment losses did have a strong and

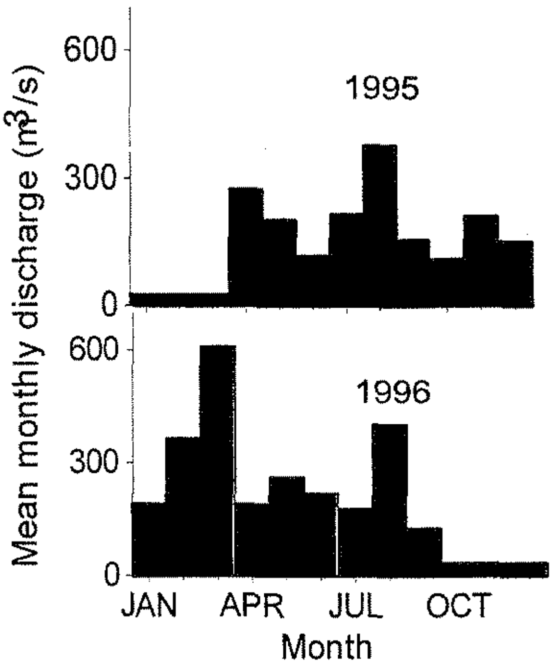

Figure 6. Mean monthly discharge for Dworshak Dam, Idaho, during 1995 and 1996.

obvious effect on the population. Some compensation may occur within the next generation of kokanee possibly through better egg to fry survival and through a higher fecundity in mature females. Considering the low numbers of kokanee left in the population, it is doubtful the population will rebound within one generation.

Counts of spawning kokanee also supported the finding that very large losses occurred in 1996 as well as in several previous years (Figure 5). These large entrainment events have occurred about every four or five years from 1981 to 1997, indicating this was not an isolated event. What appeared to be unique, however, was that entrainment losses in 1996 included both age-1 and age-2 kokanee. Fry abundance was also very low in 1996 indicating that eggs in tributary streams were impacted by flooding (Table 1). Possibly, egg mortality was high since they were subjected to redd destruction or sedimentation. Thus, a whole generation of kokanee has been severely reduced. High releases of water during July and August of 1995 did not cause massive entrainment losses of kokanee. Populations of age-1 and age-2 kokanee dropped only 16 % between June and August 1995 even though the reservoir elevation was lowered 24 m and discharge averaged 380 m^3 /s for August (Table 1 and Figure 6). The impact of this drawdown was minimized by the distribution of kokanee in the reservoir. Kokanee fry at this time of year were in the upper reaches of the reservoir. Age-1 kokanee were spread throughout the reservoir, and adult kokanee were moving toward the upper end in preparation for spawning (Figure 3).

The sport fishery on Dworshak Reservoir was also greatly affected by the fish losses in 1996. Mauser et al. (1989) calculated a harvest of 207,000 kokanee from the reservoir during 1988 with 140,000 hours of angling effort. No creel survey was conducted in 1996, however angling effort had dropped to only a fraction of its former level with very few anglers even fishing for kokanee. Obviously, having an adult kokanee population of only 29,000 fish could not support the sport fishery at its former harvest level of several hundred thousand fish annually.

During the late winter and early spring of 1996, many dead and dying kokanee could be seen floating down the Clearwater River below Dworshak Dam. Numbers of fish were high enough that the Idaho Department of Fish and Game opened a salvage fishery on the river, which allowed these injured kokanee to be netted or picked up from the river. A 50 fish limit was imposed, but this was later removed because of people's desire to collect more fish.

CONCLUSIONS

Our study has shown that massive losses of kokanee can occur from large storage reservoirs. In the case of Dworshak Reservoir, 95% of the age-1 and age-2 kokanee in the entire reservoir were lost in a five-month period of time. The exceptionally high entrainment occurred during a period of late winter and spring flooding. We found during this time kokanee were congregated near the dam making them particularly vulnerable to entrainment. Conversely, large releases of water in July and August had little effect on the population. This was likely due to adult kokanee movements up the reservoir during summer and the fact that age-1 kokanee were distributed throughout the reservoir. Lastly, we found that split-beam hydroacoustics can be an effective tool in monitoring kokanee populations.

RECOMMENDATIONS

1. The kokanee population in the reservoir is so low that some benefit could be derived by stocking kokanee fry. This could help the population build towards our objective of 30 to 50 adults/ha assuming that future entrainment losses will be lower than in 1996.

2. Researchers should look for methods to "screen" the outlets of the reservoir to prevent fish losses. Options include strobe lights, sound producing devices, or physical barriers such as screens or nets.

ACKNOWLEDGMENTS

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