DWORSHAK DAM IMPACTS ASSESSMENT & FISHERIES INVESTIGATIONS

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CHAPTER 1

HISTORY OF KOKANEE DECLINES IN LAKE PEND OREILLE, IDAHO

ABSTRACT

Lake Pend Oreille, 38,000 hectares, is Idaho's largest natural lake. Fisheries for kokanee Onchorynchus nerka, rainbow trout Onchorynchus mykiss, and bull trout Salvelinus confluentus have gone through major declines over the last 40 years. To date, the decline in kokanee abundance has not been fully explained. Water level management may be the single largest contributing factor to this decline. Two aspects of water level management appear critical. Dropping water level once kokanee spawning has occurred was correlated with poor fishery harvest five years later ($r = -0.71$) ($\alpha = 0.005$). Secondly, dropping the water level more than 2 m immediately before spawning leaves wave-washed gravel high on the bank and forces kokanee to spawn in low quality substrates, which again reduces survival. Changes in water level management coincided with the sharp declines in the kokanee fishery during the 1960s. Although the water level has been stabilized once spawning has occurred, the deep drawdowns resulting in poor spawning substrates continues to cause problems for the kokanee population. Recognizing the importance of these two factors gives hope that changes in water management can reverse the 30-year trend of declining kokanee populations before they are lost from the system. We recommend an experimental test of higher winter lake elevation for several years to document potential changes in kokanee abundance.

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INTRODUCTION

This report addresses the history of declines in one of Idaho's premiere fisheries. It is an attempt to review past research and explain the causes of the kokanee decline.

The Systems Operation Review (SOR) is being conducted by the Bonneville Power Administration, the Army Corps of Engineers, and the Bureau of Reclamation. The goal of the SOR is to integrate the management of 14 dams on the Columbia River Drainage. Albeni Falls Dam, which controls the elevation of Lake Pend Oreille, is one of these projects. To understand the consequences of changing water levels in Lake Pend Oreille, it is first important to understand the effect past changes in water levels have had on the kokanee population.

STUDY AREA

Lake Pend Oreille is a natural oligotrophic lake formed by continental glaciers which receded approximately 10,000 to 30,000 years ago (Figure 1). It is Idaho's largest (38,000 hectares) and deepest lake (400 m). Summer mean temperatures averaged 13°C in the upper 15 m of the water column (Rieman and Bowler 1980). Thermal stratification typically occurs from late June to September. The main body of the lake rarely has ice cover during winter.

Fisheries on the lake are currently calculated to be worth millions of dollars in actual expenditures and to be worth millions more in intrinsic value. Several towns on the shore of the lake rely heavily on tourism for economic stability. Native species in the lake include westslope cutthroat trout <u>Oncorhynchus clarkii lewisi</u> and bull trout. Gerrard strain of Kamloops rainbow trout were first stocked into the lake in 1941, and the current world record rainbow trout of 17 kg (37 pounds) was caught here in 1947. Rainbow trout are still commonly caught which are over 10 kg. Kokanee entered the lake in the 1930s by migrating downstream from Flathead Lake Montana. They became established and formed a regionally important fishery. Fishing effort on Lake Pend Oreille was as high as 100,000 angler days during the 1950s (Irizarry and Ellis 1975). Kokanee mature at 25 to 35 cm in length and are the primary forage for bull trout and rainbow trout. Currently, the fishery is managed to provide a consumptive yield fishery for kokanee and a trophy fishery for rainbow and bull trout. The success of both of these fisheries is dependent to a large degree on wild kokanee that utilize shoreline spawning gravels.

Cabinet Gorge Dam was built on the Clark Fork River, the major tributary to the lake, in 1952. This dam blocked all upstream fish migration into 90% of the drainage, thus preventing spawning of a segment of the populations of bull trout, kokanee, and rainbow trout.

A second dam, Albeni Falls Dam, was built on the Pend Oreille River. It was also built in 1952. This dam continues to control the elevation of Lake Pend Oreille and has changed the elevations of the lake considerably. Under pre-dam conditions, the lake was low in winter and early spring (624.2 m, 2,048 feet elevation), but then filled with spring run-off to a high pool elevation (628.2 m, 2,061 feet) (Figure 2). The water level rapidly dropped during July back to the low pool elevation. Once Albeni Falls Dam was in place, the lake was kept at a high stable elevation (628.7 m, 2,062 feet) throughout summer and dropped to a lower elevation (626.7 m, 2,056 feet, or in more recent years 625.1 m, 2,051 feet) throughout the winter (Harenberg et al. 1990).

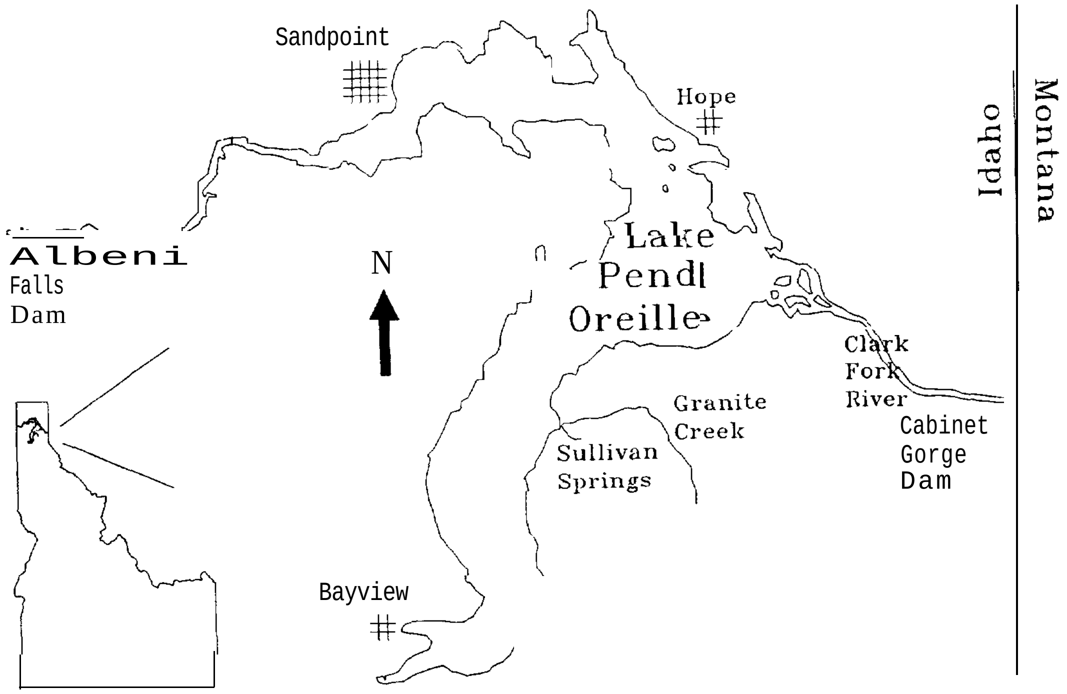


Figure 1. Map of Lake Pend Oreille, Idaho, showing location of towns and dams.

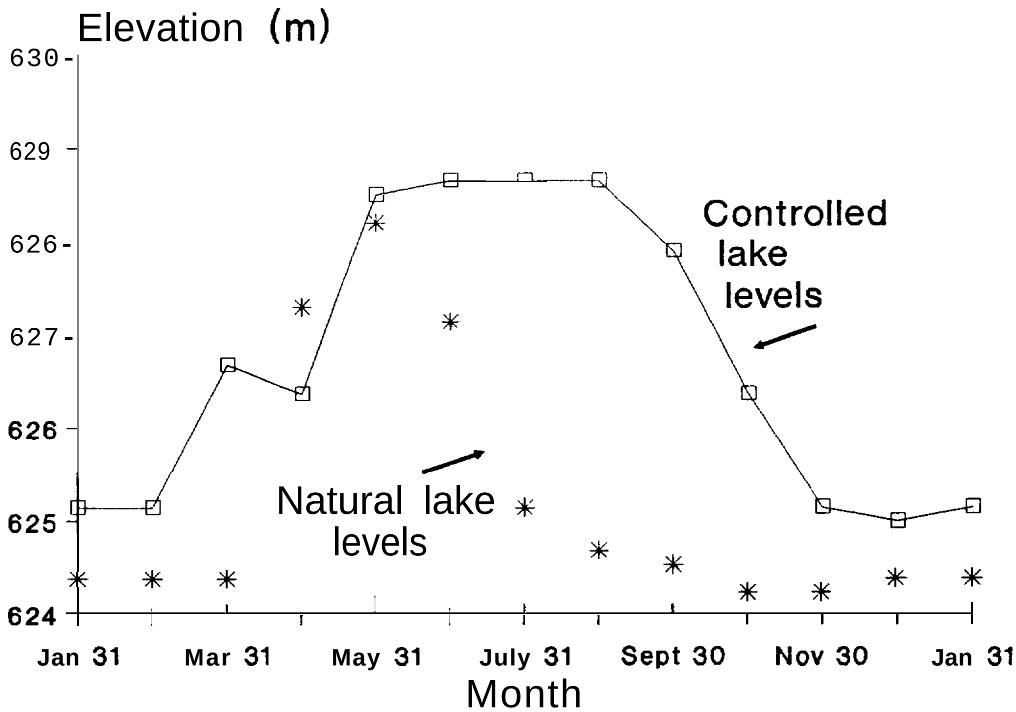


Figure 2. Natural elevations and post-dam elevations for Lake Pend Oreille, Idaho.

OBJECTIVES

1. To determine the effects of water level management on the kokanee population in Lake Pend Oreille.

2. To provide this information in a form usable to the Systems Operation Review.

HISTORY OF THE KOKANEE FISHERY

The Idaho Department of Fish and Game (IDFG) began creel surveys on Lake Pend Oreille in 1951. Summaries of creel survey information are found in Ellis and Bowler (1980), Bowles et al. (1987), and Paragamian et al. (1991). From 1951 to 1957, kokanee harvest was thought to be largely independent of the construction of either dam. Kokanee have predominantly a 5-year life cycle, so the effects of dam operation on eggs or spawning adults would have first been observed in the fishery in 1957. During this time period (1951-1957), kokanee harvest averaged 914,000 fish (Figure 3). The kokanee harvest remained high from 1957 to 1966, with harvests averaging 1,008,000 kokanee annually. During these years, harvest varied and ranged from a low of 651,000 kokanee to 1.2 million kokanee in 1962 and 1958, respectively.

Harvest began declining in about 1966, and reached a low point in 1985 of 82,000 fish (Bowles et al. 1987) (Figure 3). This represents a decline of 92% from the 1 million fish averages in the late 1950s. With intensive hatchery stocking of 13 million fry in 1988, harvest increased to 227,000 kokanee in 1991. This increased harvest was thought to be a short-lived "recovery" since the number of fry stocked was reduced to 5 to 6 million fish annually (Paragamian et al. 1992).

CAUSES OF THE KOKANEE DECLINE

Several theories have been postulated for the decline of kokanee. One theory was that the blockage of the Clark Fork River by Cabinet Gorge Dam impacted the spawning population. Cabinet Gorge Dam became a barrier to upstream fish migration in the spring of 1951 (Anonymous 1983). Rich (1954) mentioned good records of large runs and large catches of kokanee in the Clark Fork River before Cabinet Gorge Dam was built. He stated that there was no way to determine what percentage of fish were spawning in the river, but that it must have been "appreciable."

In spite of this blockage, the fishery averaged one million fish harvested annually for the next 12 years (Figure 4). These kokanee had predominantly a 5-year life cycle and so completed over two generations without any apparent long-term declines. Possibly there was a delayed effect of blocking the Clark Fork River spawning run, but since no declines occurred for the next 12 years, this seems unlikely. More likely, there was sufficient spawning elsewhere in the system (shoreline areas) to fully seed the population and prevent fishery declines. Observations made in 1951 by the United States Fish and Wildlife Service estimated that "the lake was of considerably greater importance for spawning than were the tributaries" (Rich 1954), although this observation was questioned in forthcoming years.

A second potential reason for the kokanee decline was commercial fishing. It was never seriously considered as the cause of declines, since exploitation was thought to be only 10-20% (Bowler 1980). Also, commercial fishing was ended

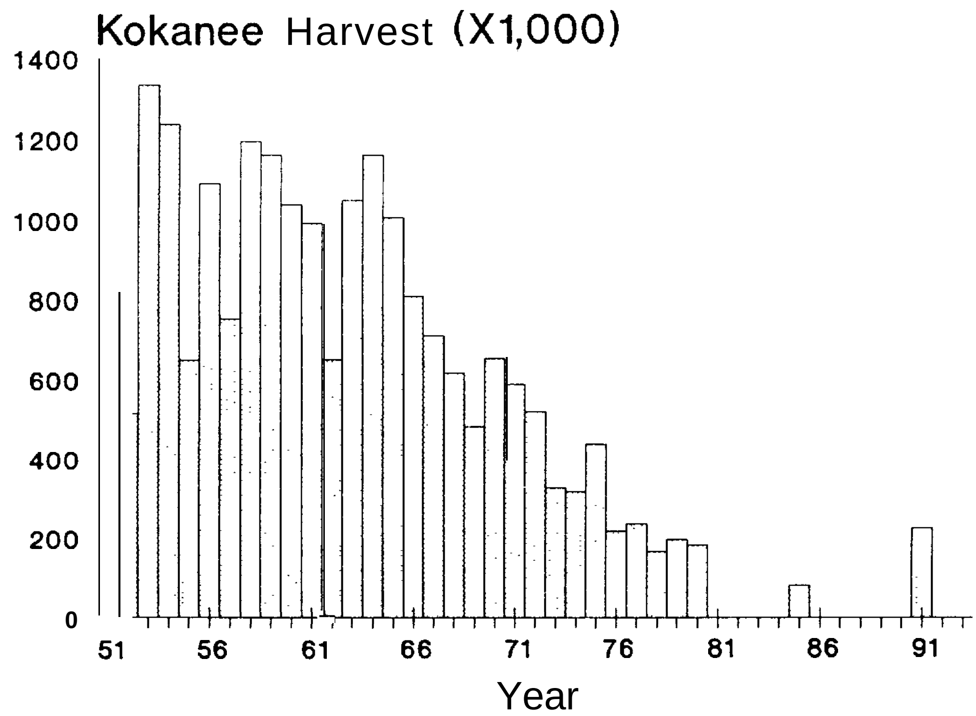


Figure 3. Kokanee harvest from Lake Pend Oreille, Idaho, 1951 to 1991.

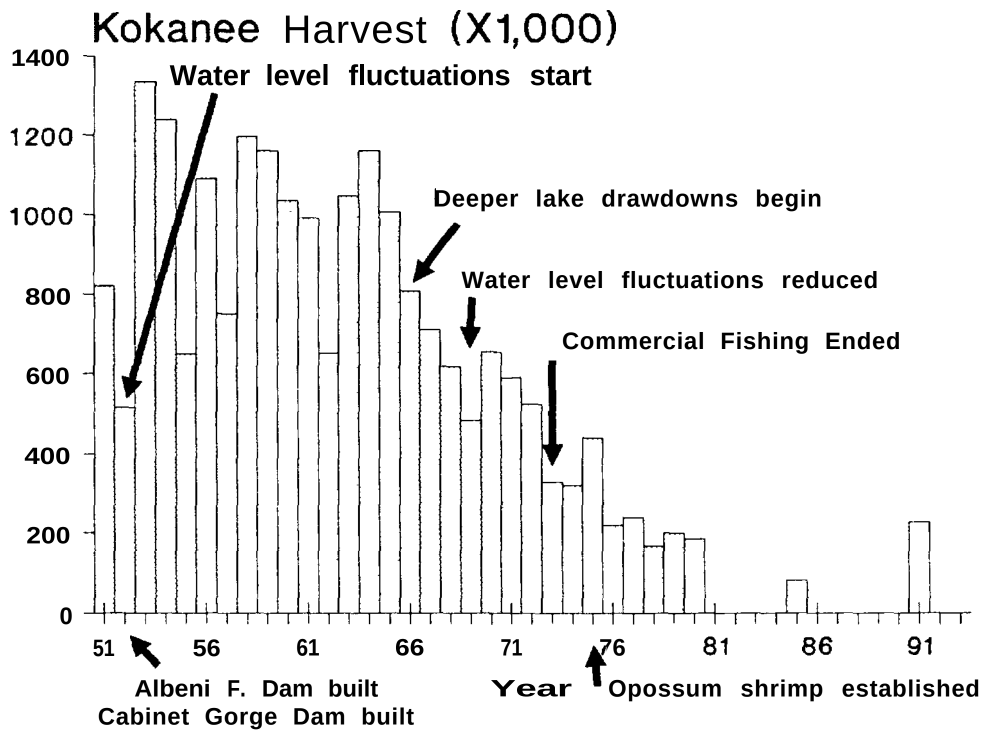


Figure 4. Kokanee harvested from Lake Pend Oreille, Idaho, with the timing of significant events added.

in 1973, and no increases were noted in the fishery in following years. This would indicate other factors were involved.

Recently, biologists, managers, and the public have suggested opossum shrimp *Mysis relicta* as the foremost reason for the declines of kokanee. Shrimp were first introduced to the lake in 1966. By 1972, their densities were estimated at only 0.1 mysid/m^3. Densities began to increase, and by 1974, estimates of 1.2 shrimp/m^3 were recorded (Bowler 1975). Shrimp densities then increased from about 5 shrimp/m^3 in 1975 to 35 shrimp/m^3 in 1976. Currently, their densities have varied from 15 to 60 shrimp/m^3 (Paragamian 1993, in press). Based on this trend in the data, shrimp most likely became "established" in approximately 1975. The lag time in the establishment of opossum shrimp for 9 years after initial stocking is consistent with other locations world wide (Nesler and Bergersen 1991). This points out the main problem with the idea that shrimp caused the kokanee decline. By the time shrimp became established, kokanee had been declining for about 10 years and were already at a rather depressed level (Figure 4). It therefore appears that factors other than shrimp caused the initial large declines of kokanee.

Rieman and Falter (1981) suggested that the declines in kokanee after 1974 could be due to mysids delaying the spring-time increases in cladoceran abundance. This remains a viable hypothesis, but it is important to remember that it was not an attempt to explain the overall cause of kokanee declines.

Water temperature profiles in Lake Pend Oreille showed that a substantial volume of water >14°C exists in the lake throughout summer (Paragamian et al. 1992). Water of this temperature is known to be a barrier to opossum shrimp, and thus forms a refuge for the development of abundant zooplankton populations (Rieman and Falter 1981, Martinez 1986). A similar situation exists in Grandby Lake, Colorado, where researchers concluded that shrimp had no significant effect on the total kilograms of kokanee harvested, the number of kokanee harvested, the kokanee spawner size, or the kokanee egg take (Martinez and Wiltzius 1991).

Thus, none of the current theories offered a complete explanation of the kokanee declines.

ROLE OF LAKE LEVEL MANAGEMENT

Mid-winter Drawdowns of Lake Level

The late-spawning strain of kokanee in Lake Pend Oreille are primarily shoreline spawners. They typically spawn on gravel substrate at a depth of 0.4 to 0.8 m of water, although redds have been recorded to depths of 2.4 m (Hassemer 1984). Winter drawdowns of the lake have been as large as 3 m (Figure 5). During the kokanee declines of the early and mid-1960s, the lake was lowered as much as 1.7 m after spawning had occurred.

Early researchers on Lake Pend Oreille recognized the relationship between lowering the lake levels and the resulting impact on egg incubation success in shoreline redds (Hassemer 1984, Anonymous 1983). Simply stated, if the water level was lowered after spawning occurred, the eggs become desiccated or frozen. The inverse relationship between drawdown after November 15 (the time kokanee spawning begins in earnest) and the fishery 5 years later was highly significant ($P = 0.005$, $r = -0.71$) for the years 1952 to 1966 (Figure 6). This negative trend, however, only continued until 1966. After this time, even holding the water level relatively stable throughout the winter resulted in a poor kokanee fishery.

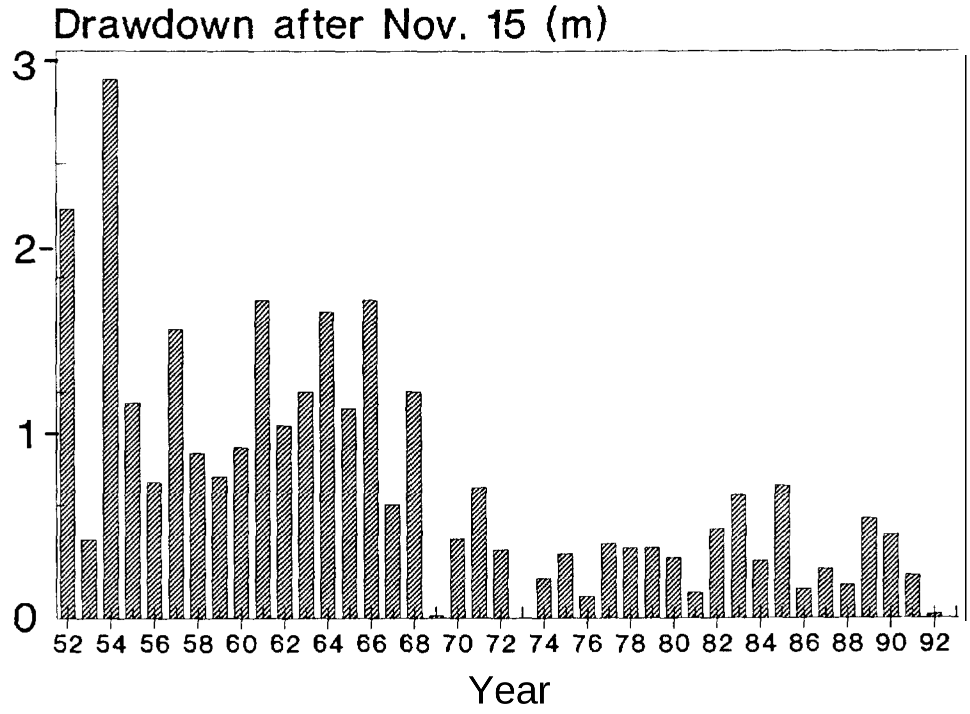


Figure 5. The reduction in lake elevation in Lake Pend Oreille, Idaho, after the initiation of kokanee spawning (November 15).

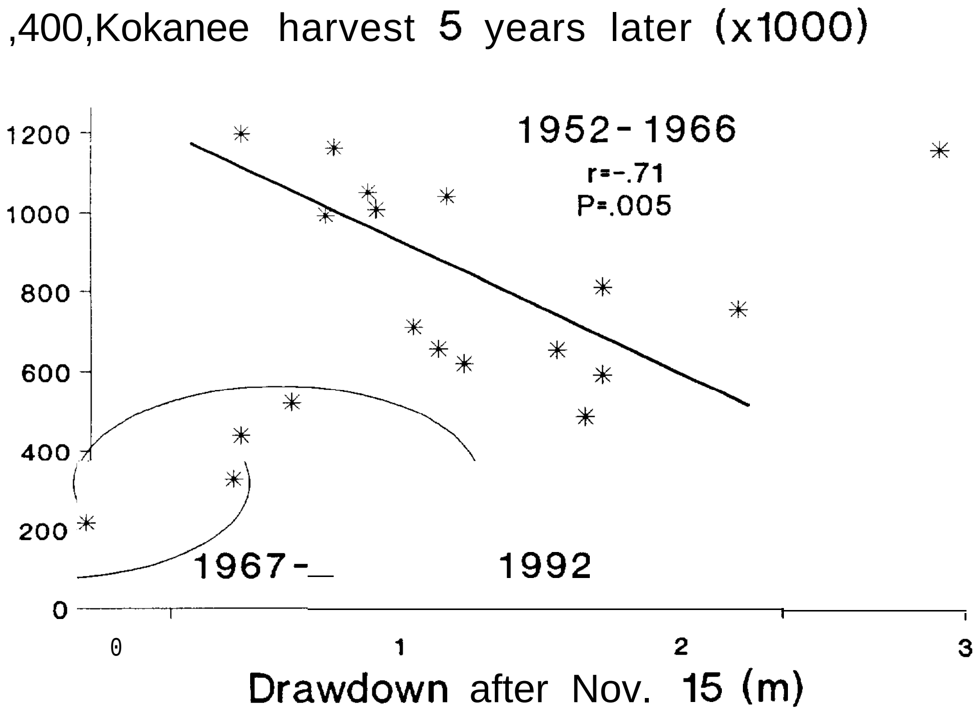


Figure 6. Relationship between winter drawdown of Lake Pend Oreille, Idaho, and the kokanee harvest five years later. One point (upper right) was omitted from the regression analysis because it represented a late spring drawdown.

The Idaho Department of Fish and Game reached an agreement with the Army Corps of Engineers in 1968 to minimize the fluctuation in lake levels once kokanee eggs were spawned. In spite of this agreement, kokanee harvests continued to decline (Figure 4). Based on this finding, it appeared that some other factor(s) was contributing to the decline. It also pointed out that this other factor(s) appeared to influence the kokanee population beginning around 1966.

Winter Lake Elevations

The natural level for Lake Pend Oreille was for the lake to be low throughout summer, fall, and winter, and then to rise 3 to 4 m during spring runoff (May and June). By July the lake would rapidly fall to its summer through winter pool elevation of 624 m (2,048 feet above sea level) (Figure 2). Regulation by Albeni Falls Dam changed this pattern beginning in 1952. After this date, the lake was held high and stable during June through September. The lake level is dropped during October to reach the low point for the year (Figure 2).

The winter pool elevation for Lake Pend Oreille has not always been the same. The dam has had two distinct patterns of operation (Figure 7). From 1955 to 1965, winter minimum elevation was relatively high, about 626.7 m (2,056 feet). This elevation provided space for flood control. Beginning in 1966, the lake was drawn down to a lower elevation of about 625.3 m (2,051.5 feet) to enhance power production.

This change in operation coincided with the change in the relationship in Figure 6. It therefore appears that drawdowns of the lake level after spawning occurred were controlling the fishery from 1952 to 1966. Beginning in 1966, the deeper drawdown of the lake, for addition power production, appears to have become the predominant factor controlling the fishery. From 1966 to the present date, kokanee harvest has been poor due to the low quality substrates available for spawning even though mid-winter changes in lake elevation were minimized. Of all the factors examined (opossum shrimp, commercial fishing, dam construction, and water level management), only low winter pool elevations and mid-winter drawdowns occurred during the time of the major kokanee declines.

Lake elevations appear to relate to the years of good and poor harvests in the kokanee fishery, even back as far as 1957 (Figure 8). For example, the low elevation of the lake in 1957 may have at least partially precipitated the reduced harvest in 1962. Similarly, the higher lake elevations in 1958, 1959, and 1960 may have contributed to the improved harvests in 1963, 1964, and 1965 (Figure 8). The kokanee harvests dropped to a lower level within two generations once the lake was routinely dropped to a lower minimum pool.

Depth of drawdown is thought to control kokanee abundance by controlling the quality of the spawning substrate. With the higher stable summer pool elevations, waves clean the shoreline gravel around the perimeter of the lake to a depth probably dependant on current velocity. With the deeper drawdowns, the lake level is dropped below the zone of clean wave-washed gravel. Kokanee must then spawn in substrates containing a high percentage of fine sediment which reduces egg survival.

Hassemer (1984) recognized the poor quality substrates being utilized by kokanee. He stated that kokanee "had to 'clean' 1 to 4 cm of fine material from the substrate before reaching larger particles," and that large amounts of fine material still remained within the redds. He also estimated that only 10% of the total number of redds observed were in areas of clean gravel. To date, however, there have been no explanations of why kokanee were using this poor substrate

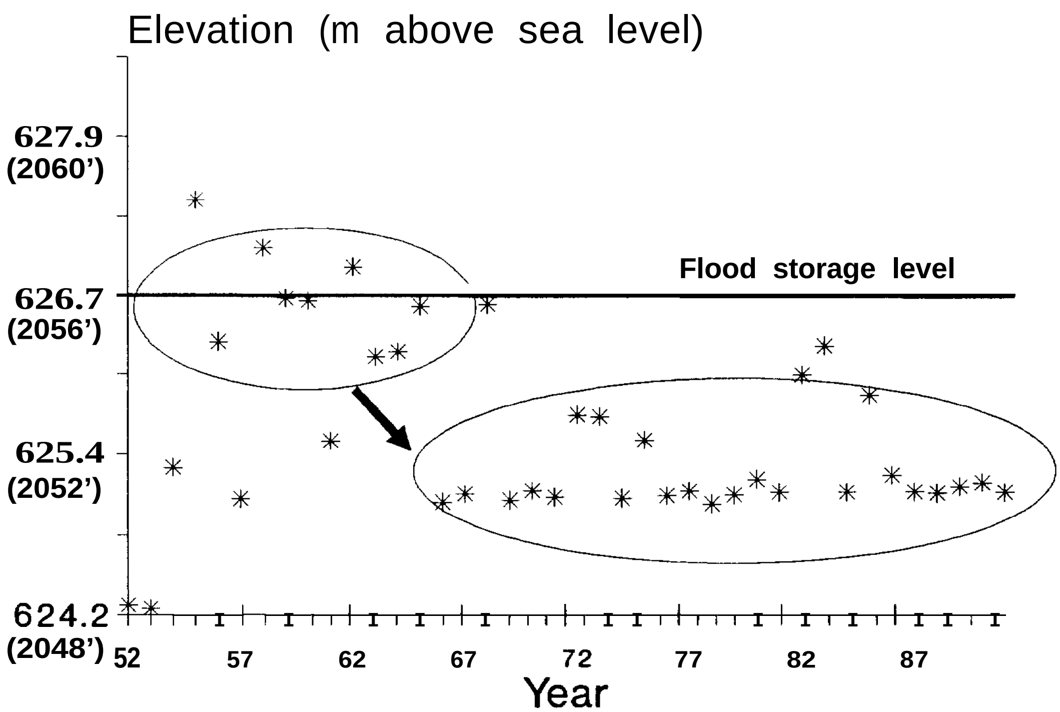


Figure 7. Minimum winter elevation for Lake Pend Oreille, Idaho, from 1952 to 1991. Circles drawn by inspection. Year represents the kokanee spawning year class not the calendar year.

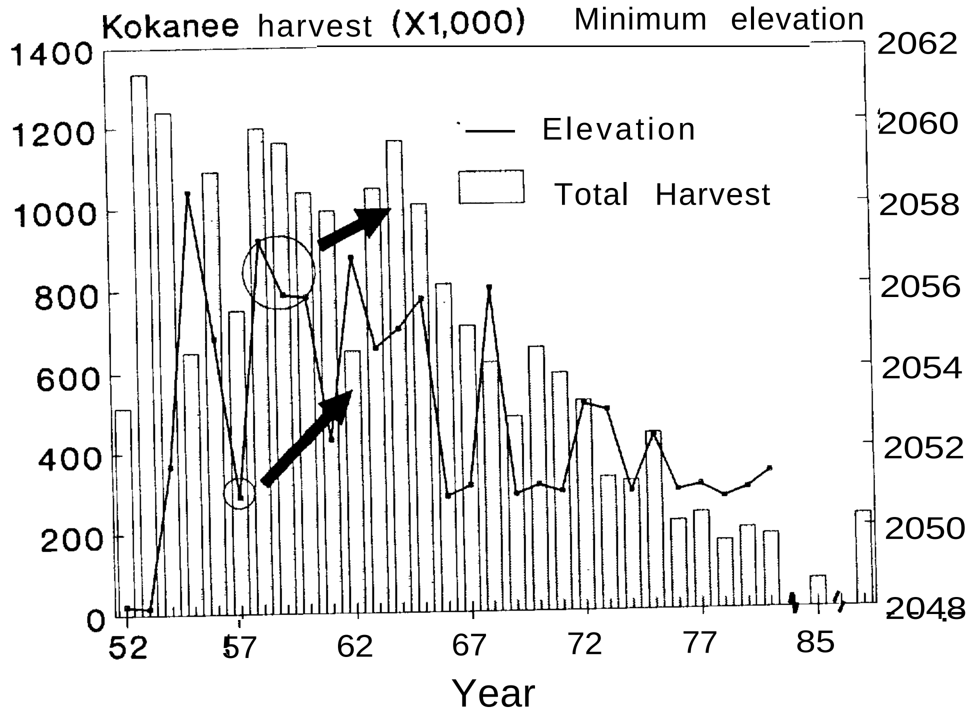


Figure 8. Kokanee harvest in Lake Pend Oreille, Idaho, and the minimum lake elevation for each kokanee spawning year class.

(because it is all that was available to them under the present drawdown regime), and how the deeper drawdowns since 1966 have accentuated this problem (because it leaves nearly all of the clean gravel higher on the banks).

Examples of the Effect of Higher Winter Water Levels

Since 1966, there have been several cases of higher minimum pool elevations in Lake Pend Oreille. The first case was during the winter of 1968-69 (Figure 7). During that year, the winter minimum elevation was 626.59 m (2,055.74 feet). Eggs spawned in 1968 became the predominant kokanee year class in the fishery in 1973. But no increase was noted in the 1973 fishery harvest. This was also the year that the commercial fishery closed, which may have had the effect of reducing harvest and angler participation in the fishery. Visual counts of spawning kokanee are made each year along kokanee spawning beaches. In 1973, however, we had our record high shoreline spawning count of 19,800 fish (Bowler 1975). This was up from 2,700 fish the previous year, for an increase of 730%. Apparently a very strong year class of kokanee was produced by the higher water in the winter of 1968-69.

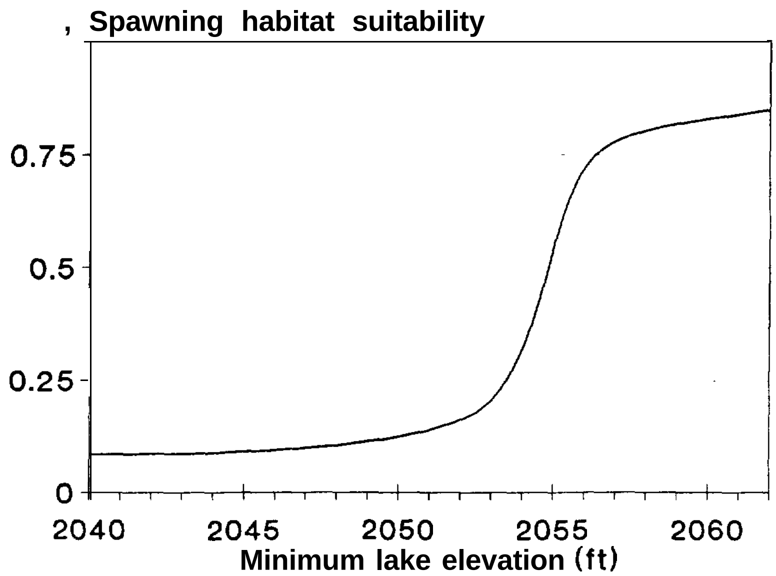
Somewhat higher water levels than currently normal occurred in the kokanee spawning years of 1982 (2,053.95 feet), 1983 (2,054.68 feet), and 1985 (2,053.45 feet) (Figure 7). These elevated lake levels were not as high as those in 1968. The increases in kokanee abundance were not as dramatic during those years, based on our trawling estimates, but there were notable increases. Kokanee abundance at age 3 was 540,000, 430,000, and 450,000 resulting from the high water years of 1982, 1983, and 1985. This could be compared to kokanee abundance resulting from the lower water elevation years of 1980, 1981, and 1984 of 270,000, 370,000, and 380,000, respectively (Paragamian et al. 1991). This would represent an average increase of 39% more kokanee recruited to the fishery at age 3, likely due to the higher winter water elevations.

SHORELINE GRAVEL LOCATIONS

Historically, kokanee spawn in high numbers on the north south, east, and west sides of Lake Pend Oreille (Jeppson 1960). Currently, the only abundant spawning area of kokanee is near Bayview in the south end of the lake (Paragamian et al. 1991). Shoreline gravel sampling was conducted in the winter of 1991-92 at five of these once prominent spawning areas. In each case, we found high quality spawning gravel on the shore above the water line during the winter drawdown. Kokanee had only very poor substrates available for spawning in each of these areas (Chapter 2). It is highly likely that the loss of kokanee from these traditional spawning sites was due to the lack of clean gravel available for spawning.

IMPLICATIONS TO THE SYSTEMS OPERATION REVIEW

The Systems Operation Review process relies on computer simulations to determine the effects of operational changes at various dams on resident fish. We recommend that the effects to kokanee spawning of both lake elevation and changes in lake elevation be incorporated into these simulations (Figure 9). Computer models for other reservoirs in the SOR process strongly utilized the relationships of dam operation on fish forage production. In the case of Lake Pend Oreille, forage production is of lesser concern than the direct losses of fish during spawning and egg incubation.



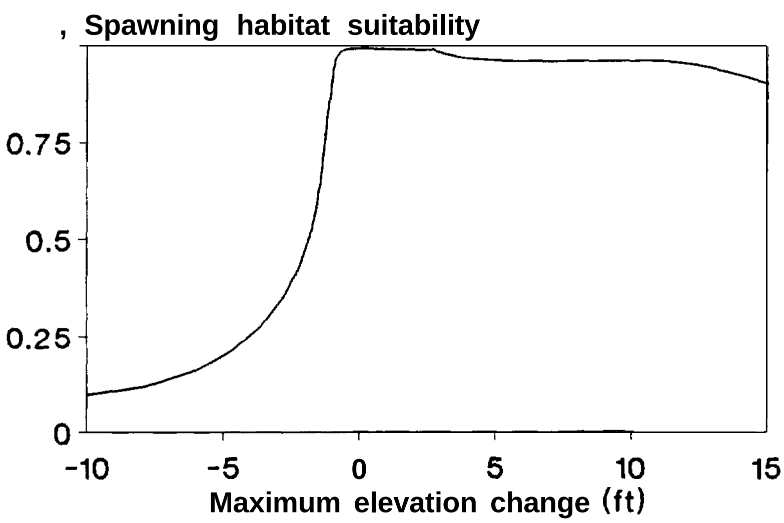


Figure 9. Proposed habitat suitability curves for the functional relationships of minimum lake elevation and the amount of drawdown after kokanee have spawned, for Lake Pend Oreille, Idaho.

CONCLUSIONS

After an historical review of Lake Pend Oreille studies, there appears to be ample evidence that water level changes may have caused the kokanee population declines. Two factors appear to be of paramount importance. First, water levels need to be adjusted so that the high quality gravels are available for kokanee spawning. This could be accomplished by keeping the winter minimum elevation at 626.7 m, (2,056 feet) or above. And secondly, lake elevation should not be lowered once kokanee begin spawning on approximately November 10, and should remain stable or higher until kokanee fry emerge in May.

As with any set of observational data, some uncertainties in the cause and effect relationships still exist. Also, the system has changed since declines occurred in the 1960s, and so the extent of recovery possible is currently unknown. This could be defined with an experimental test of the effects of higher water elevations. It may take two generations of kokanee to see the full effects of enhanced spawning. Tests of higher water should take this into account.

Without changes, the 30-year decline of kokanee will likely continue. Hatchery stocking cannot revitalize the wild segment of the population, and it may be impossible to maintain the stocking program once wild kokanee are lost. This population appears to be just able to replace itself, even at low densities and with ambitious stockings. The hope is that changes in water level can reverse this trend before the population declines irretrievably.

RECOMMENDATIONS

1. The Department should pursue higher winter water level management in Lake Pend Oreille. This would require getting the cooperation of the Army Corps of Engineers to conduct tests to determine the effect of a higher (626.7 m, 2,056 feet) lake elevation during winter. The enhancements to kokanee should be monitored, but it is also important to quantify the effect on wildlife and waterfowl habitat, the maintenance of shoreline gravels, warmwater fish habitat, boating access, and marina facilities.

2. We recommend that the Corps of Engineers adopt written constraints which minimize further drawdown of the lake elevation after November 10. Keeping a stable pool elevation is critically important for eggs incubating in shoreling gravels. Currently, operating criteria of the dam allows for water levels to continue to decline until December.

3. Models used in the Systems Operation Review should include the impacts to kokanee spawning from fluctuating lake levels during winter and the impact of various minimum lake elevations. We also advise continued input into the Systems Operation Review process in an attempt to modify lake levels.

4. The Department should call for a review of the operation of Albeni Falls Dam to see if there is another route toward changing dam operation.

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CHAPTER 2

INFLUENCE OF LAKE ELEVATION ON AVAILABILITY OF KOKANEE SPAWNING GRAVELS IN LAKE PEND OREILLE, IDAHO

ABSTRACT

We examined the spawning gravel quality on the shores of Lake Pend Oreille, Idaho to determine its availability to kokanee spawners. Researchers collected samples in areas where kokanee spawning was once abundant, but now appeared to be reduced to remnant levels. The current operation of Albeni Falls Dam regulates the water level to be 3.4 m below full pool during winter, to rise during spring run-off to a stable full pool, and then drop to the low pool elevation during fall. Under this operation regime, a band of clean gravel has formed in most traditional spawning locations at about 1 to 2 m below the summer pool elevation. This clean gravel band is, therefore, unavailable for kokanee spawning. Our sampling and visual observations of the substrate below the low pool elevation revealed only very poor quality substrates were available to spawners. We believe the lack of available gravel may have caused the loss of most of the lakes spawning sites and contributed to the overall declines of kokanee in Lake Pend Oreille.

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INTRODUCTION

Kokanee declines in Lake Pend Oreille were attributed primarily to two factors: 1) the elevation at which the lake was held during winter, and 2) fluctuations of the lake level after kokanee spawning occurred. A careful review of the history of kokanee declines in the lake illustrated the overriding importance of these two factors (Chapter 1). We conducted research in 1992 to determine why a higher lake elevation during winter may be important and to gain insights into what elevation would provide improved conditions for kokanee spawning.

OBJECTIVES

1. To determine if shoreline gravel in traditional kokanee spawning areas becomes limiting as the water level is dropped.
2. To determine the effect of various water level changes in Lake Pend Oreille as it relates to kokanee spawning potential.
3. To provide this information to the resident fish work group of the Systems Operation Review so that it can be incorporated into their models.

METHODS

Our sample sites included historic spawning locations on Lake Pend Oreille (Jeppson 1960). We sampled historic spawning sites to determine why these areas were lost from production. The areas we chose were ones with historically high spawner counts; from 100 to greater than 1,000 fish seen on shoreline surveys. These areas included: Garfield Bay, approximately 110 m southeast of the breakwall at the public boat ramp; Ellisport Bay, approximately 400 m east of the public launch at the Lighthouse restaurant; the lake shore at West Hope; the lake shore south and east of Trestle Creek; and the lake shore immediately north of the mouth of North Gold Creek.

We sampled on February 4-6, 1992 when the shorelines were neither snow-covered nor frozen. The water level had been drawn down to an elevation of 625.60 m (2,052.49 feet). Our core sampler was made of 15-cm diameter pipe and was used to remove a plug of substrate to a depth of 10 cm. At Garfield Bay, we collected a sample every 1.2 m along a randomly placed transect that extended from the 602.97 m (2,050.92 feet) elevation to the 628.26 m (2,061.22 feet) elevation (from 0.5 m below the water line to about the summer full pool elevation).

At all other locations, we marked horizontal bands of similar-sized substrates with stakes. Elevations to the top and bottom of these horizontal bands were measured with a stadia rod and hand level using the lake surface as a known reference elevation. Two random core samples were collected in each substrate band. Nearshore areas were then waded to look for the presence of suitable gravels that may have been missed by our survey transects and to visually note substrate quality in deeper water.

Each sample was individually bagged, labeled, and air dried. We then sorted the substrates through a column of soil sieves of the following sizes: 63.5 mm, 31.75 mm, 16 mm, 9.5 mm, 6.35 mm, 2 mm, and 0.85 mm. The substrate retained on each screen was then weighed and calculated as a percent of the total sample. We defined "cobble" as substrates retained by the 31.57 mm and larger screens, "gravel" as substrates between 31.57 and 6.35 mm, and "fines" as the substrate that passed through the 6.35 mm screen.

RESULTS

Substrates ranged from 100% cobble in areas that were rip-rapped for shoreline protection to 100% fines (Appendix A). Garfield Bay had pronounced bands of various sized particles (Figure 1). The band of potential spawning gravel (31% cobble, 47% gravel, and 22% fines) was above the 627 m (2,058 feet) elevation. Trestle Creek and Ellisport Bay sites had areas of high quality spawning gravel from 626 m (2,054 feet) to 627 m (2,058 feet) (Figures 1 and 2). North Gold was found to have intermittent gravel bars along a slowly sloping shoreline (Figure 2). One area of potential spawning gravel at this site was at the water line where waves were washing the shore (625.59 m). This area was not suitable for spawning because of its shallow nature. One of the best gravel bands (54% gravel, 24% fines) was at the 626.14 elevation. This gravel band is only a very small bar on Figure 2, which is based on elevation, but it encompasses a 10-m wide section of shore. Similar results were found at the Hope site, in that no potential spawing gravel was found below the low pool elevation (Figure 3). Gravels suitable for spawning occurred above the 626.15 m elevation (31% gravel and 14% fines) and continued up the shoreline to the high pool elevation.

Visual observations in deeper water (0.5 to 1.5 m) adjacent to all of the historic spawning sites failed to reveal any potential spawning gravel. Typically, the lake bed below the depths we sampled was heavily armored with cobble that was highly embedded with sand. This was true at West Hope, North Gold Creek, Trestle Creek, and Garfield Bay. Often times, directly underneath the cobble armoring was a layer of clay or sand. Beyond the depths of this cobble layer (l-2 m), the bottom substrate appeared to be composed of almost entirely fine material.

DISCUSSION

In Chapter 1 we demonstrated that the deeper drawdowns of Lake Pend Oreille coincided with the historic declines in kokanee abundance. We also reported that higher winter lake elevations correlated on four occasions with improvements in kokanee density. In this chapter, we provide data from surveys of the shoreline areas to document the functional basis for why lake drawdowns may be impacting the kokanee population. Once lake levels were dropped to 625.1 m (2,051 feet), nearly all of the relatively clean gravel substrates in these historic spawning locations were above the water line. This left only poor quality gravel in very shallow water, and no suitable spawning gravel at deeper depths.

Numerous studies have documented the relationship between the amount of fines in spawning gravels and egg survival (Tappel and Bjornn 1983, Chapman 1988, Phillips et al. 1975, Reiser and White 1988). Regardless of fish species, as the percent of fine material increases, egg survival declines. These fine sediments block the diffusion of oxygen to the egg, prevent the movement of waste products away from the egg, and hinder the movement of fry attempting to emerge from the gravel. Kokanee egg survival declines in a non-linear fashion with increasing amounts of fine material (Irving and Bjornn 1984). Survival was reduced to 50% when the percentage of material less than 6.35 mm was 35% of the substrate (Irving and Bjornn 1984). These tests were conducted in troughs of flowing water, and thus survival may be different on the lake shore.

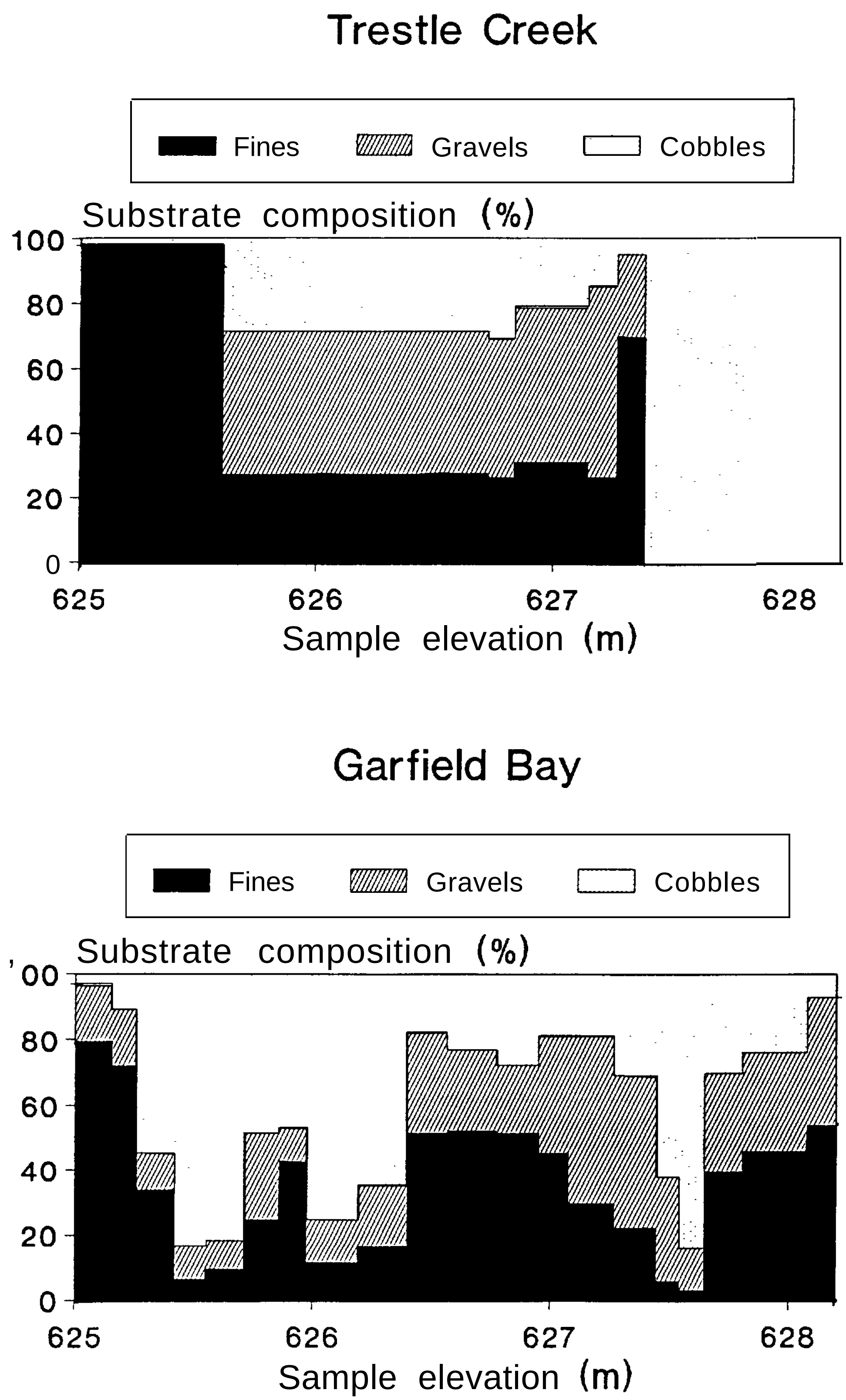

Figure 1. Composition of substrate samples collected on the shorelines of Lake Pend Oreille, Idaho, near the mouth of Trestle Creek and in Garfield Bay.

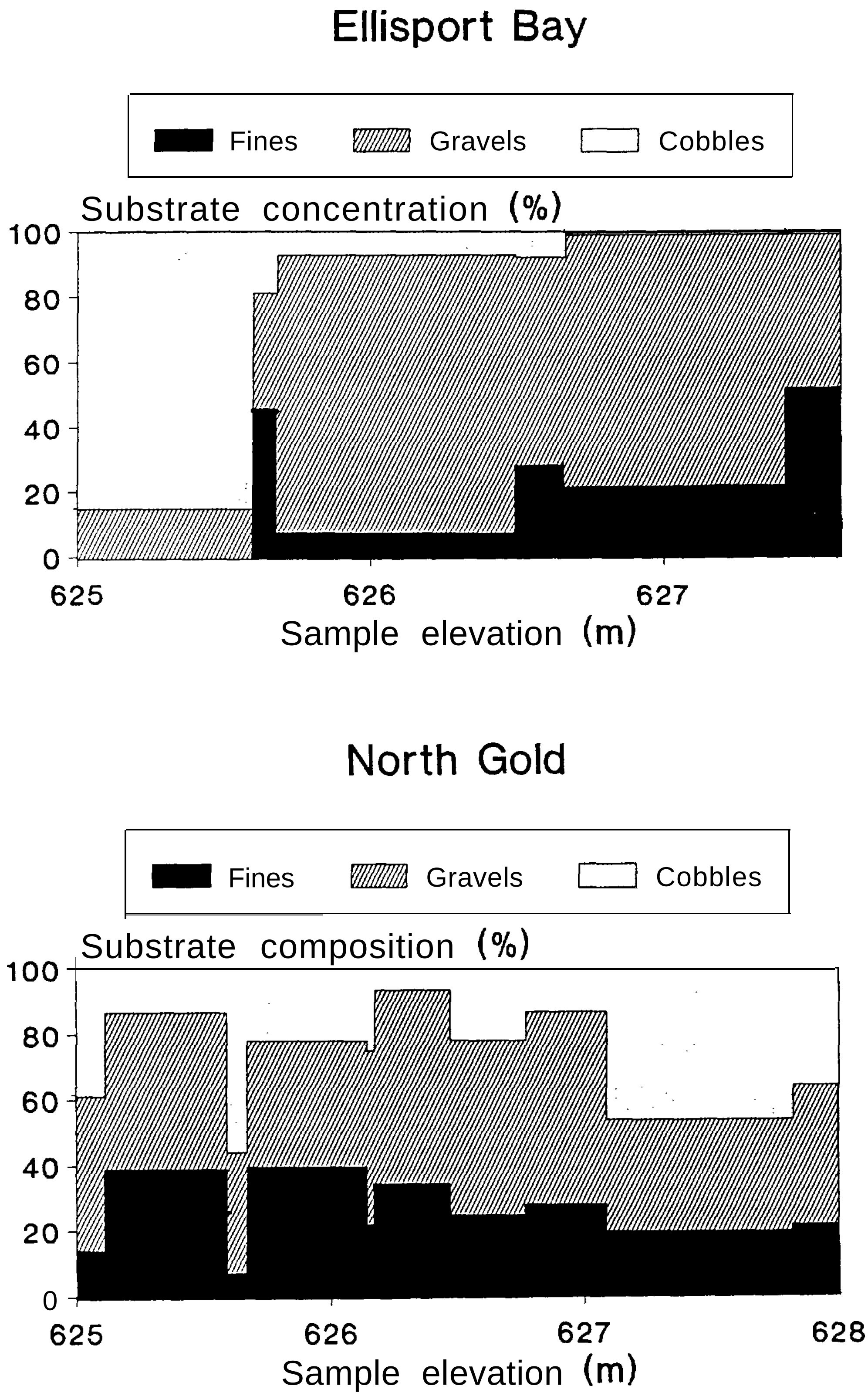

Figure 2. Composition of substrate samples collected on the shorelines of Lake Pend Oreille, Idaho, in Ellisport Bay and near the mouth of North Gold Creek.

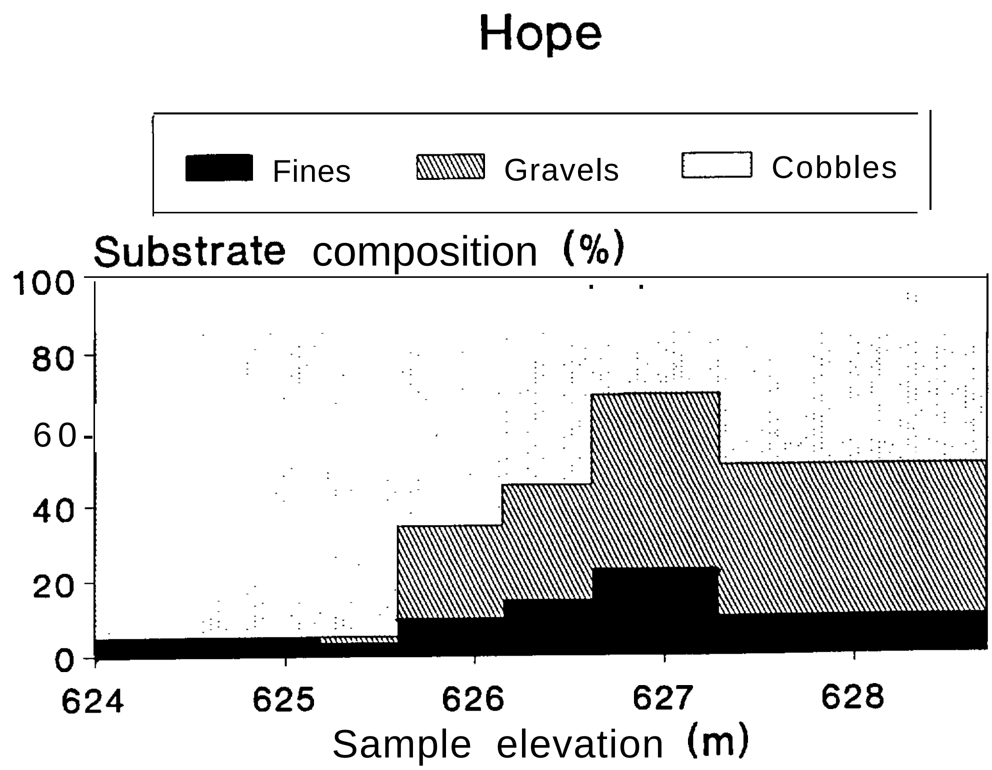

Figure 3. Composition of substrate samples collected on the shorelines of Lake Pend Oreille, Idaho, near the town of Hope.

Gibson (1973) surveyed shoreline spawning areas in Lake Pend Oreille and found 53% of the lakeshore gravels contained 40% or more fine material (<6.35 mm). Hassemer (1984) also documented the poor quality of spawning substrate in the lake. Both of these researchers examined substrates in areas where kokanee were spawning and maintaining a viable population. Even here substrate quality was rather poor. Our study examined the substrates in areas that were nearly lost from kokanee production. At each of these sites, the elevation of the lake could profoundly affect the amount of gravel available for spawning. Nearly all clean gravel is above the water line with the current 3.4-m drawdown. Apparently, without this spawning gravel, these groups of kokanee were lost.

Recovering the fishery on Lake Pend Oreille may be largely dependant on bringing these historic areas back into production. If this could be accomplished, fry would be produced in widely separated locations where competition for food would be minimized. Thus, age 0 kokanee could more fully utilize the habitat available to them without competition that may have been enhanced by the presents of opossum shrimp *Mysis relicta*. Also, multiple spawning stocks could help to minimize the year-to-year variations in fry abundance. It would also help to minimize the damage to kokanee abundance if a chance event (such as a chemical spill) impacted the Bayview spawning population.

The Army Corps of Engineers has a flood control rule curve for Lake Pend Oreille which specifies a winter pool elevation of 626.7 m (2,056 feet). At this elevation, numerous hectares of high quality spawning gravel would be inundated in most of these historic spawning areas. The exception to this appears to be the Garfield Bay site. The best band of gravel in this location was above the 626.7 m (2,056 foot) elevation. Possibly, gravels are shallower in this bay since it was somewhat protected from storms and the associated high current velocities and agitation from waves.

We have discussed the possibility of cleaning shoreline gravel in historic spawning areas to improve the survival of kokanee spawning. Based on our findings, most of these areas had very little gravel below the low pool elevation to clean. Thus, cleaning would not seem like an advisable management approach. Moving gravels to a lower location has also been suggested. Based on 0.1 m^2/ spawning pair of kokanee, and a population of 1 million pairs, a 6-m strip of gravel 17 km (10 miles) long would need to be provided. This would be a major construction project. Considering the armoring of the near shore areas and the amount of fines in deeper areas, this gravel strip would probably not last long. Thus, repeated major construction efforts would be needed which would have its own environmental impacts.

Limitations of the Data Set

There is some question as to what particle sizes should be considered fines or spawning gravel for kokanee. We defined "fines" as particles under 6.35 mm to be consistent with Irving and Bjornn (1984) and Gibson (1973). In this report, the authors felt the results were so striking that reasonable changes in definitions would not change the outcome of our conclusions. Nevertheless, all size fractions are included in Appendix A for possible future reference.

RECOMMENDATIONS

1. We recommend holding Lake Pend Oreille at 626.7 m elevation (2056 feet) during winter on an experimental basis. During this experiment, we suggest close monitoring of kokanee egg and fry survival, spawning location and depths, and substrate quality.

2. We propose that the habitat suitability curves shown in Figure 9 of Chapter 1 be included in any attempts to model the effect of water level changes on the kokanee population in Lake Pend Oreille.

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A P P E N D I X

Appendix A. Weights (g) of substrate samples from shoreline spawning areas on Lake Pend Oreille, Idaho, 1992.

Site	Band	Elevation to top of band (ft)	Distance from waterline to top of band (ft)	Size fractions (mm) >63.5	31.75-63.50	16.00-31.75	9.50-16.00	6.35-9.50	2.00-6.35	0.85-2.00	<0.85
Ellisport Bay	A	2,061.87	41.3	--	--	122	317	715	2,898	1	1
				--	40	777	996	605	847	1	--
	B	2,058.43	30.3	--	60	601	808	1,940	602	--	--
				--	--	172	1,046	1,771	1,103	4	4
	C	2,055.97	18.0	--	317	1,134	1,019	788	498	1	--
				--	346	469	457	1,096	1,680	2	2
	D	2,055.41	15.2	165	165	1,272	804	454	140	--	--
				--	172	2,113	754	513	309	2	7
	E	2,052.75	2.8	--	796	649	443	186	1,405	1	1
				--	579	528	293	551	1,852	--	--
	F	2,050.59	-13.9	--	2,070	173	--	--	--	--	--
				278	1,254	397	45	11	4	--	--
West Hope	A	2,062.63	107.8	680	813	866	304	152	519	362	288
				631	1,250	571	189	64	56	7	3
	B	2,058.00	79.9	--	985	873	496	214	232	67	540
				983	558	1,060	598	215	330	255	405
	C	2,055.84	54.1	1,954	1,193	287	68	8	7	1	1
				248	665	951	590	323	443	237	365
	D	2,054.29	20.8	1,242	792	797	215	146	344	155	31
				1,555	1,122	338	113	82	140	44	16

Appendix A. Continued.

Site	Band	Elevation to top of band (ft)	Distance from waterline to top of band (ft)	Size fractions (mm) >63.5	31.75–63.50	16.00–31.75	9.50–16.00	6.35–9.50	2.00–6.35	0.85–2.00	<0.85
West Hope	E	2,051.08	-11.4	1,546	1,735	72	68	59	151	50	8
				2,327	890	41	--	--	--	--	--
North Gold	A	2,063.44	192.3	334	649	572	881	764	1,289	133	15
				1,701	--	606	340	108	165	23	4
	B	2,059.77	185.3	558	786	296	441	241	313	178	96
	C	2,057.37	158.3	--	572	756	495	282	221	45	10
				--	130	462	762	570	869	245	154
	D	2,055.34	90.3	--	942	777	601	353	396	221	136
				--	477	957	523	326	377	290	147
	E	2,056.32	63.1	--	167	807	677	443	624	91	26
				--	185	652	400	364	970	177	48
	F	2,054.35	32.2	--	251	660	713	613	708	131	6
				546	585	580	331	161	208	108	40
	G	2,054.25	12	624	335	335	249	231	1,005	575	175
				--	330	457	675	430	367	230	4
	H	2,052.71	3.4	1,577	201	286	153	79	121	45	13
				471	585	538	493	310	193	4	0
	I	2,050.88	--	308	427	585	417	232	515	296	116
				--	--	186	528	789	1,278	40	2
	J	2,050.02	--	--	994	609	106	44	18	6	4
				--	565	725	295	142	258	212	123

Appendix A. Continued.

Site	Band	Elevation to top of band (ft)	Distance from waterline to top of band (ft)	Size fractions (mm) >63.5	31.75-63.50	16.00-31.75	9.50-16.00	6.35-9.50	2.00-6.35	0.85-2.00	<0.85
Trestle Cr.	B	2,057.97	132.9	--	61	347	304	138	223	130	1,289
				--	217	408	125	62	80	4	2,137
	C	2,056.69	81.5	--	--	911	787	398	728	444	115
				--	979	990	432	188	181	123	71
	D	2,057.58	64.5	--	707	1,046	380	206	407	280	383
				--	700	945	462	217	342	445	280
	E	2,056.53	55.3	--	1,096	845	519	119	342	359	345
				609	478	690	530	267	395	257	112
	F	2,056.16	50.8	--	1,286	688	692	248	430	399	172
				--	989	903	537	330	575	429	145
	G	2,050.59	-30.6	--	--	--	--	--	1	--	2,183
				--	112	10	5	2	--	--	2,447

Site	Distance from water level (ft)	Elevation (in feet)	Size fractions (mm) >63.5	31.75-63.5	16.00-31.75	9.50-16.00	6.35-9.50	2.00-6.35	0.85-2.00	<0.85
Garfield Bay	60	2,061.22	--	234	668	412	272	354	654	854
	56	2,060.07	--	964	506	359	329	488	827	550
	52	2,059.41	572	232	345	259	200	318	372	378
	48	2,059.02	--	2,535	303	60	17	33	35	31
	44	2,058.72	888	1,050	874	76	36	57	95	51
	40	2,058.40	--	993	946	405	191	272	291	151

Appendix A. Continued.

Site	Distance from water level (ft)	Elevation (in feet)	Size fractions (mm) >63.5	31.75-63.5	16.00-31.75	9.50-16.00	6.35-9.50	2.00-6.35	0.85-2.00	<0.85
Garfield Bay	36	2,057.54	--	692	1,107	571	253	384	440	278
	32	2,057.12	--	561	626	258	205	593	603	164
	28	2,056.72	574	248	259	254	114	429	610	442
	24	2,055.94	--	730	385	237	157	380	806	464
	20	2,055.34	--	680	543	388	221	566	868	494
	16	2,054.85	450	1,995	504	97	75	153	364	125
	12	2,054.06	2,621	473	415	86	45	87	143	198
	8	2,053.44	709	894	220	67	68	222	396	835
	4	2,053.21	695	840	545	170	147	182	280	282
	0	2,052.49	1,629	1,202	114	152	31	89	122	101
	-4	2,052.16	1,644	1,453	201	126	75	88	81	67
	-8	2,051.60	2,611	--	255	188	119	298	440	823
	-12	2,051.11	--	271	152	136	138	297	477	905
	-16	2,050.92	--	101	227	240	215	656	1,290	967

CHAPTER 3

KOKANEE POPULATION STATUS IN DWORSHAK RESERVOIR

ABSTRACT

We continued to monitor the kokanee population in Dworshak Reservoir, Idaho, by mid-water trawling and counting spawners in representative streams. Our estimates of age 0 kokanee abundance in 1992 were the highest on record; 1,043,000 fry. Older age groups were also fairly abundant, though not record-setting. Dworshak Dam discharged more water between July 1, 1990 and June 30, 1991 than any of our recent years of study. Based on a past relationship with a r^2=0.99, we would have expected age 2 kokanee abundance to be very low. Instead, we estimated kokanee abundance to be three times higher than anticipated. Perhaps the change to a higher winter pool elevation reduced kokanee entrainment losses, although this finding is still preliminary.

Kokanee were also smaller than expected in 1992 based on their density. We speculate that the high discharges through Dworshak Dam during spring and fall may have reduced zooplankton density.

We also found that the number of mature kokanee estimated by trawling correlated well (r^2=.98) to our spawner counts in representative streams. This will give us the means to convert the older spawner count data into age 2 kokanee estimates.

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INTRODUCTION

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

Additional data were collected in 1992 to continue to build on this data base and to provide information to the System Operation Review (SOR) being conducted by the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the Bonneville Power Administration. Data from this report will be used in the final analysis of alternatives generated by work groups in the SOR.

DESCRIPTION OF STUDY AREA

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

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

The drawdown regime for Dworshak Reservoir changes annually depending on forecasted snowpack and operating criteria such as water releases for salmon flows. During the winter of 1991-92, the winter pool elevation was the highest since our studies began (Figure 2). Also, the reservoir did not maintain a stable summer pool level, but instead began dropping through the May to July period.

METHODS

Kokanee Abundance

Oblique tows of a mid-water trawl were used to obtain density estimates of kokanee and representative samples of fish for aging. An 8.5 m, 140-horsepower diesel engine boat towed the trawl net, which 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 the body of the net and terminated in a 6 mm mesh cod end.

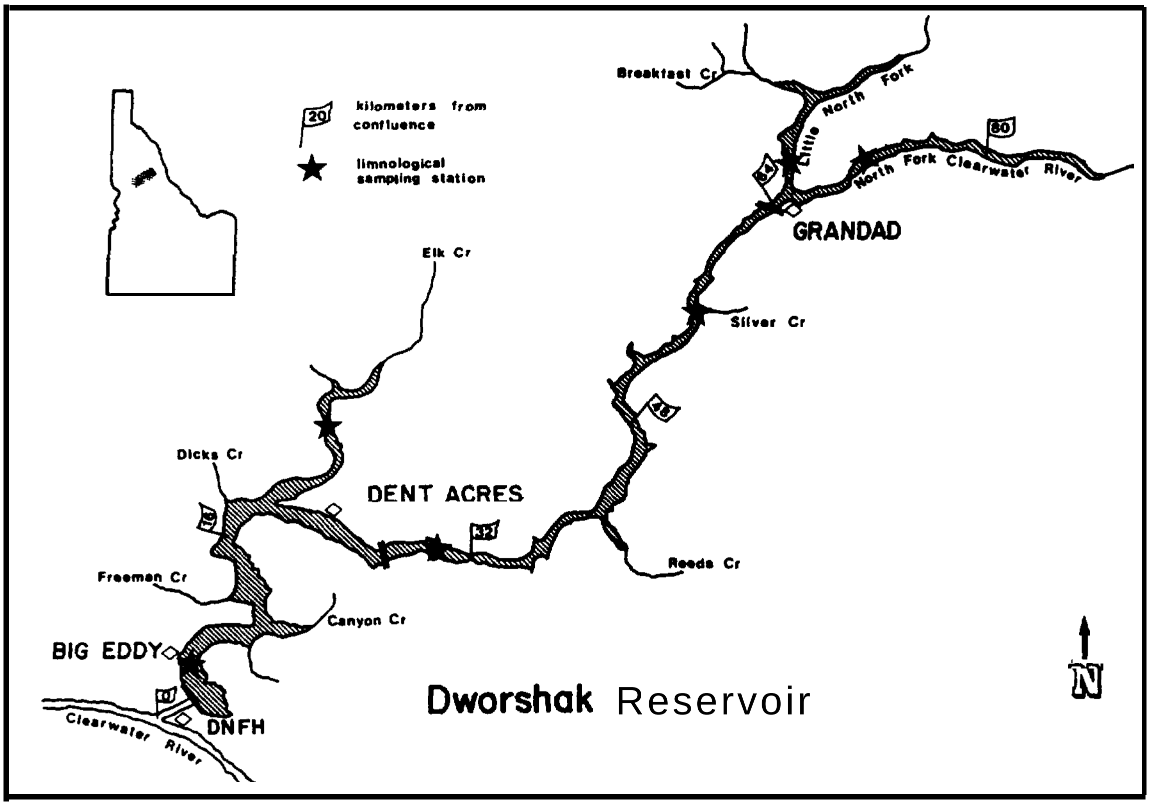

Figure 1. Dworshak Reservoir and major tributaries, North Fork Clearwater River, Idaho. The reservoir was divided into three sections for sampling: Section 1 (dam to Dent Bridge), Section 2 (Dent Bridge to Grandad Bridge), and Section 3 (Grandad Bridge to end of pool).

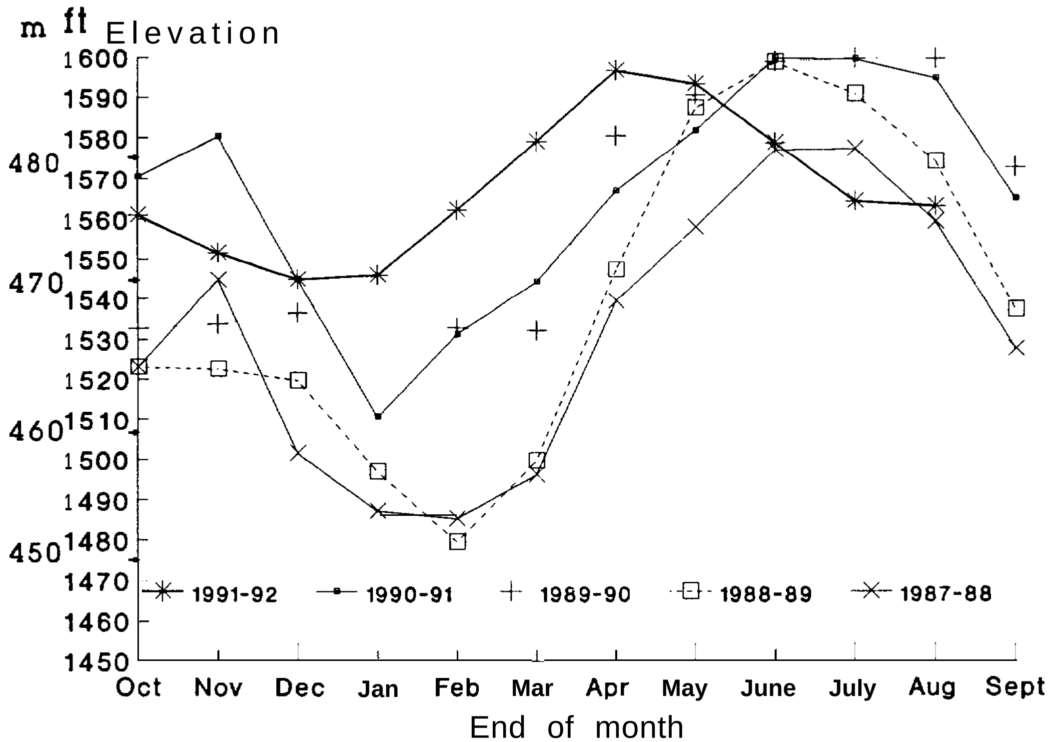

Figure 2. Elevations of Dworshak Reservoir, Idaho, on the last day of each month, 1987-1992.

All trawling was conducted after dark during the new moon phase to optimize capture efficiency (Bowler et al. 1979). Net towing speed was standardized at 1.5 m/s. Depth of the net was determined for each 15.2-m distance of tow cable and checked annually. The layer of kokanee distribution was determined using a Raytheon Model 78841 depth sounder with a 20 degree transducer. This 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. The net was pulled for 3 min in each sublayer, sampling 2,832 m^3 of water over a distance of 315 m (at a boat speed of 1.5 m/s). The time it took to readjust the net between sublayers and the time the net was in the kokanee layer while initially setting the net was also entered into density estimates (approximately 30 seconds between sublayers while raising and lowering the net).

A stratified random sampling design was used to choose trawl locations. The reservoir was divided into three sections with Dent bridge and Grandad bridge serving as boundary lines (Figure 1). Section 1 was the lower end of the reservoir (2,562 hectares of kokanee habitat), section 2 the middle (1,499 hectares of kokanee habitat), and section 3 was the upper reservoir (520 hectares of kokanee habitat). During trawling, the reservoir was at 477 m elevation (1,564 feet), and the mid-point of the kokanee layer at about the 20 m depth, therefore kokanee habitat was defined as the area inside the 457 m contour (1,500 feet). Five to seven trawls were made in each section. Reservoir sections were the same each year, but trawl locations were randomized annually. During 1992, trawls were begun at river kilometers 5, 8, 19, 23, 16, 26, 32, 35, 40, 49, 61, 68, 71, 74, and in the Little North Fork Clearwater arm at river kilometers 2 and 3. Trawl direction was parallel to the long axis of the reservoir due to spacial limitations. Trawling was conducted on the nights of July 27, 28, and 29, 1992.

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 meters) 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 that lake 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 limits. Mean kokanee weights in each 10-mm size group were averaged to determine the mean weight of kokanee in an age class, and multiplied by the population estimate of that age class to determine biomass.

Kokanee Ageing

Scales were removed from trawl-caught kokanee and impressed in clear plastic laminate sheeting using a Carver Model C laboratory press. We exerted 6 metric tons of force at a temperature of 70°C for approximately 10 seconds in making the impressions. Plastic impressions were then read on a microfiche reader by two individuals to resolve discrepancies.

Spawning Trends

Visual counts of kokanee spawners were made by walking upstream in selected tributaries of Dworshak Reservoir during the peak of the fall spawning run to obtain a relative index of kokanee spawner abundance. Streams surveyed included Isabella, Skull, Quartz, and Dog creeks. Surveys ran from the creek mouth upstream to the end of spawning run or to a migration barrier. Surveys were conducted on September 28, 1992, since muddy water prevented counting fish on the standardized date of September 25.

Tributary Access

We attempted to determine the effects of reservoir pool elevation on kokanee access to tributary streams. Surveys of the stream mouths during the spawning run were not conducted since the reservoir was drawn down only 13.7 m. We therefore used large scale maps of the reservoir to calculate the slope of tributary streams between 15.2-m (50 foot) contour intervals.

RESULTS

Kokanee Abundance

Total kokanee abundance within Dworshak Reservoir was estimated at 1,395,000 fish during July of 1992 (Table 1). Of this total, 1,043,000 (± 53%) were age 0, 254,000 (± 7%) were age 1, and 98,000 (± 15%) were age 2 ($P=0.10$). This equates to a density of 21.5 kokanee/hectare that were recruited to the fishery. Total biomass of kokanee in the reservoir was 8.3 kg/hectare.

Density of age 0 and age 2 kokanee was highest in the upper reservoir (Section 3) (Table 2). Age 1 kokanee were more evenly distributed, with the highest density occurring in the middle of the reservoir (Section 2).

Survival Rates

Survival rates were 47% for kokanee between the ages of 1 and 2, and no survival between the ages of 2 and 3 (Table 3). Age 0 kokanee were underestimated during 1991, which precluded us from estimating survival for the age 0 to age 1 group.

Age and Maturity

Three age classes of kokanee were caught by mid-water trawling (Figure 3). Kokanee of age 3 were not documented based on our scale analysis, although they occurred in low abundance in past years. Necropsies of trawl-caught kokanee showed that 14% of the kokanee over 240 mm were immature ($n=28$) and should provide some age 3 kokanee in the fishery of 1993.

Spawning Trends

Isabella Creek had the highest kokanee counts (7,085 fish) of the streams we surveyed (Table 4). Next highest counts were made in Skull Creek (4,299 kokanee) Quartz Creek (1,808 kokanee) and, lastly, Dog Creek (1,120 kokanee). Total number of kokanee spawners in Isabella, Skull, and Quartz creeks was 13,192 fish, up from last years count of 5,995 (Table 4). Number of spawning kokanee in representative streams correlated well ($r^2=0.98$) with the estimates of mature kokanee in the reservoir based on trawling (Figure 4).

Table 1. Kokanee population estimates (thousands) in Dworshak Reservoir, Idaho, From 1988 to 1992.

	Year Estimated						
Year Class[1] of kokanee	July 1992	July 1991	September 1990	September 1989	Late June 1989	Early June 1989	July 1988
1991	1,043						
1990	254	132					
1989	98	208	978				
1988		19	161	648	148	294	
1987		6	11[2]	165	148	100	553
1986			3[2]	45	175	140	501
1985						5	144
1984							12
Totals	1,395	365	1,153	858	471	539	1,210
Number/ hectare	305	68	214	159	87	100	224
Age 2+3/hectare	21.5	4.6	2.6	8.3	32.4	26.9	28.9
Biomass (kg/hectare)	8.3	2.9	4.4	5.9	5.2		9.7

[1] Year class was defined as the year eggs were laid.

[2] Mature kokanee underestimated in September sampling.

Table 2. Densities (number/hectare) of kokanee in each section of Dworshak Reservoir, Idaho, 1992. Section 1 was from the dam to Dent Bridge, section 2 was from Dent Bridge to Grandad Bridge, and section 3 was from Grandad Bridge to the end of slack water.

	Densities				
	Age 0	Age 1	Age 2	Age 3	Total
July 27-30, 1992					
Section 1	5	31	17		53
Section 2	333	94	10		437
Section 3	1,018	64	79		1,161
July 8-12, 1991					
Section 1	28	50	6	2	86
Section 2	22	23	0	0	45
Section 3	17	27	3	0	47
September 17-20, 1990					
Section 1	143	14	2	0	159
Section 2	289	71	3	2	365
Section 3	345	35	0	0	380
September 25-28, 1989					
Section 1	135	38	21	0	194
Section 2	172	53	8	0	233
Section 3	144	17	0	0	161
June 27-30, 1989					
Section 1	6	42	34	0	82
Section 2	20	16	25	2	63
Section 3	147	0	22	0	169
July 11-14, 1988			Age 2+3		
Section 1	167	78	20		265
Section 2	49	96	17		162
Section 3	71	135	71		277

Table 3. Survival rates (%) for kokanee in Dworshak Reservoir, Idaho, 1989 to 1992, by age class.

Year of Estimate	Age Class		
	Age O-I	Age I-2	Age 2-3
1989	18	28	3
1990	55	11[2]	2
1991	21	12	55
1992	192[1]	47	0
Mean	31	29	15

[1]In 1991 the age 0 year class was underestimated, this value was not used in the average.

[2]In 1990 the age 2 year class was underestimated, this value was not used in the average.

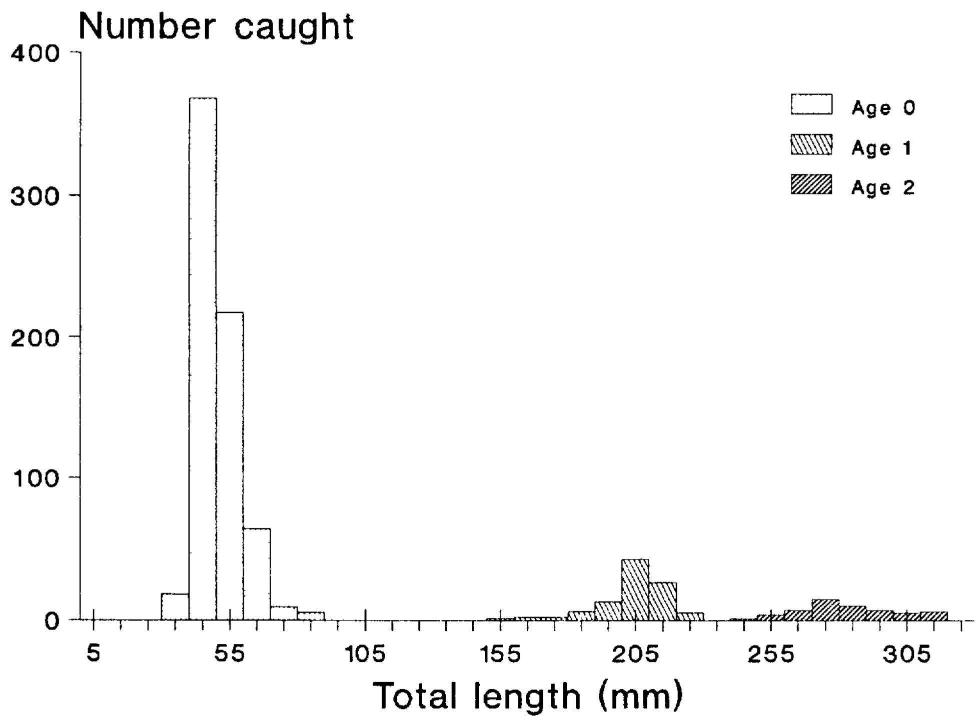

Figure 3. Length frequency distribution of kokanee caught by mid-water trawl in Dworshak Reservoir, Idaho, July 27-30, 1992.

Table 4. Number of spawning kokanee observed in selected tributaries to Dworshak Reservoir, Idaho, 1981 to 1992.

Stream	9/81	9/82	9/83	9/84	9/85	9/87	Date 11/87	Surveyed 9/88	9/89	9/90	9/91	9/92
Isabella	4,000	5,000	2,250	9,000	10,000	3,520	0	10,960	11,830	10,535	4,053	7,085
Skull	3,220	4,500	135	2,200	8,000	1,351	0	5,780	5,185	3,219	1,249	4,299
Quartz	850	1,076	66	1,000	2,000	1,477	0	5,080	2,970	1,702	693	1,808
Dog						700	0	1,720	1,720	1,875	590	1,120
Break-fast						23[1]		14,760[1]	14,402[1]	1,149[1]	3,557	
Beaver	2,117	4,000	384		8,000		0	1,700[1]	2,362[1]			
Elk							0	30[1]				
Total of Isabella, Skull, Quartz	8,070	10,576	2,451	12,200	20,000	6,348	0	21,820	19,985	15,456	5,995	13,192

[1] Surveys were not conducted to the end of the spawning run.

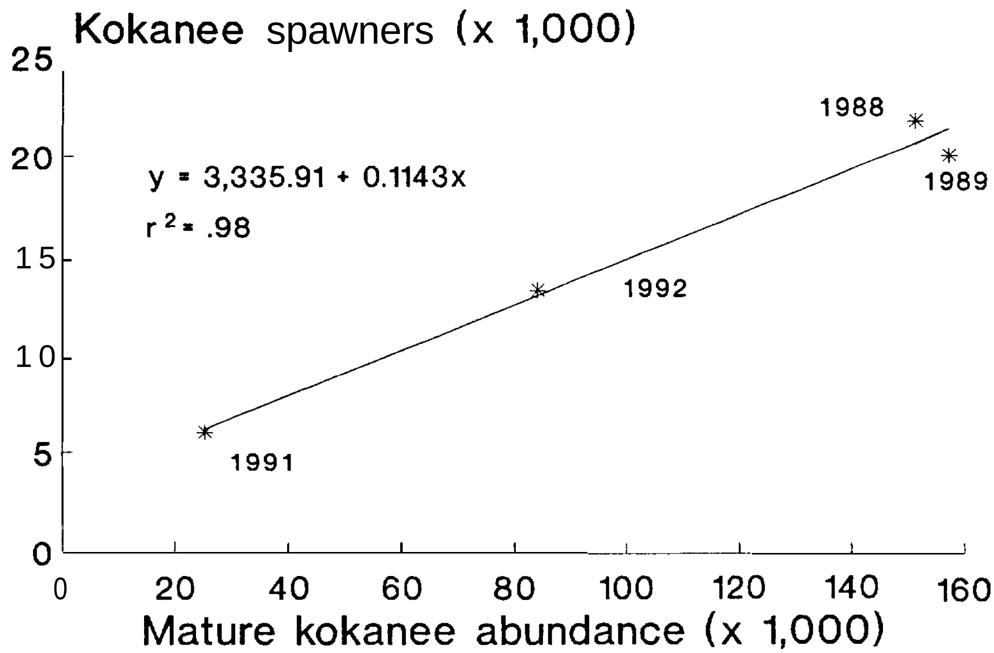

Figure 4. Relationship between the number of kokanee spawners in Isabella, Skull, and Quartz creeks and the number of mature kokanee determined by trawling Dworshak Reservoir, Idaho.

Kokanee spawners ranged in size from 220 mm to 330 mm (n=501). Modal size of all spawners was 280 mm, mean total length was 285 mm, mean length of females was 287 mm, and mean length of males was 285 mm (Figure 5).

Over the history of this project, spawner length was inversely correlated to spawner abundance (r^2=0.78) and was highly significant (p=0.001) (Figure 6). Length of kokanee during the 1991 and the 1992 spawning runs was lower than expected based on this regression.

The number of kokanee spawners in the three index tributaries continues to be inversely correlated (r^2=0.99) to the amount of discharge from Dworshak Dam the previous year (Figure 7). From July of 1990 through June of 1991, discharge from the dam totaled 5.33 billion m^3 (an average of 5,990 cfs), and spawner counts were 13,192 kokanee (Appendix A).

Potential Egg Deposition

We estimated Dworshak Reservoir contained 98,000 age 2 kokanee during 1992. Eighty-six percent of these kokanee were mature (84,280 fish). We assumed a 1:1 male to female ratio. Based on a mean female length of 287 mm, we estimated females averaged 598 eggs/fish (Rieman 1992). We therefore calculated potential egg deposition at 25,200 million eggs (Table 5).

Tributary Access

Tributary streams, in the reaches between the high and low pool elevations in Dworshak Reservoir, have slopes which range from 1% to 80% (Table 6). In general, the bigger streams have lower gradients. Some streams have steeper gradients at lower elevations, and then flatten in the upstream sections. Rooney Creek, for example, changes from a 16% slope between the 457 m contour and the 472 m contour. It then flattens to a 9% slope up to the 488 m contour. Thus, the steeper stream section would be inundated if the reservoir were within 15 m of full pool. Dicks, East Fork White, Slide, Canoe, Elkberry, Robinson, McIntyre, Nylon, Mosquito, Joes, and Thrasher creeks all have steep sections on the lower ends, which could be inundated if reservoir pool levels are above the minimum elevation of 440 m.

Because of the high reservoir elevation in the fall of 1992, these streams were not examined for the presence of actual fish barriers. Also, we did not have flow data for these streams, which would indicate which streams were large enough to be potential spawning tributaries.

DISCUSSION

Kokanee Abundance

The end of July proved to be an effective time for trawling. Young-of-the-year kokanee seemed to be relatively well recruited to the open water, although they were still primarily in the upper section of the reservoir. Mature kokanee had started migrating to the upper end of the reservoir (Table 2), but did not appear to be entering streams. Spawner counts were well correlated to the trawl estimates of adults indicating that we were not missing adult kokanee by trawling too late (Figure 4). Late July can be recommended for future trawl sampling, if that is when the new moon occurs.

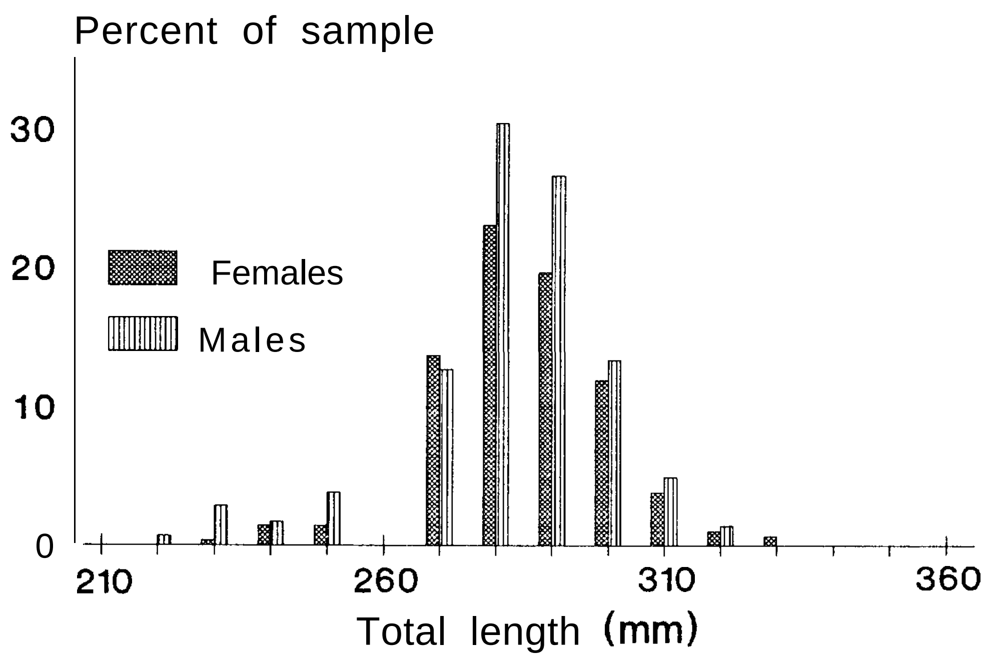

Figure 5. Total length and sex of kokanee spawners in Isabella, Skull, and Quartz creeks, tributaries to Dworshak Reservoir, Idaho, September 1992.

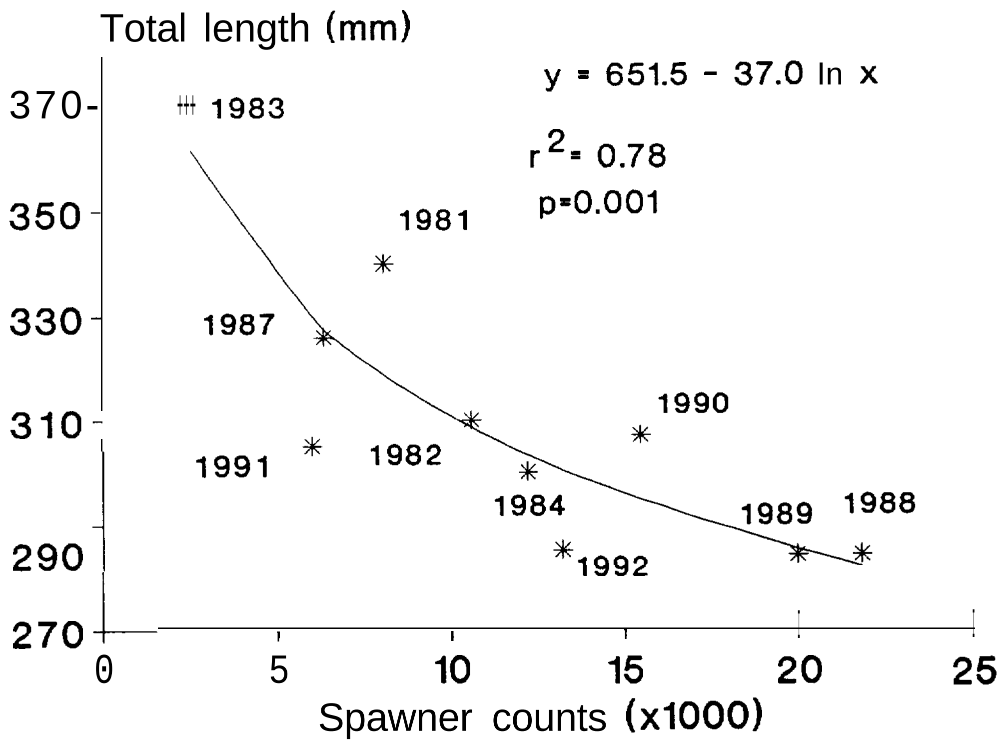

Figure 6. Number of kokanee spawners counted in Isabella, Quartz, and Skull creeks, compared to their mean total length.

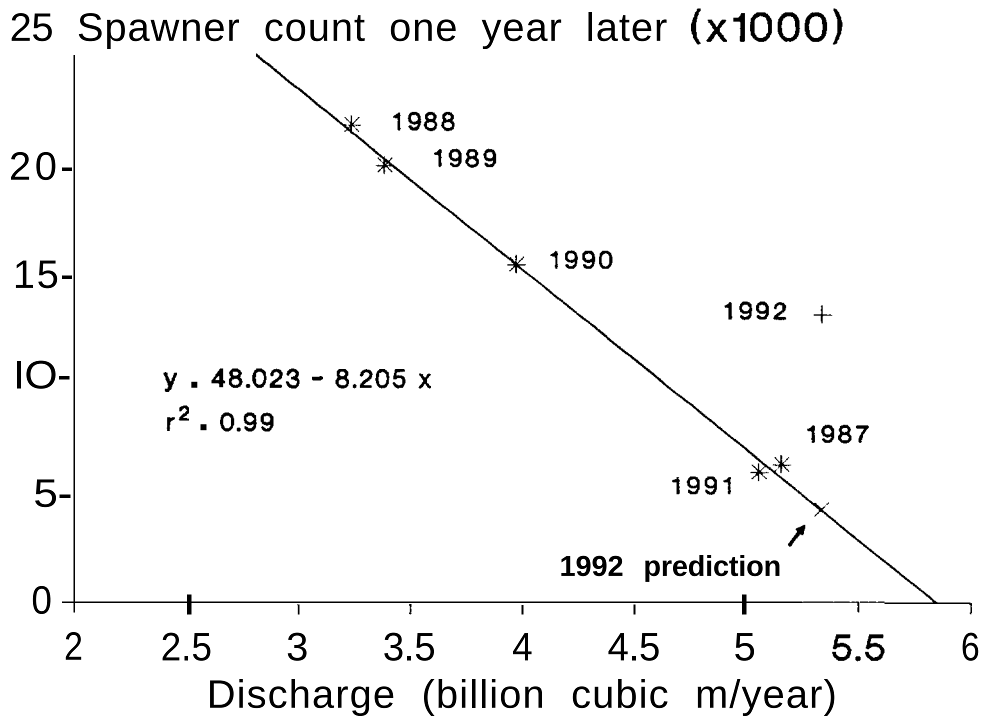

Figure 7. Relationship between the amount of water discharged from Dworshak Dam from July 1 to June 30 and the number of kokanee spawners the following year in Isabella, Quartz, and Skull creeks.

Table 5. Potential egg deposition and survival rates of resulting fry in Dworshak Reservoir, Idaho.

Year	Estimates Female spawning escapement (x 1,000)	Potential egg deposition (xl ,000)[1]	Fall fry from previous years escapement (x 1,000)	Potential egg to fall fry survival (%)
1988	78	41,028	--	
1989	88	41,626	648	1.6
1990	--[2]	--	978	2.3
1991	13	7,514	--	
1992	42	25,199	1,043	13.9

[1] Calculated from Rieman (1992).

[2] September trawling too late in year to get a reliable estimate.

Table 6. Percent slopes of tributaries to Dworshak Reservoir, Idaho. Slopes are between 50'(15.24m) contour elevations.

Creek name	Creek mouth to 1500'[1] (mouth-457m)	1450' to 1500' (442m-457m)	1500' to 1550' (457m-472m)	1550' to 1600' (472m-488m)
Indian	-	10	11	11
Canyon	-	4	4	4
Freeman	-	9	8	12
Dicks	-	40	32	27
Elk	-	1	2	2
Long Meadow	-	1	2	3
Cranberry	-	5	3	4
Oneil	-	20	18	40
McKinon	-	27	27	27
Hudson	-	16	20	13
Ladds	-	18	27	32
East Fork White	-	27	40	27
White	-	23	18	18
Weller	-	23	40	23
Reeds	-	4	5	3
swamp	-	8	10	13
Caldwell	-	10	11	23
Bishop	-	9	11	18
Big	-	15	11	11
Cold	-	12	7	11
Evans	-	15	18	18
Falls	-	18	18	11
Weitas	-	5	5	5
Slide	-	80	80	32
Boathouse	-	13	11	15
Canoe	-	20	18	12
Silver	-	5	6	5
Gold	-	8	11	6
Elkberry	-	13	6	6
Little Meadows	-	40	53	40
Elmberry	-	15	20	20
Robinson	-		11	6
North Fork Robinson	-	5	5	6
Grandad	-	11	11	11
McIntyre		20	13	16
Long		6	7	5
Nylon		53	53	27
No-see-um	8		7	13
Mosquito	7		11	9
Gleason		18	11	23
Homestead	6		6	7
Breakfast	1		1	1
Stanton				5
Little North Fork	1		1	1
Telephone	-	11	11	12
Benton		3	6	4
Croty	9		12	13
Joes	11		20	11

Table 6. Continued.

Creek name	Creek mouth to 1500'[1]	1450' to 1500'	1500' to 1550'	1550' to 1600'
Whiskey	14		12	16
Loop	6		18	18
Anderson	4		8	11
Larkins	3		18	15
Rooney	-	-	16	9
Long Bar	-	-	8	11
Spires	-	-	13	13
Thrasher	-	-	11	9
Butte			-	7
Milk			-	9
Syringa			-	16
Salmon	-	-	-	8
Thompson	-	-	-	

[1] 1500'= 457.2 m

From June of 1990 to July of 1991 was a relatively normal water year and, based on past correlations, we predicted a low spawner count of 4,278 fish (Figure 7). Spawner counts were actually three times better than expected. Operation of Dworshak Dam changed in the winter of 1991-1992. Flood control responsibilities were shifted to Grand Coulee Dam, reservoir drawdown was not as deep, and more water was released during spring and fall for anadromous fish flows. Possibly the higher winter water levels had a positive effect on kokanee abundance by reducing entrainment losses. This effect will need several more years of observation before it can be verified, but it is nevertheless an encouraging sign. We recommend continued monitoring of the kokanee population to determine if the change in dam operation affects kokanee abundance (based on discharge) or kokanee size (at a given density) (Figures 6 and 7).

The authors recommend that the relationship of discharge to kokanee spawner abundance (and thus adult kokanee abundance) be included in the final screening modeling for the Systems Operation Review (Figure 7). This correlation is our best example of how dam operation affects kokanee abundance.

Survival Rates

Survival rates of kokanee from 1991 to 1992 were the highest ever recorded for Dworshak Reservoir. Most encouraging was the 47% survival from age 1 to age 2; much better than the previous mean of 17%. The improved survival may hopefully be due to a change in dam operation, although it is speculative at this point. As stated earlier, the shallower winter drawdown may have kept the turbine intakes deeper, thus reducing entrainment losses.

We found no age 3 kokanee (Figure 3). This was consistent with last year's finding that all age 2 kokanee were mature, although this was based on a very small sample size (n=6). These fish would have spawned and died during 1991, and we therefore expected few age 3 fish. The low sample size in 1991, however, makes it difficult to accurately assess survival of this oldest age class.

Fourteen percent of the large kokanee in the trawl samples in 1992 were immature, which should provide a group of larger age 3 kokanee in 1993.

Scales read from age 2 kokanee appeared to have a check just before the second annuli. On some scales, the check was so pronounced that they could easily have been misread as annuli. However, scales did not show a summer's growth between the check and the true second annuli. Future fisheries workers need to be aware of the potential for checks.

Kokanee Size

The large kokanee in the fishery is one of the reasons for the popularity of Dworshak Reservoir. In most lakes in northern Idaho, kokanee average about 250 mm. Dworshak Reservoir kokanee have averaged from 280 to 370 mm in the spawning run. The total length of kokanee has varied inversely with the abundance of kokanee (Figure 6). During 1991 and 1992, however, kokanee were not as large as would have been expected based on their abundance. This may have been due to chance variation in kokanee growth caused by weather, limnological conditions, or bias in our samples.

A second possibility is that the operation of the dam, which withdrew more water in the spring and fall, entrained more zooplankton than in the past, thus impacting kokanee growth. In the past, drawdowns were in the late fall and winter when zooplankton abundance is low and kokanee are less actively feeding. This may have had less of an effect on growth. Refilling the reservoir in the spring may have trapped nutrients entering the reservoir during spring run-off and benefitted growth. Although based on very limited data, the new drawdown regime may have reduced kokanee entrainment losses but also slowed kokanee growth. The Nez Perce Tribe is currently conducting studies on dam operation and reservoir productivity. We strongly support the need for these studies.

Tributary Access

Our examination of the slopes of many of the tributary streams which enter Dworshak Reservoir indicated that low pool elevations could be a potential problem for spawning kokanee. Many of the smaller streams had lower reaches that became increasingly steep near the low pool elevation of the reservoir. Thus, low pool elevations in September could expose barriers to fish migration. Currently, however, we do not know if actual barriers exit, or if these small streams are important spawning areas for the kokanee population. If this becomes a critical concern, we suggest surveys of the streams be conducted during the spawning run to locate actual fish barriers.

RECOMMENDATIONS

1. The relationship of discharge to adult kokanee abundance should be included in the final screening modeling for the Systems Operation Review. This correlation is our best example of how dam operation affects the kokanee population. Changes in the numerical abundance of kokanee should be given higher importance in the SOR modeling than changes in kokanee growth.

2. We recommend continued monitoring to relate the changing pattern of operations of Dworshak Dam to kokanee population, i.e. high winter pool elevation (above 470 m elevation), to determine if the trend towards more kokanee will continue. Late July can be used for effective trawling and population estimates, which include maturing adults.

3. We also recommend a close examination of the selector gate positioning to determine if it can be used to minimize kokanee losses.

ACKNOWLEDGEMENTS

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A P P E N D I X

Appendix A. Annual discharge through Dworshak Dam July 1 to June 30, number of kokanee spawners in Skull, Quartz, and Isabella creeks, and the modal lengths of kokanee spawners in these tributaries to Dworshak Reservoir, Idaho.

Year	Discharge (billon m^3/ year)	Spawners	Spawner total lengths (mm)
1992		13,192	285
1991	3.72	5,995	305
1990	5.33	15,456	307
1989	5.05	19,985	284
1988	3.97	21,827	284
1987	3.38	6,348	326
1986	3.23		
1985	5.15	20,000	
1984	4.82	12,200	300
1983	5.29	2,451	370
1982		10,576	310
1981		8,070	340