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Effects of the Operation of Kerr and Hungry Horse Dams on the Kokanee Fishery in the Flathead River

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Effects of the Operation of Kerr and Hungry Horse Dams on the Kokanee Fishery in the Flathead River System

Final Research Report
1979-1985

by

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and
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Prepared for

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Bonneville Power Administration
Division of Fish and Wildlife

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EXECUTIVE SUMMARY

This study was undertaken to assess the effects of the operation of Hungry Horse Dam on the kokanee fishery in the Flathead River system. Studies concerning operation of the dam on the Flathead River aquatic biota began in 1979 and continued to 1982 under Bureau of Reclamation funding. These studies resulted in flow recommendations for the aquatic biota in the main stem Flathead River, below the influence of Hungry Horse Dam on the South Fork. Studies concerned specifically with kokanee salmon have continued under Bonneville Power Administration funding since 1982. This completion report covers the entire study period (September 1979 - June 1985).

An estimated annual average of 80,000 (range: 38,900-131,500) kokanee reached spawning grounds in the Flathead River system from 1979-1984. An annual average of 61,600 (range: 31,000-103,500) kokanee spawned in McDonald Creek, the major spawning area in the drainage. The main stem Flathead River averaged 10,800 (range: 1,100-19,100) spawners annually. Almost eight times more kokanee than predicted by a stage-discharge/year class strength model spawned in the main stem in 1984. Other river system spawning areas include the Whitefish River and the South and Middle Forks of the Flathead River.

Observation of the first concentration of kokanee spawners above Kalispell generally occurs in early September. Aerial counts were valuable in estimating general trends of abundance and migration timing. Analyses of kokanee migration data indicated no significant relationship between aerial kokanee counts and sixteen environmental variables.

Average length of kokanee spawners in a particular cohort is assumed to be a function of the strength of that year class and the strengths of adjacent year classes. Analysis of kokanee spawner length, i.e. year class strength, and flow conditions in the main stem Flathead River from 1966 through 1984 indicated a strong relationship between average spawner length and differences in spawning and incubation stage as affected by discharges from Hungry Horse Reservoir ($r=-0.93$, $p<.001$). Length of 1984 female spawners averaged 346.5 mm, close to the 337.7 mm predicted by the river stage-discharge model.

Prior to the initiation of this study, and in its early years, large kokanee daily and possession limits were allowed. In recent years harvest limits were adjusted frequently over the course of the study to reduce pressure on the depressed population. From 1981 to 1984 cumulatively, over 43,300 man-days of pressure were expended in the river system to harvest almost 200,000 kokanee.

The management goal of 330,000 preharvest main stem spawners should be reached by 2003. Recovery of the main stem kokanee population was projected with a 20 percent egg to fry survival rate, a 2 percent fry to adult return rate, a 20 percent age class overlap and a 10 percent harvest.

Survival of eggs to the eyed stage in the main stem Flathead has averaged 64 percent since 1979. Survival was lowest in the first year of the study before any flow restrictions were in place. Survival of eggs in other spawning areas in the river system ranged from 33 to 94 percent.

Kokanee fry, during their migration to Flathead Lake, traveled as fast or faster than the average current velocity, indicating active swimming during emigration. Migrating fry travel during nighttime hours as few were captured until after dusk each day. Approximately eight days are required at moderate flow levels for fry to reach Flathead Lake from McDonald Creek, a distance of 100 km. Lengths of emigrating fry ranged from 22-30 mm.

Dipteran larvae were the most abundant food item in the stomachs of kokanee fry in the Flathead River system. Copepoda, Cladocera, Trichoptera, Ephemeroptera and terrestrial insects were also represented.

Experiments conducted in spawning areas indicate that 73 percent of the kokanee eggs are deposited after dark and 27 percent during the day. If the present flow regime in the Flathead River was altered for power peaking operations during daylight hours, kokanee incubation success would be significantly reduced. The present flow regime of 3,500-4,500 cfs during the spawning period and no less than 3,500 cfs during the incubation period should remain in effect 24 hours per day.

Major results of this study were (1) development and refinement of methods to assess hydropower impacts on spawning and incubation success of kokanee, (2) development of a model to predict kokanee year class strength from Flathead River flows, and (3) implementation of flows favorable for successful kokanee reproduction. A monitoring program has been developed which will assess the recovery of the kokanee population as it proceeds, and to recommend management strategies to maintain management goals for the kokanee fishery in the river system.

ACKNOWLEDGEMENTS

Many people and agencies contributed to the completion and success of this study. Pat Graham, presently Chief of the Department's Fisheries Management Bureau, had the drive and determination to see that the study got off the ground and maintained the proper direction. Steve McMullin and John Fraley each served as project biologist and project coordinator during the study. Mike Aderhold provided valuable media exposure and aided in field operations. Paul Leonard, Ken Frazer, Rick Adams, Jon Cavigli, Mark Gaub, Steve Bartelt, Paul Suek, Beth Morgan, Tim Bodurtha, Elinor Pulcini and Janice Pisano all served as field workers at some time during the study. Their effort was invaluable in accomplishing field work.

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Jean Blair typed the manuscript.

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INTRODUCTION

The Pacific Northwest Electric Power Planning and Conservation Act of 1980 called for the Northwest Power Planning Council (NPPC), established by the Act, to develop and adopt a program to protect, mitigate and enhance fish and wildlife and their habitats which had been, and are presently being, adversely affected by hydroelectric development in the Columbia River System. The Act also directs the administrator of the Bonneville Power Administration (BPA) and other federal agencies to implement the program. In 1981, BPA agreed to the concept of this study. The NPPC included the study of kokanee below Hungry Horse Dam in the Columbia River Basin Fish and Wildlife Program in 1982 (NPPC, 1982).

Kokanee were introduced into Flathead Lake in 1916 (Montana Fish and Game Commission, 1918) and a popular fishery had developed by the 1930's. Spawning kokanee were observed in McDonald Creek by the late 1930's. The closing of Hungry Horse Dam on the South Fork of the Flathead River in 1953 altered the water temperature regime of the main stem Flathead below the South Fork and probably increased the incubation success of the kokanee population which used that portion of the river for spawning.

Kokanee are presently the most abundant and popular gamefish in the drainage, comprising over 80% of the harvest in 1975 and over 90% in 1981-82 (Hanzel 1975, Graham and Fredenberg 1982, Fredenberg and Graham 1982). The Flathead kokanee fishery attracts anglers from the western United States and Canada. A healthy kokanee fishery may be worth more than 8 million dollars annually to the Flathead area.

Hungry Horse Dam, located 8 kilometers (km) upstream from the mouth of the South Fork, is operated by the Bureau of Reclamation (BOR) for flood control and for hydroelectric energy production, which is marketed by the BPA. Peak capacity of the dam is 328 Megawatts (Mw) at a flow capacity of 11,417 cfs. Operation of Hungry Horse is coordinated with electrical energy production, water consumption needs and flood control requirements throughout the Northwest.

Kokanee spawning in the South Fork and in the main stem of the Flathead River below the South Fork has been adversely affected by the operation of Hungry Horse Dam. Kokanee eggs, which are deposited primarily in side channels and along stream margins, have experienced desiccation and freezing mortality due to the daily and seasonal vertical fluctuations of river levels. Incubation mortality resulting from dewatering of redds has affected year class strength of kokanee in the Flathead System. The main stem kokanee spawning run has declined from an estimated post harvest level of 150,000 in 1975 to a low of 1,120 in 1980.

Past studies by the MDFWP (Graham et al. 1980, McMullin and Graham 1981, Fraley and Graham 1982) conducted for BOR resulted in flow recommendations to eliminate dewatering of kokanee spawning beds and to provide a stable environment for other fish species and invertebrates.

The study continued in 1982 under BPA funding with emphasis on evaluating and fine tuning the flow recommendations, monitoring the effects of flows on kokanee reproduction and recommending management strategies to enhance main stem kokanee spawning. Major objectives under BPA funding were to:

1) Continue development of a stock-recruitment relationship begun in 1979.

2) Quantify effects of the amount and timing of controlled flows on kokanee distribution and reproductive success in the regulated portion of the river and to determine the contribution of day and night spawners to total reproduction.

3) Determine the relative contribution of major river system spawning areas to the total population.

4) Identify timing and destination of successive runs of kokanee spawners in the Flathead River and their use by fishermen, and determine if timing of migration is affected by discharge from Hungry Horse Dam.

The Department's overall management goal for the Flathead System's kokanee population is to provide a balance between total numbers, harvest, and average size and to maintain a diversity of spawning areas throughout the lake-river system. The kokanee escapement goal for the main stem Flathead River is approximately 330,000 spawners averaging 300-330 mm in length.

BACKGROUND

In 1979 the Department began the Lower Flathead River Aquatic Resources Study (Graham et. al. 1980) with funding from the U.S. Water and Power Resources Service (The Bureau of Reclamation). At that time, Hungry Horse Dam was being operated for peak power production. Large daily and seasonal fluctuations during the fall and winter were common. Peak discharges for generation occurred for days or weeks at a time, followed by days or weeks of no generation at all. The study was initiated by the Department to assess the impacts of various proposed alternative flow regimes from Hungry Horse Dam on the aquatic biota in the Flathead River. Several operating alternatives were being reviewed to increase power production from Hungry Horse Dam. These alternatives, which included no change in operation, could have increased peaking capacity and total annual power out of the dam by ten percent.

The initial year of research was comprehensive with studies of fisheries, aquatic invertebrates and temperature regimes. During that year drainage wide surveys were undertaken to identify actual and potential kokanee salmon spawning areas, to evaluate migration, enumerate spawners, assess incubation success and to investigate stream flow-fish length relationships.

The next two years of study under BOR funding concentrated on the effects of the operation of Hungry Horse Dam on the kokanee fishery in the Flathead River (McMullin and Graham 1981, Fraley and Graham 1982). During these years experimental spawning and incubation flows in the main stem Flathead River were provided from Hungry Horse. These study flows were intended to prevent kokanee from spawning in areas which would become dewatered during the incubation period. Experimental egg plants were made in the river and in hatchery channels to evaluate the timing and duration of dewatering on green and eyed egg survival. Analysis of stream flow in relation to fish length data continued and several models were developed which predicted kokanee length, an indicator of year class strength, from a weighted three year moving average of flow conditions. Fry emergence and emigration studies were begun in 1982 to determine the source, timing and magnitude of fry travel to Flathead Lake.

As the main stem spawning population decreased, kokanee creel and possession limits in the Flathead System were reduced to decrease fishing pressure and harvest on the population.

In July 1981, the Department submitted a proposal to BPA to fund research to identify possible affects of the operation of Hungry Horse Dam on kokanee production in the main stem Flathead River. The impetus for this study came from the Pacific Northwest Electric Power Planning and Conservation Act of 1980, which stated that "BPA is authorized and responsible to use its legal and financial resources to protect, mitigate and enhance fish and wildlife affected by the development, operation and management of hydroelectric facilities on the Columbia River and its tributaries." (Northwest Power Planning Council, 1982).

In November 1981 the Department recommended to the Council preliminary flows at Columbia Falls of not less than 4,000 cfs and not more then 4,500 cfs between the hours 1700 and 2400 throughout the spawning period (October-November) and a minimum flow of 2,500 cfs from December 1 through March 31. Minimum flows at Columbia Falls were to be at least 4,000 cfs from April 1 until combined flows of the North and Middle Fork Flathead River exceeded 4,000 cfs. These flows were necessary to insure successful and adequate reproduction of kokanee and other fish species and invertebrates in the Flathead River. In March 1982 these recommendations were amended to flows at Columbia Falls of not less than 3,500 cfs and not more than 4,500 cfs from October 15 through December 15, a minimum flow at Columbia Falls of 3,500 cfs from December 15 through April 30 and emergence flows of 3,500 cfs from May 1 through June 30 to flush emerging fry downstream to Flathead Lake (Table 1). Final department recommendations will be made to the NPPC by March 1, 1988.

Table 1. Spawning and incubation flows (in cfs) and effective dates of each. Spawning flows are expressed as the recommended range of discharges and incubation flows are minimum recommended discharges.

Year	Spawning Flow		Incubation Flow	
	cfs	period	cfs	period
1979	none		none	
1980	5,000	November	2,000	Dec-April
1981	4,000	November	2,300	Dec-April
1982	3,500-4,500	Oct 15-Dec 15	3,500-4,500	Dec 16-April 30
1983	3,500-4,500	Oct 15-Dec 15	3,500	Dec 16-April 30
1984	3,500-4,500	Oct 15-Dec 15	3,500	Dec 16-April 30

DESCRIPTION OF THE STUDY AREA

The Flathead River drains 21,876 km^2 of northwest Montana and southeast British Columbia and is the northeastern most drainage of the Columbia River Basin (Figure 1). The North, Middle and South Forks, all of approximately equal size, provide about 90% of the water flowing through the Flathead watershed.

The North Fork of the Flathead flows south out of British Columbia and forms the western boundary of Glacier National Park. The North Fork is classified as a scenic river under the National Wild and Scenic Rivers Act from the Canadian border to Camas Creek, a distance of 68 km. The lower 24 km of the North Fork is classified as a recreational river.

The Middle Fork of the Flathead is classified as a wild river from its source in the Bob Marshall Wilderness area to its confluence with Bear Creek near Essex, Montana. Below Bear Creek, the Middle Fork is designated a recreational river. The Middle Fork forms the southwestern boundary of Glacier National Park.

The upper South Fork of the Flathead River is also classified as a wild river from its headwaters in the Bob Marshall Wilderness to Hungry Horse Reservoir. A short stretch of the South Fork, from the headwaters of Hungry Horse Reservoir upstream to Spotted Bear, is classified recreational. The lower South Fork is regulated by flows from Hungry Horse Dam. Vertical water level fluctuations in the lower South fork have been as much as 2.5 m daily due to peak hydroelectric energy production (Figure 2).

The main stem Flathead River is classified a recreational river from the confluence of the North and Middle Forks to the confluence of the South Fork. Streamflows in the Flathead River downstream from its confluence with the South Fork are subject to fluctuations due to the operation of the Hungry Horse powerhouse.

Peak flows in the main stem normally occurred in late May or early June, coinciding with peak runoff in the North and Middle Fork drainages (Figure 3). During fall and winter the main stem hydrograph mirrors that of the South Fork. Daily vertical water level fluctuations in the main stem varied up to 1.4 m due to Hungry Horse operation (Figure 2).

Water temperature in the main stem was also partially regulated by discharge from Hungry Horse Dam. Hypolimnial water releases from Hungry Horse Dam lowered summer water temperatures and elevated winter water temperatures (Figure 4).

Kokanee salmon, westslope cutthroat (*Salmo clarki*) and bull trout (*Salvelinus confluentus*) are the three major sport fish in the Flathead River (Hanzel 1977). Cutthroat and bull trout are native to the Flathead, but kokanee were introduced. In 1916, 500,000 chinook salmon eggs obtained from the Oregon Fish

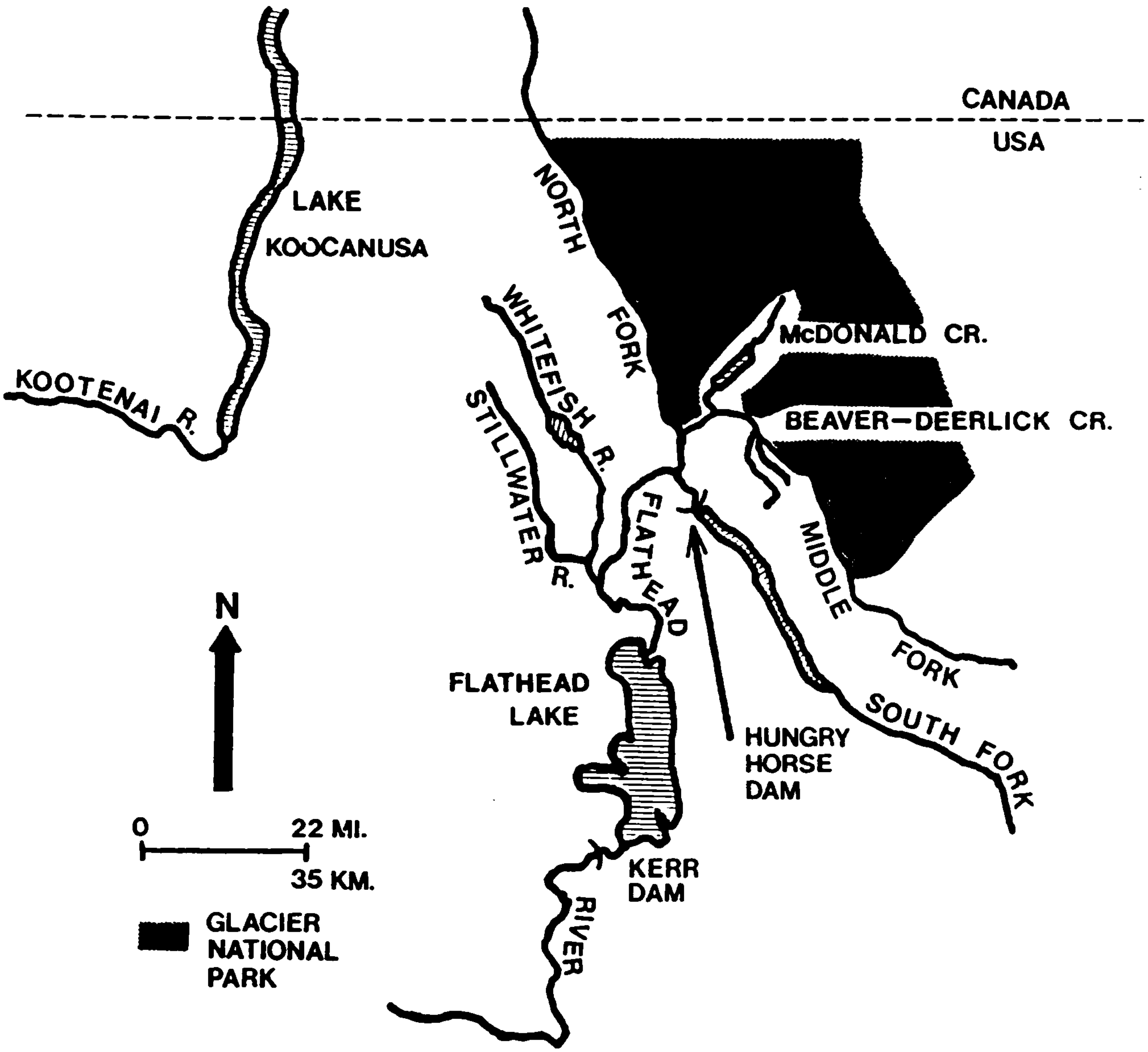

Figure 1. The Flathead Drainage.

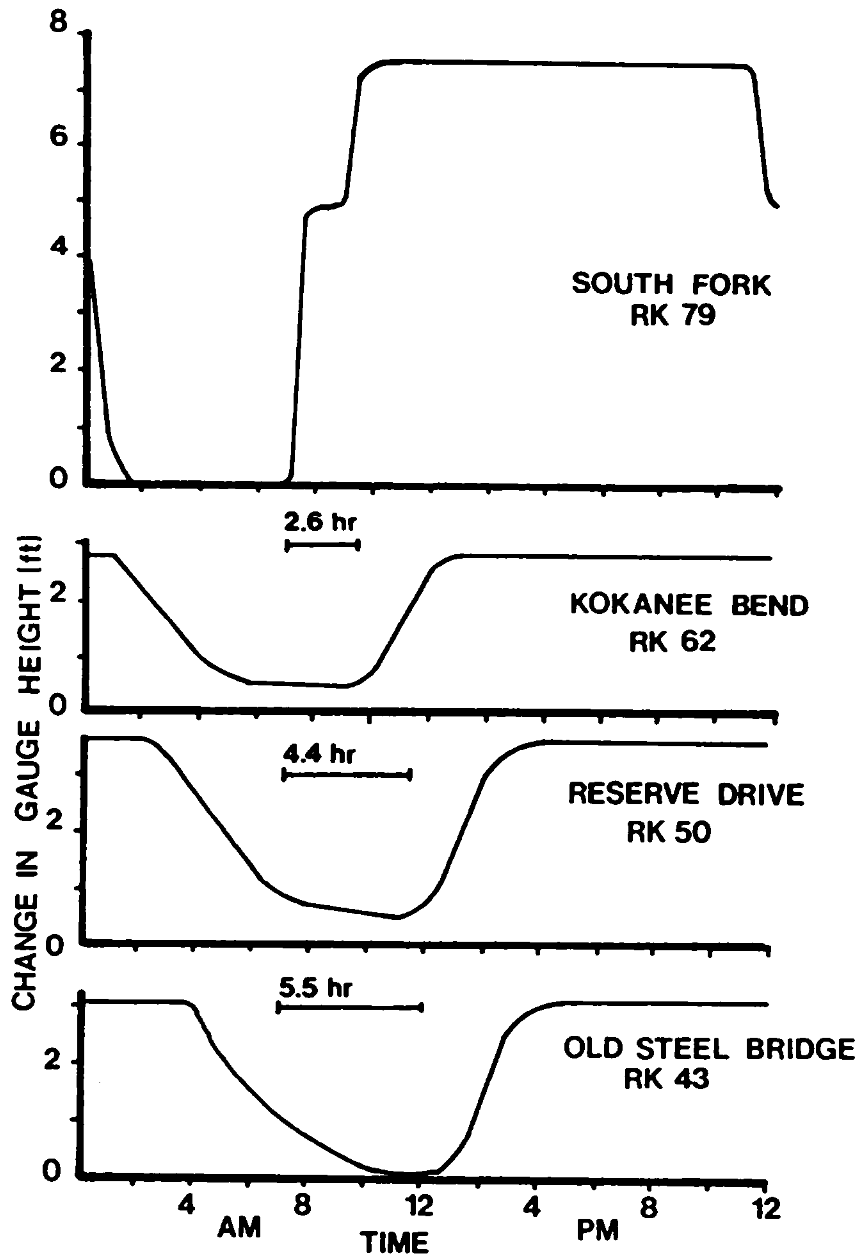

Figure 2. Vertical water level changes in the South Fork and three areas of the main stem Flathead River as a result of generation at Hungry Horse Dam, August 2, 1979. Range of flows is 164 cfs to 9,100 cfs in the South Fork and 3,210 cfs to 12,100 cfs in the main stem (from McMullin and Graham 1981).

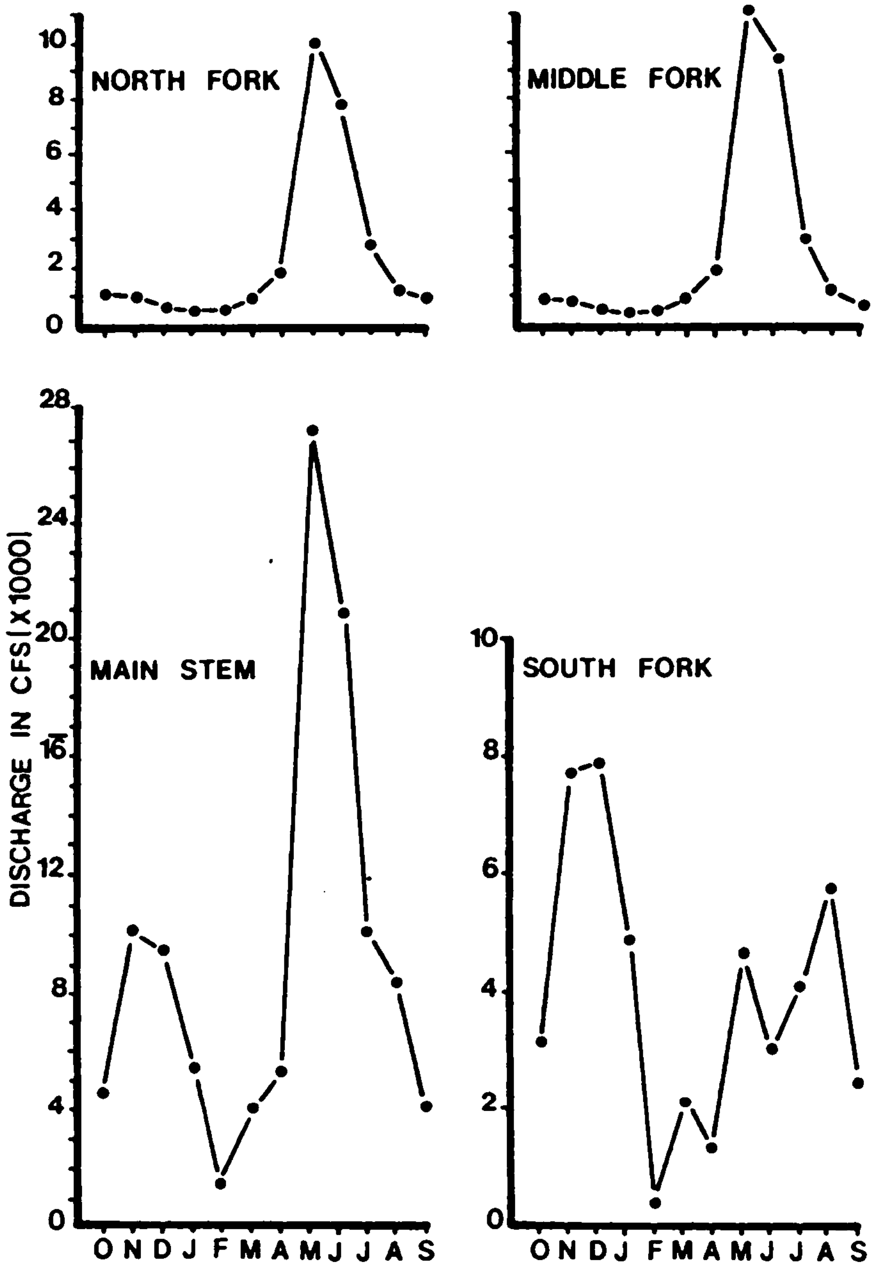

Figure 3. 1979 hydrographs for the North Fork near Canyon Creek, Middle Fork near West Glacier, South Fork near Hungry Horse and Flathead River at columbia Falls (from McMullin and Graham 1981).

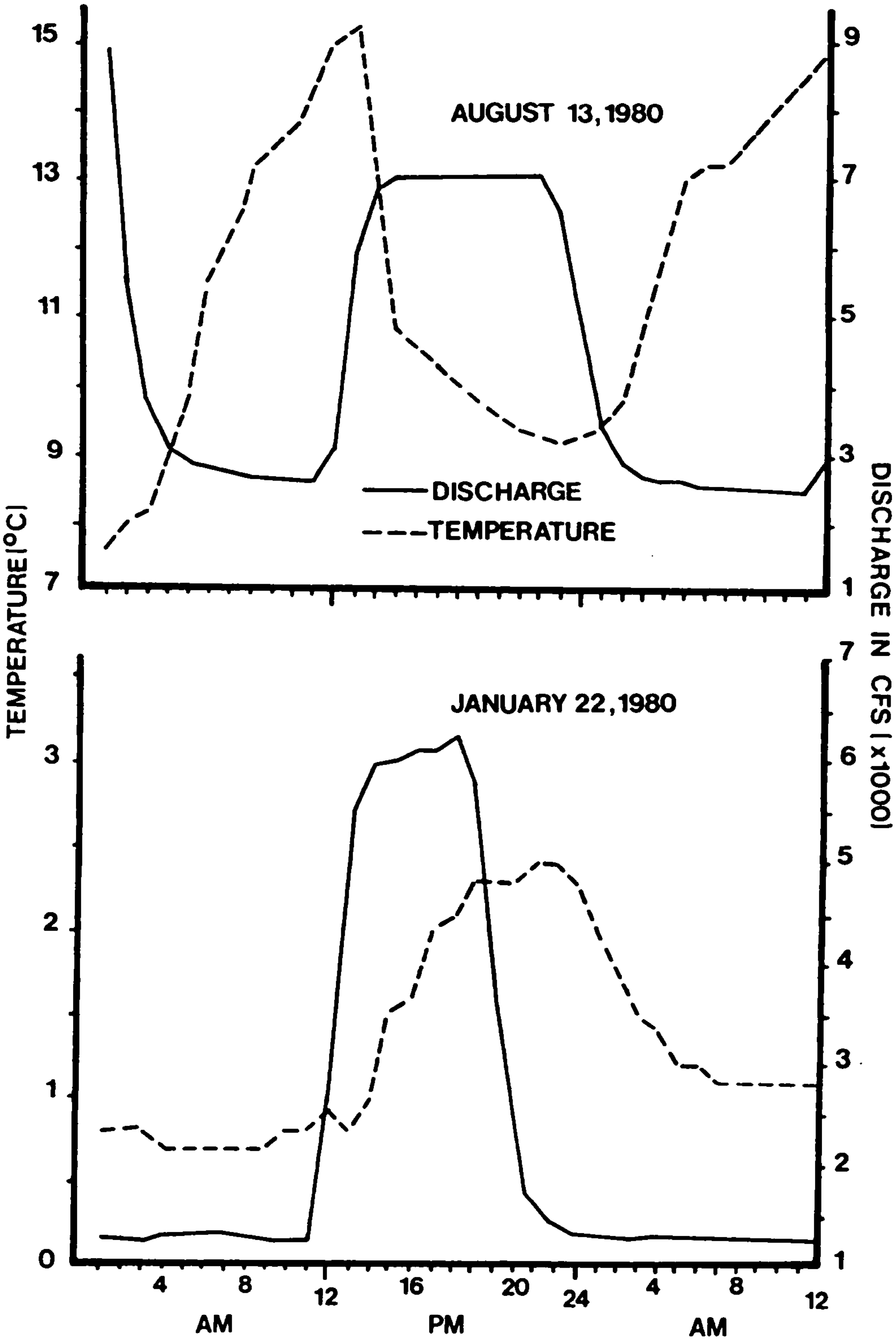

Figure 4. Flow related temperature fluctuations in the main stem Flathead River at Columbia Falls on a winter day and a summer day (from McMullin and Graham).

Commission were reared in the Flathead Lake Hatchery and the fry were stocked in several area lakes (Montana Fish and Game Commission 1918). In subsequent years, mature kokanee salmon, or "redfish", were netted in Lake Mary Ronan and Flathead Lake; apparently they had been mixed in with the chinook salmon eggs. Kokanee became established in Flathead Lake and their numbers continued to grow. By 1933, a kokanee trolling fishery was underway on Flathead Lake. That fall an estimated catch of 100 tons of kokanee was canned for the Montana Relief Commission. Thousands of kokanee were spawning along the shores of Flathead Lake and runs were ascending the Flathead River system (Montana Fish and Game Commission 1934, Alvord 1975).

By the late 1930's, a run of kokanee had become established in McDonald Creek (Fish and Wildlife Service 1968) and probably in the Whitefish River and spring areas in the main stem Flathead River. The kokanee population in the main stem continued to grow in size from the 1960's through the early 1970's. This was partly associated with flow patterns and modified temperatures of water discharged from Hungry Horse Dam. During the mid-1960's, local residents first noticed large numbers of kokanee in Beaver and Deerlick Creeks in the Middle Fork drainage. Department personnel first observed kokanee spawning in the Middle Fork of the Flathead River from McDonald Creek upstream to the mouth of Deerlick Creek in 1981.

Other fish species found in the Flathead River include rainbow trout (Salmo gairdneri), mountain whitefish (Prosopium williamsoni) and largescale sucker (Catostomus macrocheilus). Several other species encountered less frequently include brook trout (Salvelinus fontinalis), Yellowstone cutthroat trout (Salmo clarki bouvieri), lake trout (Salvelinus namaycush), lake whitefish (Coregonus clupeaformis), pygmy whitefish (Prosopium coulteri), and northern squawfish (Ptychocheilus oregonensis). Several more species are known to be present in the drainage, but are rarely encountered in the Flathead River.

METHODS

ADULT KOKANEE ABUNDANCE AND MIGRATION

Abundance and migration of kokanee river spawners were monitored by snorkeling, aerial census, fisherman tag returns of marked fish, and redd counts.

Snorkel surveys were conducted each year in selected areas of the Middle Fork above McDonald Creek in late September and the North Fork from Kintla Creek to Canyon Creek in early October. Several snorkel counts were made on the entire length of McDonald Creek each fall. Two observers snorkeled downstream and forced kokanee schools upstream between them. Each observer reported a count to a data recorder following behind in a canoe. The two counts represented the high and low estimate for each school of fish.

Aerial counts of kokanee spawners were made as part of a fisherman census on the Flathead River from Flathead Lake upstream to the confluence of the North and Middle Forks. These aerial counts were also made on the Middle Fork below West Glacier. A small plane carried the observer at an elevation of approximately 100 m over the river channel and counts were made by estimating the size of schools of adult spawners. The counts were made approximately three times weekly from late August to mid October. Other researchers have successfully used aerial counting methods to enumerate salmon (Gibson 1973, Nielson and Geen 1981, Church and Nelson 1963).

Kokanee spawner abundance was estimated from redd counts in all segments of the river system except McDonald Creek, where redds were too dense to be enumerated individually. Abundance was estimated by multiplying redd counts by an average figure of 2.4 spawners per completed redd (Fraley 1984). This ratio was determined by comparison of trap counts of spawners and redd counts in confined areas in 1982 and 1983. Inventories were made when spawning was considered at least 90 percent complete in each area, as indicated by observation and the condition of spawners.

Timing of kokanee migration, as measured by spawner abundance in the main stem, was regressed against sixteen individual variables (Appendix A, Table 1) and combinations of those variables to determine which, if any, keyed spawning migration.

YEAR CLASS STRENGTH AND FLOW CONDITIONS

Historical relationships between year class strength of kokanee spawners and flow conditions in the main stem Flathead River were analyzed. Kokanee spawning in the main stem is directly affected by the operation of Hungry Horse Dam, which has regulated water levels since 1953. Most kokanee spawning beds are located along shallow river margins and are subject to dewatering with only a small drop in discharge.

Historical flow conditions were measured by the difference in average river stage between the main kokanee spawning period (November), and incubation period (December-March). Stage differences of zero or greater were favorable for kokanee egg survival. Differences of less than zero would result in dewatering of spawning beds and produce conditions unfavorable for egg survival.

The total length of female kokanee spawners was used as the measure of year class strength in the Flathead System. It was assumed that growth was inversely related to population size. Many workers have reported that growth of juvenile anadromous and landlocked sockeye salmon is density dependant (Foerster 1944, Bjorn 1957, Johnson 1965, Goodlad et al. 1974, Stober et al. 1978, Rogers 1975).

Growth of kokanee can also be affected by interactions between and within year classes (Ward and Larkin 1964), accentuated by the close association of the species in schools. It was assumed that fry or age 0+ fish interact with their cohorts and age I+ fish, but not with older fish. In subsequent years, interactions take place within cohorts and between a cohort and adjacent year classes. The majority of kokanee in Flathead Lake mature, spawn and die after four growing seasons (age III+). In summary, an age class interacts three years with the previous age class, four years within the cohort, and three years with the following year class.

To account for these age class interactions, a three year weighted moving average was used in calculating spawning and incubation period stage differences. Female kokanee lengths for each spawning year from 1966-1983 were correlated to the weighted mean stage differences (GHD) which produced them. For example, length of 1983 spawners was correlated with 3(1978 GHD) + 4(1979 GHD) + 3(1980 GHD)/10; where GHD represents the average river stage during spawning minus the average spawning river stage during incubation. The analysis began with the 1962 water year.

It was assumed that the main stem Flathead River contributed a substantial portion of the total recruitment to Flathead Lake during the 1960's and 70's. Strong year classes of Flathead kokanee were produced when flow conditions were favorable; weaker year classes resulted when main stem flows were less favorable. Recruitment from McDonald Creek and the upper drainage was also substantial but was probably relatively constant, due to spawning gravel quality and quantity limitations (annual emigrating fry estimates from McDonald Creek were similar from 1981-84, despite a threefold difference in spawner numbers). Recruitment from the other lower drainage areas such as the Whitefish River and Flathead River spring areas was probably also relatively constant.

Flathead Lakeshore spawning probably declined during the 1970's due to the operation of Kerr Dam and its effects on Flathead Lake levels (Decker-Hess and Clancey 1984).

CENSUS OF THE RIVER SYSTEM KOKANEE FISHERY

A survey of the kokanee fishery was conducted on the Flathead River from Flathead Lake to Nyack Flats on the Middle Fork from August 28 through October 15 in 1982 and 1983. The purpose of the survey was to determine catch rates, fishing pressure, harvest, and other information concerning the kokanee salmon fishery in the main stem and Middle Fork. The 1984 census began on August 28, but the fishery was closed on September 20 due to the high harvest of kokanee in the Salmon Hole during the early part of the spawning run.

The creel census design was a modification of the method described by Neuhold and Lu (1957) and used by Fredenberg and Graham (1982). A complete description of the methods is given in Fraley and McMullin (1983).

POPULATION RECOVERY

To project the recovery of the main stem kokanee population, an egg to fry survival rate of 20 percent and various fry to adult survival rates were assumed. A 20 percent overlap of the previous kokanee year class was assumed and the number of returning kokanee spawners was projected for each year from 1983 to 2033. A computer program which incorporated the above assumptions was written by Roger Larson of the Bureau of Reclamation in cooperation with the Department of Fish, Wildlife and Parks. The program was calibrated with kokanee escapement estimates made from 1979-1983.

Determining the diel timing of kokanee spawning in Flathead River spawning areas was of critical importance in fine tuning flow recommendations in the main stem below Hungry Horse Dam.

To accomplish this, areas of gravel in the main stem and McDonald Creek were selected for diel spawning studies. In areas where sufficient spawners were present, areas of gravel were alternately covered and uncovered with chicken wire during day and night periods to determine the relative contributions of day and night spawners. Redd construction and egg deposition were compared in areas available for daytime and nighttime kokanee spawning.

FRY PRODUCTION

Survival of kokanee eggs and sac fry was monitored in natural redds in the main stem Flathead River during incubation to evaluate the effects of the requested flows. A hydraulic egg sampler (Graham et al. 1980, McNeil 1963) and kick net were used to sample natural redds.

Survival of eggs and alevins in natural redds was monitored in spawning areas of the Middle Fork, the South Fork, McDonald Creek and the Whitefish River to document and assess natural fluctuations in areas not affected by water level fluctuations. Portions of McDonald Creek were sampled with the hydraulic sampler and kick net to estimate the density of live eyed eggs and sac fry in the gravel.

Experimental egg plants were used to monitor the affects of dewatering on incubation and development and to determine egg to fry survival rates in various sediment mixtures (Graham et al. 1980, McMullin and Graham 1981, Fraley and Graham 1982).

Experimental planting programs began in two main stem areas in the spring of 1984 and in Beaver and Deerlick Creeks in 1985. These areas were selected for experimental recovery plants because they had been high quality spawning areas before the mid 1970's, but had been virtually unused in recent years. Planting methods and stage of embryo development at planting were tested in the main stem areas (Fraley 1984).

Timing and abundance of emerging fry were evaluated using 0.5 m^2 drift nets suspended in the water column and 0.12 m^2 fry emergence traps (Fraley et. al. 1986) placed over the redd. Sampling was begun in January and continued until emigration and emergence were complete or nearly complete. Fry emergence traps were placed in river system spawning areas to help determine emergence timing and abundance of kokanee fry (Fraley et. al. 1986). Phillips and Koski (1969) used similar traps in Oregon river systems to capture salmonid fry. The traps consisted of a nylon net and metal frame with a nylon sock and plastic collecting bucket to capture emerging fry.

Drift nets were used in river system spawning areas to filter swimming fry from various depths of the water column (Fraley and Graham 1982). Net sets were made at least weekly at all sites. Areas monitored during the study were McDonald Creek, the Whitefish River, Brenneman's Slough, the Middle Fork and the main stem Flathead River. Drift nets were suspended on the surface and in the water column overnight at each area. Fry were counted, the volume of water filtered by the net was calculated, and a total estimate of fry emigration from each area was made. This estimate was made by expanding the density of fry captured per unit volume of water filtered out to the entire river. These data were used to estimate production and egg to fry survival rates from each area. Distribution of fry in the water column was evaluated in overnight experiments using drift nets distributed laterally and vertically in the water column in McDonald Creek.

Experiments were conducted in 1983 and 1984 to monitor fry movements in the river system (Fraley and McMullin 1983, Fraley 1984). Fry were captured in drift nets, dyed with Bismark brown stain (1:30,000 concentration) and released in McDonald Creek and their movements followed by setting drift nets at several locations in the river.

Fry Food Habits and Fry Quality

Kokanee fry were collected for food habits analysis from four Flathead River system spawning areas - Brennemans Slough (Main stem Area 1), McDonald Creek, Beaver Creek and the Middle Fork of the Flathead River.

RESULTS AND DISCUSSION

ADULT KOKANEE ABUNDANCE AND MIGRATION

Kokanee Abundance

One of the major objectives of the study was to assess the relative contribution of various river system spawning areas to the total recruitment of the Flathead Lake kokanee population (Table 2). An annual average of 80,000 (range:38,900 - 131,500) kokanee spawned in the Flathead River System from 1979-1984.

In the main stem Flathead River, 50 individual spawning areas were identified (Figure 5; Appendix B, Table 1). These locations were described and mapped in Fraley and Graham (1982). An average of 24 areas were used each year from 1979-1984. Numbers of kokanee using individual main stem spawning areas within any quadrennial cycle has been inconsistent at the low population levels existent during the study period. These inconsistencies cannot be explained by age class composition of spawning kokanee. In the six years since research began, two spawning cycles have been repeated, the 1979-83 cycle and the 1980-84 cycle. Survival from the weak 1979 main stem year class was too low to supply the number of returning adults necessary to comprise 92 percent of the 1983 spawning population, as indicated by age class composition samples (Fraley and McMullin, 1984). Although survival was similar in 1980, the spawning effort was very weak and could not possibly have provided the stock necessary to comprise 85 percent of the 1984 spawning run. Combined, the age II+ and IV+ kokanee comprised only 8 percent of the 1983 and 15 percent of the 1984 spawning populations. This was not enough to account for the large number of spawners in each of those years.

Fourteen specific spawning areas were used during most years. Areas which contained up to several hundred redds during any given year contained few or no redds four years later, and areas which were not used or were used sparsely during a particular year contained several hundred to over 1,000 redds four years later. The number of main stem spawning areas used increased in the second year of the 1979-83 and 1980-84 cycles (Appendix A, Table 1). This may not be unusual in an expanding population, but only twelve (55%) and five (36%) of the areas used in 1979 and 1980, respectively, were used in 1983 and 1984. One major spawning area was not discovered until 1981, so the 1979 and 1980 counts were probably low. An average of 10,780 (range: 1,100 - 19,100) kokanee spawned in the main stem Flathead River from 1979-1984, accounting for 13.5 percent of the spawning in the river system.

The South Fork of the Flathead River supported 4.3 percent of the kokanee spawning during the study period. Spawning runs in the South Fork have increased dramatically since flow restrictions went into effect in 1982.

Table 2. Estimated numbers of post harvest spawners in the Flathead River System during 1979-84. The percent contribution of each area is in parenthesis.

	McDonald Creek[a]	Main Stem Flathead River[b]	Whitefish River[b]	South Fork Flathead River[b]	Beaver - Deerlick Creeks[b]	Middle Fork Flathead River[b]	Total
1979	65,000 (90.5)	6,785 (9.5)	___[c]	___[c]	0	___[c]	71,785
1980	49,500 (95.9)	1,121 (2.2)	1,022 (1.9)	___[c]	___[c]	___[c]	51,643
1981	103,500 (78.7)	19,073 (14.5)	988 (0.8)	720 (0.5)	1,723 (1.3)	5,520 (4.2)	131,524
1982	30,965 (79.6)	3,720 (9.6)	1,836 (4.7)	480 (1.2)	101 (0.3)	1,802 (4.6)	38,904
1983	34,306 (58.8)	16,279 (27.9)	1,272 (2.2)	5,170 (8.8)	2 (<0.1)	1,330 (2.3)	58,359
1984	86,500 (75.5)	17,700 (15.5)	2,400 (2.1)	7,500 (6.6)	0	400 (0.3)	114,500
Mean	61,629 (77.0)	10,780 (13.5)	1,503 (1.9)	3,468 (4.3)	365 (0.5)	2,263 (2.8)	80,008

[a] Peak mean snorkel count of spawners
[b] Estimated by multiplying redd counts by 2.4
[c] No count

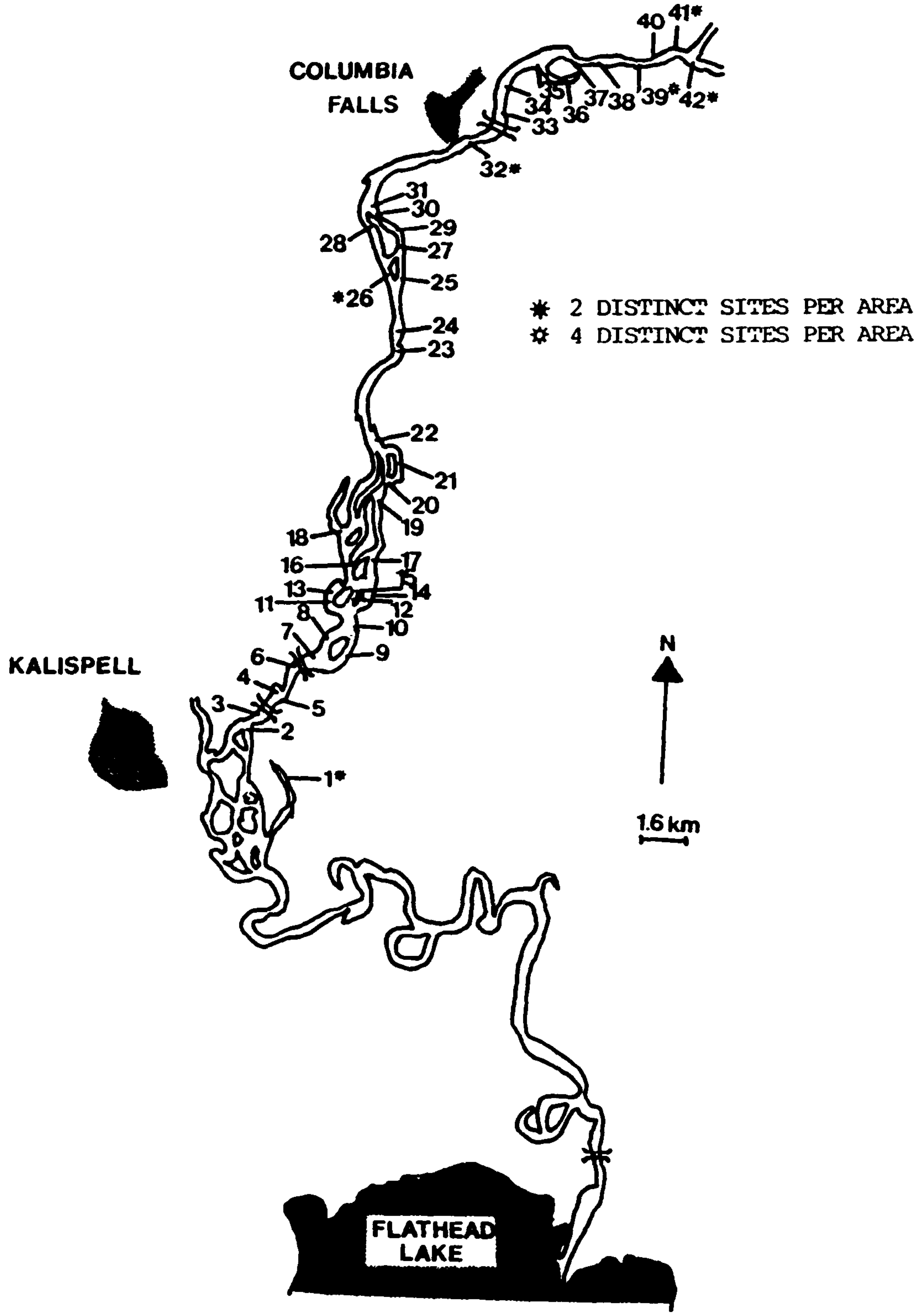

Figure 5. Map of kokanee spawning areas in the main stem Flathead River.

The stable diel flow regime now existent in the main stem and South Fork may be attracting kokanee which were migrating to areas farther upstream to spawn, and increasing incubation success. The combination of these two factors, straying spawners and increased incubation success, would lead to increases in the numbers of spawners in the main stem and South Fork, as seen in the 1979-83 and 1980-84 spawning cycles. However, in 1979 there were no restrictive flows and in 1980 the difference between the spawning and incubation flows was great enough to cause a significant portion of the redds not built in spring areas to be constructed at sites where dewatering would occur. Effects of the adopted flows on the main stem kokanee spawning run will begin to be assessed in the fall of 1985, four years after the 1981 flows provided by BOR affected a spawning population. Presently, doubling of the main stem spawning population is expected each successive generation, however, almost eight times as many spawners returned in 1984 as expected.

These data suggest that homing may not play an important role in the selection of spawning sites in the Flathead River system at low population levels, but that straying from other river system spawning areas into the main stem Flathead River occurs to a large degree. The improved flow conditions in the main stem may draw fish from other areas such as McDonald Creek. It is possible in the early years of the recovery that cohorts affected by the present flow regime will show much greater increases than projected. Once the main stem population is approaching target levels, straying may occur from it back into areas such as the Middle Fork and Whitefish River.

Monitoring the abundance of kokanee in areas unaffected by discharge from Hungry Horse provides a reference to monitor natural fluctuations in kokanee spawning populations. McDonald Creek was consistently the major spawning area in the Flathead System. During the period of study, an annual average of 61,629 (range: 31,000-103,500) kokanee were counted in McDonald Creek, accounting for 77.0 percent of the river system spawning.

An annual average of 2,263 (range: 400-5,520) kokanee spawners was estimated in the Middle Fork of the Flathead. The number of spawners in the Middle Fork has decreased each year since counting began. Only in 1981, the strongest spawning year of the study, did a significant number of spawners enter Beaver and Deerlick Creeks, tributaries to the Middle Fork of the Flathead River. Beaver dams at the mouths of the streams may have prevented migration into those streams for several years and channel changes in Beaver Creek caused by flooding in 1975 and 1979, and subsequent diking, may have caused kokanee to miss their homing cues. Beaver Creek supported strong runs of kokanee before 1979 (Gordon Pouliot, Nyack MT, pers. comm.)

The Whitefish River attracted 1,503 (range: 990-2,400) spawners during an average year and exhibited the most stable annual spawning run of all the areas. The 1984 year class is the strongest yet seen in the Whitefish River, however, it's parental generation in 1980 is the second weakest cohort seen.

Estimates of the average number of spawners in areas other than McDonald Creek and the main stem Flathead may be incorrect because no counts were made in those areas in 1979 and 1980.

Kokanee Migration

Observation of the first concentration of kokanee spawners above Kalispell generally occurs in early September. However, spawners in the 1980-84 cycle don't appear in this river section until mid-September. Aerial counts of spawners were effective in establishing general trend information regarding migration timing and relative abundance. Peak aerial counts of spawners in the river do not correspond temporally to initial sightings of schools.

Timing and intensity of spawner migration into streams has been attributed to light intensity rather than temperture, and strength of offshore winds aided in attracting kokanee to the mouth of the stream by diffusing the stream water into a widespread area of the lake, spreading the olfactory cues over a wider range (Lorz and Northcote, 1965). Migration timing of sockeye salmon has been associated with sunspot maxima, moon phase and abundance of sockeye (Gilhousen 1960).

Analysis of kokanee migration data revealed no significant relationships between timing of migration and environmental variables such as river stage, temperature, and photoperiod measurements (Figure 6; Appendix A Table 1) or combinations of those variables. Correlation of the average gauge height at Columbia Falls from mid-August to mid-September and the Julian day which kokanee were first observed above Kalispell showed no significant relationship ($r=0.45$, $p=.56$). More frequent counts and a more accurate method of counting is probably necessary to establish a relationship between environmental factors and kokanee migration.

YEAR CLASS STRENGTH AND FLOW CONDITIONS

Analysis indicated a strong relationship between kokanee spawner length and flow conditions from 1966 through 1984 (Table 3, Figure 7). The correlation between female kokanee spawner length and spawning and incubation stage differences from 1966 through 1983 was highly significant ($r=-0.93$, $p<.001$). This indicates that a large proportion (87%) of the variation in spawner length could be attributed to differences in spawning and

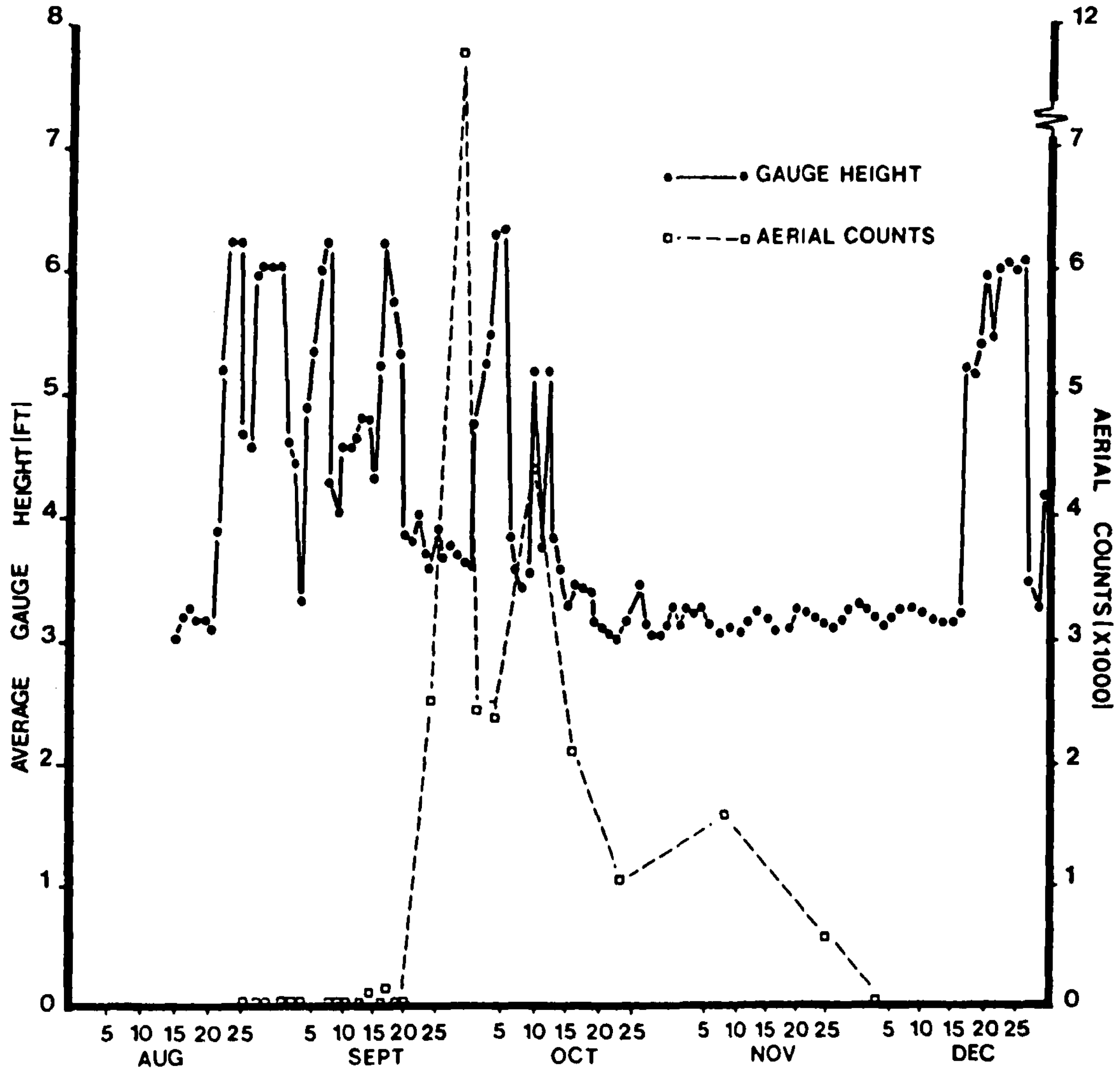

Figure 6. Average river stage and numbers of kokanee from aerial counts in the main stem Flathead River during 1984.

Table 3. Flow conditions and female kokanee spawner lengths in the Flathead System for spawn years 1966-1984.

Spawn year	Water years in 3 year average	Incubation-spawning stage difference (ft)	Weighted 3 year moving average (ft)	Actual female spawner length (mm)	Predicted female spawner length (mm)	Residual error (mm)
1966	1962-64	1.53	2.06	283	271.0	12.0
1967	1963-65	3.16	2.44	263	262.5	0.5
1968	1964-66	2.39	2.20	266	267.9	-1.9
1969	1965-67	0.99	0.65	303	302.3	0.7
1970	1966-68	-1.54	-0.36	314	324.8	-10.8
1971	1967-69	-0.14	-0.29	324	323.2	0.8
1972	1968-70	0.76	-0.14	324	319.9	4.1
1973	1969-71	-1.35	0.22	297	311.9	-14.9
1974	1970-72	1.78	0.23	307	311.7	4.7
1975	1971-73	-0.27	0.41	309	307.7	1.3
1976	1972-74	-0.04	0.06	305	315.4	-10.4
1977	1973-75	0.52	-0.43	314	326.3	-12.3
1978	1974-76	-2.07	-0.97	323	338.4	-15.4
1979	1975-77	-0.97	-0.87	337	336.1	0.9
1980	1976-78	0.46	-0.48	351	327.5	23.5
1981	1977-79	-1.22	-0.94	361	337.7	23.3
1982	1978-80	-1.97	-2.31	370	368.2	1.85
1983	1979-81	-3.86	-2.06	364	362.5	1.4
1984	1980-82	0.25	-0.91	346.5	337.7	8.8
1985	1981-83	0.49				

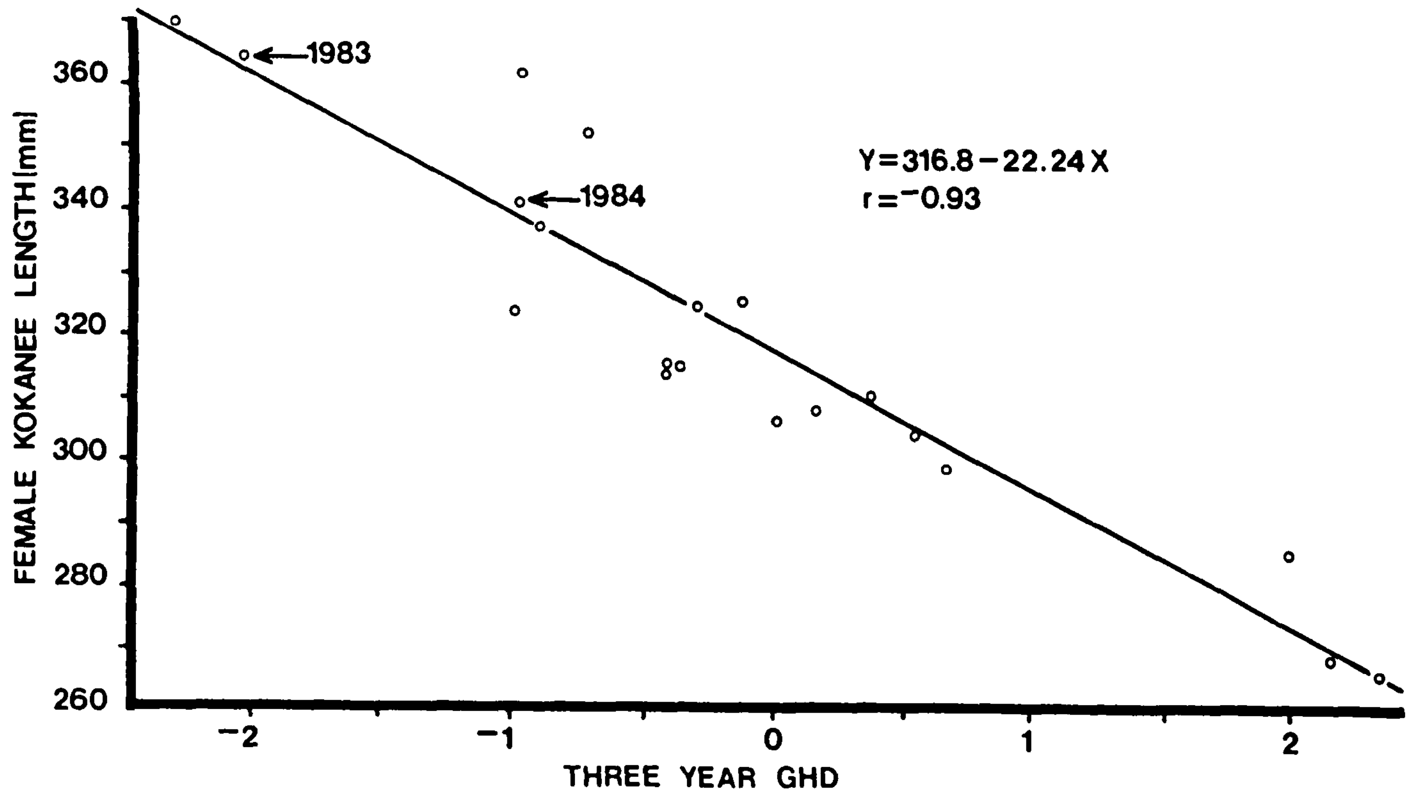

Figure 7. Relationship between female kokanee spawner length and the three year average in river stage difference (ft) in the years that produced them from 1966-84.

incubation stages in the Flathead River as affected by discharges from Hungry Horse Reservoir. Length of 1984 female kokanee spawners averaged 346.5 mm, close to the 337.7 mm predicted by the river stage difference model. Flathead Lake levels have also affected kokanee year class strength from 1966-1984 (Decker-Hess and Clancey 1984). The addition of the number of days of lake elevation less than 2,885 feet during the incubation period to the fish length - stage difference model raised the R from 0.93 to 0.96 ($p<.001$).

CENSUS OF THE RIVER SYSTEM KOKANEE FISHERY

An annual census of the Flathead River kokanee fishery began in the fall of 1981. During 1981, angling was with lures only from September 1 to September 15, then snagging was allowed until October 15. The two week delay of the snag fishery was to allow the early run of spawners to move upstream without pressure from the snag fishery.

Kokanee harvest limits were adjusted frequently over the course of the study to reduce pressure on the depressed population (Table 4). Further reductions in the daily limit should not be needed as the population recovery proceeds. Snagging was banned as a method of harvest beginning in 1983, and lures, flies and baited hooks are now the legal means of taking.

Comparisons of the 1975 and 1981-84 fisheries are shown in Tables 5 and 6. Pressure and harvest on the kokanee in the river have effectively been reduced by the decreased limit and limited harvest method. During 1984, kokanee harvest was higher than anticipated due to a delay in migration. The fish held in the Salmon Hole approximately 1 1/2 - 2 weeks longer than usual and were extremely vulnerable to the lure fishery. Daily catch rates in 1984 approached 3.0 fish per hour and pressure remained high due to the site-specific fishery. Over 12,000 kokanee were harvested in 12 days. On September 20 the fishery was closed to protect the spawning run.

POPULATION RECOVERY

Recovery of the main stem kokanee population is aimed at returning the main stem fishery to the management goal of 165,000 postharvest (330,000 preharvest) spawners 300-330 mm long. Over the past six years (1979-84) the postharvest spawning run in the main stem has been extremely depressed. Recovery of the main stem population is largely dependent on flow conditions in that section of the river. Flow during the incubation period must be sufficient to keep most of the redds wetted. Prior to the restrictive flows implemented during this study, incubation flows were not nearly adequate to meet this need.

Table 4. Annual creel and possession limits on the Flathead River kokanee spawning runs, 1979-84.

Year	Creel Limit	Possession Limit	Harvest Methods
1979	35	70	Snag/lure
1980	35	70	Snag/lure
1981	35	70	Snag/lure
1982	20	40	Snag/lure
1983	10	10	Lure only
1984	10	10	Lure only

Table 5. Comparison of characteristics of the 1975, 1981, 1982, 1983, and 1984 river system kokanee fisheries. The 1975 fishery data is for the main stem only. During the fall of 1975 very little fishing occurred on the Middle Fork.

	Middle Fork				Main Stem			
	1981	1982	1983	1984[a]	1975	1981	1982	1983
Catch rate (kokanee/hour)	2.0	0.93	1.10	1.50	2.0	2.0	0.45	0.56
Fishing pressure (hours)	17,870	17,019	371	7,396	69,276	56,602[b]	25,630	8,377
Numbers of hours per completed trip	4.7	3.4	5.9	2.7	3.6	3.2	3.3	4.2
Fishing pressure (mandays)	8,040	5,006	63	2,770	19,223	17,668	7,767	1,995
Kokanee harvest	75,117	18,047	500	12,243	150,243	77,000	12,402	3,734
Percent of harvest by shore anglers	79	77	46	1	—	73	70	28
Percent of fisherman hours interviewed	6.8	19	22	40	1.6	4.8	6	8
Total number of party interviews	237	436	19	414	—	207[c]	324	177

a/ Although harvest occurred in the Salmon Hole, these fish were headed for the Middle Fork and McDonald Creek.

b/ Pressure from September and October.

c/ Interviews from September and October only.

Table 6. Estimated distribution of harvest between the Middle Fork "early" runs and the main stem "late" runs during 1975, 1981, 1982, 1983 and 1984. The percent of the estimated population which was harvested is in parenthesis. Methods for the estimates are given in Fraley and McMullin (1983).

Year	Middle Fork runs	Main stem runs	Total
1975	18,450(40-45)	131,793(40-45)	150,243(40-45)
1981	133,555(53)	18,562(44)	152,117(52)
1982	29,999(44)	450(10)	30,449(42)
1983	3,212(8)	1,022(6)	4,234(7.5)
1984	12,243(14)	(<1)	12,243(9.7)

Recovery of the main stem kokanee population could vary substantially depending on the natural reproductive success of each year class (Figure 8). Assuming a 20% egg to fry survival, recovery of the population from its present depressed level could not occur at a 1% fry to spawning adult return.

At a 2.0% fry to adult return rate and no harvest, a fishable main stem population would be reached by 1993 and over 150,000 spawners would return annually by 1997. The maximum assigned level of 330,000 preharvest spawners would be reached by 2003. A fry to returning adult survival rate of 3.0% could result in a fishable population by 1989, and by 1997 a maximum assigned level of 330,000 spawners would be reached.

The main stem kokanee population is expected to recover with an average of 20% egg to fry survival and 2.0% fry to adult survival, based on egg to fry survival studies in the Flathead, and on values in the literature. These rates would result in a doubling of numbers in each successive four year cycle of spawners for an overall return rate of 2.0 adults per spawner. Due to the present low density of spawners, reproductive success in the early years of the recovery could be substantially greater. Mean estimates of returning adults per spawner reported for seagoing salmon in streams of Alaska and British Columbia ranged from 1.7 to 3.0 and averaged 2.3 over a 40 year period (Bakkala 1970).

In the past, the main stem Flathead has supported numbers of spawning kokanee similar to the present management goal. Gravel area measurements (Fraley and Graham 1982) indicate that sufficient amounts of suitable spawning gravel is available in the main stem at the present spawning flows to accommodate the management goal. At 3,500 cfs, an estimated 531,741 m^2 of spawning gravel is available in the main stem. A total of 82,476 m^2 of spawning gravel was measured in McDonald Creek, the major spawning area in the Flathead System.

A run of 50,000 kokanee spawners in the main stem was estimated as the minimum population that could support a harvest without impairing the recovery rate of the population. With little or no harvest, the population should be safely above the 50,000 fish level by 1993. The rate at which the main stem population is harvested from that point would greatly affect the rate of population growth and recovery. A desirable harvest rate for management of the main stem kokanee population would be one that could be adjusted based on the number of spawners that return each year. This shifting harvest rate could begin at 10% when the minimum fishery level of 50,000 fish is reached, and increased to 50% at the assumed maximum population level of 330,000 spawners (Table 7, Figure 9). With this shifting harvest rate, the main stem population would increase to over 200,000 spawners after four or five generations and to over 300,000 spawners by 2007. This harvest management strategy would allow for a reasonable balance of population recovery and angler harvest. Currently the harvest

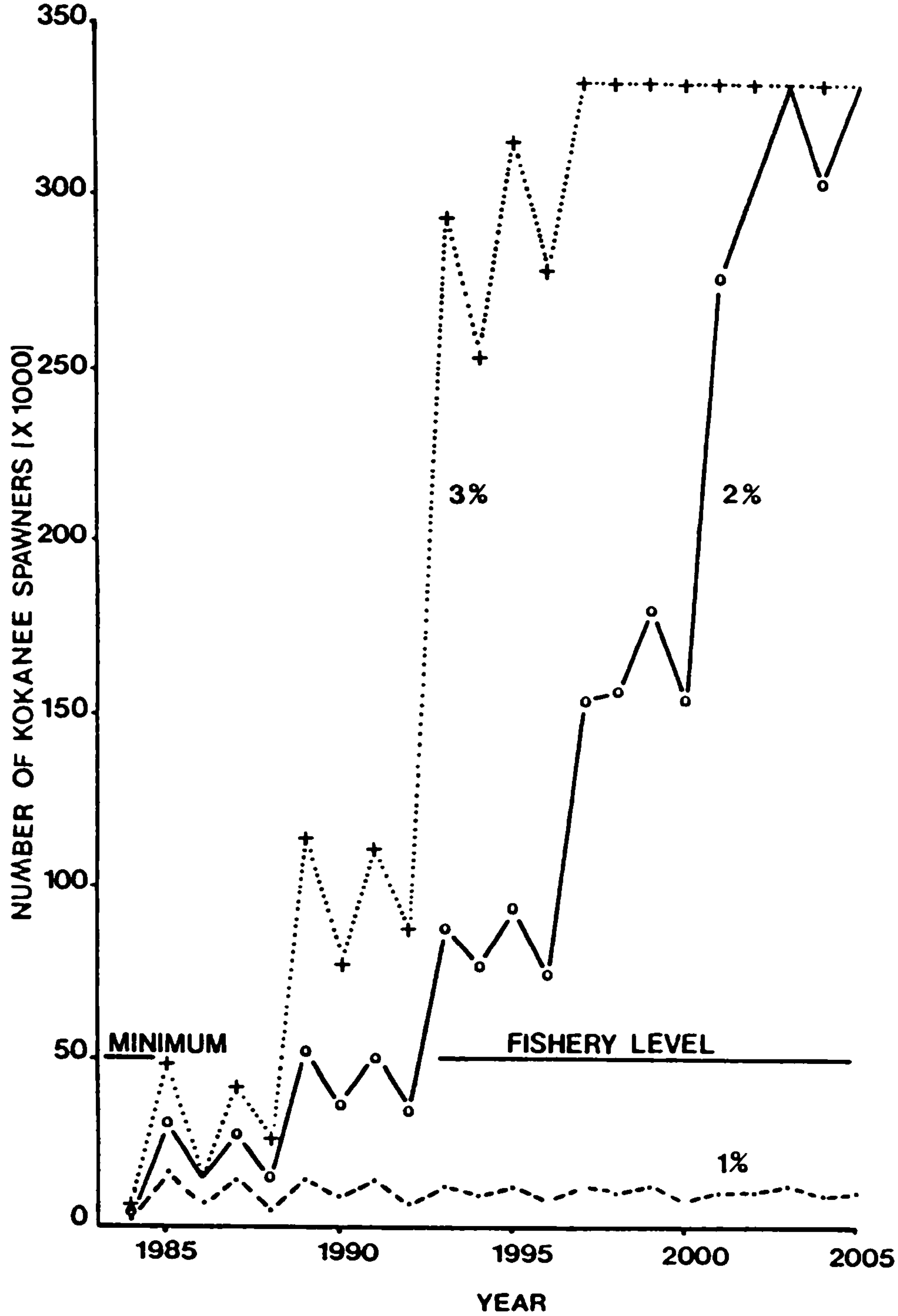

Figure 8. Projected growth of the main stem kokanee population at 20 percent egg to fry survival and one, two and three percent fry to adult returns (no angler harvest).

Table 7. Hypothetical harvest management plan for the main stem Flathead River kokanee run.

Projected preharvest population level	Estimated time Period	Mean Harvest rate	Mean number of kokanee harvested
0 - 50,000	1984-1992	0[a]	0
50,000 - 100,000	1993-1996	0.14	11,473
100,000 - 200,000	1997-2001	0.24	34,093
200,000 - 300,000	2002-2008	0.39	95,749
>300,000	2009-2033	0.50	162,235

[a] The restricted lure fishery may result in a minimal harvest of 6% or less.

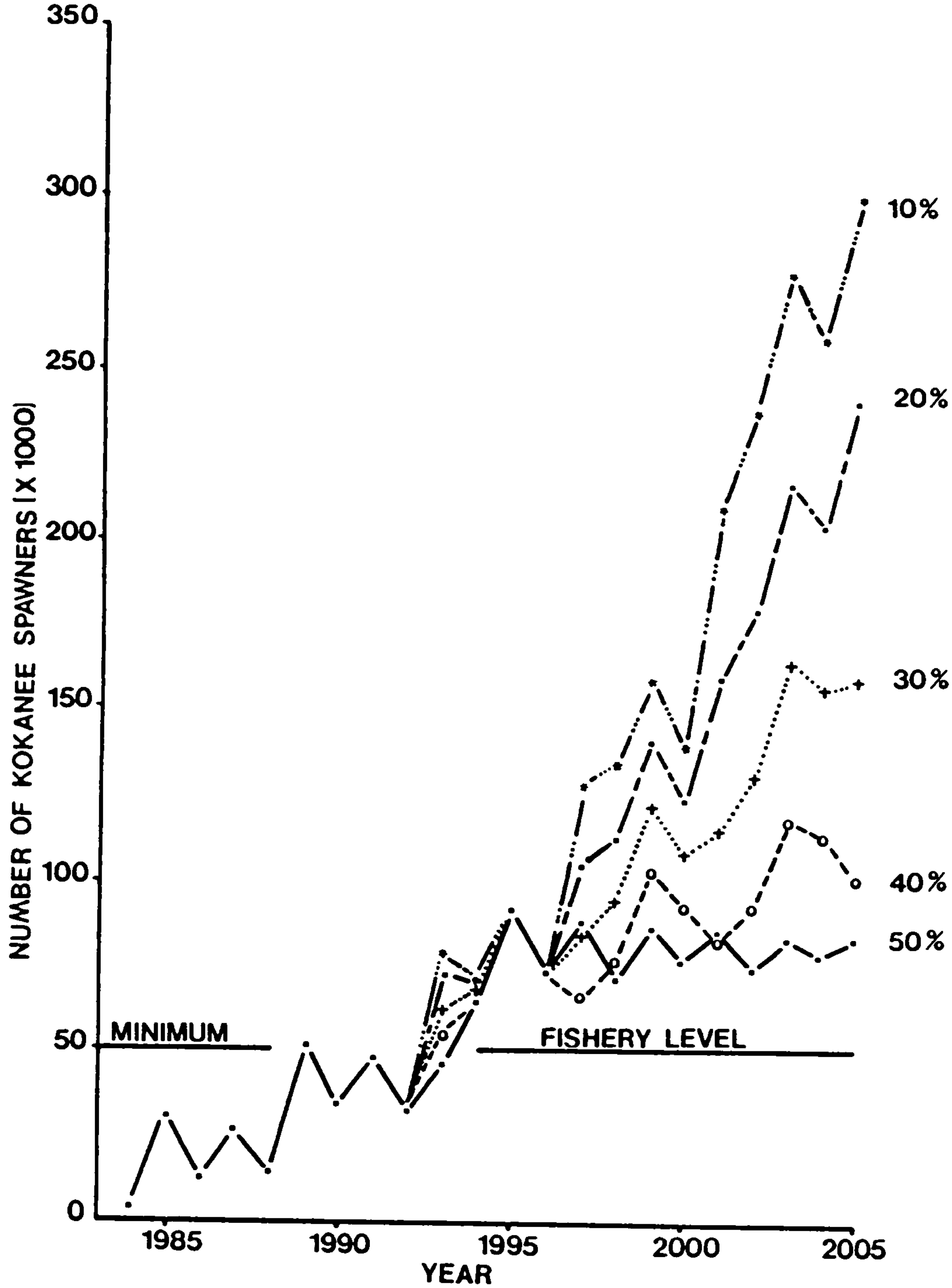

Figure 9. Projected growth of the main stem kokanee run at 20 percent egg to fry survival, 2 percent fry to adult survival and 10, 20, 30, 40 and 50 percent harvest rates.

in the river is supported by the early run fish bound for upper river system spawning areas.

Studies were undertaken in two main stem areas and McDonald Creek to compare redd construction and egg deposition from daytime and nighttime spawning. Areas available for nighttime spawning contained 73 percent of the eggs and areas available for daytime spawning contained 27 percent of the eggs. One obvious effect of generation from Hungry Horse Dam to meet daytime power needs would be the possible mortality of incubating eggs due to nighttime drawdown. Recovery of the main stem kokanee population could be substantially prolonged by daytime power generation. Another potentially adverse effect of daytime generation is the disruption of the four major elements of kokanee spawning activity: 1) behavioral interactions of spawners, 2) redd construction, 3) egg deposition, and 4) redd maintenance (Fraley and McMullin 1983). Interference with spawning activities may potentially cause a delay or discontinuation of spawning, resulting in lower survival of incubating embryos or deposition of fewer eggs in the gravel.

When the population recovery is complete, large periodic discharges from Hungry Horse Dam during the spawning period may be an effective tool in regulating the kokanee population of Flathead Lake.

The main stem Flathead River spawning population appears to be recovering from the adverse impacts caused by erratic discharge from Hungry Horse Reservoir from the mid to late 1970's. Abundance of kokanee spawners in the main stem Flathead River has shown dramatic increases in response to the spawning and incubation flows recommended by the Department through the Northwest Power Planning Council (Table 1, Page 5).

FRY PRODUCTION

Since implementation of recommended flows, survival of eggs to the eyed stage in the main stem Flathead River below the South Fork has approached survival figures for McDonald Creek (Table 8). Although these rates may be artificially high due to decomposition and consumption of dead eggs by various organisms, the trend in the main stem is one of increasing survival. Due to the uncertainty of the 1980 survival estimate in the main stem, it was not used in the calculation of average survival for the study. Main stem survival was lowest in the first year of the study, before any restrictive flows out of Hungry Horse Dam went into effect. Survival in years with flow limitations is affected by the severity of winters and the timing of the spawning runs. In 1981, when spawning flows were not to exceed 4,000 cfs, over 25 percent of the redds were constructed before those flows were implemented. At the minimum incubation flow of 2,300 cfs, 50 percent of main stem redds were dewatered. In 1983 almost 10 percent of the redds

Table 8. Estimated percent survival to the eyed stage of eggs in the main stem Flathead River and in McDonald Creek from 1979-80 to 1984-85.

	Main Stem Flathead River	McDonald Creek
1979 - 80	41	85
1980 - 81	<40	94
1981 - 82	71	78
1982 - 83	59	88
1983 - 84	62	92
1984 - 85	87	93
Mean	64	88

were built before October 15 and were later dewatered when the flow restrictions went into effect. In 1982 and 1984 spawning did not begin until after initiation of the fish flows and survival to the eyed stage was excellent.

Survival of eggs to the eyed stage in other areas has been monitored as the study progressed and the population expanded into new spawning areas. Survival in the Whitefish River, the Middle Fork and the South Fork have averaged 33, 89 and 94 percent, respectively. During the 1984-85 spawning year, survival estimates were not completed for the Whitefish River due to ice cover or for the South Fork due to high flows from Hungry Horse Dam to meet the minimum incubation flow requirements in the main stem.

Fraley and McMullin (1983) estimated between 57,000 and 86,000 spawners would most efficiently utilize McDonald Creek spawning gravels. Comparison of annual spawner counts and live egg and alevin densities also support these figures. In years when spawner counts were substantially higher or lower than those limits, densities of alevins were less than $600/m^2$, however, in years when the spawner counts were between 57,000 and 86,000, densities were greater than $1,000/m^2$. These data should be viewed with caution, however, due to the potentially large variability involved in egg and alevin sampling.

Results of experimental egg plants in main stem areas and in hatchery channels show that repeated dewatering will cause rapid mortality of embryos and prolong development of those that survive. Survival of eggs in gravel with various sediment mixtures was tested at the Somers hatchery. Eggs in gravel with 20 and 30 percent fines survived several hours longer than those in gravel with 10 or 40 percent fines when dewatered in freezing temperatures. Moderate amounts of fines insulate the eggs from the freezing temperatures and retain enough water to keep the eggs moist and viable. However, prolonged dewatering of several hours will allow the freezing temperatures to reach the eggs and cause mortality. Oxygen stress appears to be the mechanism which causes mortality in the high sediment mixture. Embryos that survived to emergence in periodically dewatered areas required fewer total temperature units, but more days, to reach that stage. Reduction in temperature during dewatering slowed development of affected embryos and caused them to emerge later than embryos in constantly wetted areas.

An average fry survival rate of 40.5 percent was calculated for eyed egg plants in main stem Areas 2 (East Side Channel below Old Steel Bridge) and 13 (Reserve Drive backwater) (Figure 5, page 19) and Beaver and Deerlick Creeks during the study. This estimate may be low as up to 18 dead fry were found in the sediment build-up beneath a single trap when the trap was removed. During the second year of planting, monitoring redds in Area 2 and Deerlick Creek was ineffective due to high flows causing gravel migration and movement of the emergence traps and in Area 13 due to movement of the traps by unknown inidividuals.

Timing and abundance of emerging fry was monitored at various areas of the river system throughout the study. The timing of emergence and abundance of fry from individual spawning areas is critical in the determination of the relative importance of Flathead River system spawning areas to the recruitment of the Flathead Lake population.

Total fry production in the Flathead River System depends heavily on production in McDonald Creek (Table 9). The decrease in fry production from McDonald Creek in 1984-85 may be partially due to inefficiency of the drift nets. High current velocities in McDonald Creek during the spring of 1985 caused the nets to rest at an angle in the water column, not faced fully into the current. Other factors, such as the high density of eggs and alevins in the gravel or water temperatures just above freezing from late January to early March, may have caused mortality in late incubation.

Production in the main stem areas cannot be estimated with drift nets because of the unconfined nature of all the main stem spawning sites except Area 1. Use of emergence traps has been the most feasible method of indexing fry emergence.

Only in 1982 did Beaver and Deerlick Creeks produce significant numbers of fry, when an estimated 429,000 fry emigrated from Beaver Creek. Dense accumulations of algae on the sampling nets prevented effective sampling in Deerlick Creek.

No consistent trend in timing of fry emigration is evident in McDonald Creek from 1980-81 to 1984-85. Peak spawner counts in McDonald Creek from 1980 to 1984 are within 2-1/2 weeks of each other, however, peaks in fry emigration in McDonald Creek vary by seven weeks (Table 10).

Fry in McDonald Creek were captured, dyed, and released during the spring of 1983 and 1984 to monitor emigration through the river system to Flathead Lake. Drift nets were set downstream from McDonald Creek at distances of 8 km (Blankenship Bridge), 34 km (old red bridge at Columbia Falls), 55 km (Old Steel Bridge at Kalispell), and 95 km (Sportsmans Bridge) and were checked every few hours. Fry were found to migrate as fast or faster than the current speed, indicating they actively swim during emigration. Migrating fry travel during nighttime hours, as few were captured until after dusk each day. Total travel time to the 55 km point ranged from 8 to 14 hours for different groups of fry. Rates of travel were fastest when flows were high. The river section between the 55 km and 95 km points is very low gradient. Fry were captured at the 95 km point during one of five experiments conducted during the two years. At that time the fry traveled between the 55 km and 95 km points at a rate twice the current speed. Control groups of stained and unstained fry were

Table 9. Estimates of fry production in areas of the Flathead River System, 1982-85.

Year	McDonald Creek	Main stem Area 1	Whitefish River
1981-82	12,000,000	430,000	110,000
1982-83	12,400,000	315,000	673,000
1983-84	13,100,000	372,000	662,000
1984-85	6,550,000[a]	131,000	31,000

[a] High current velocities in McDonald Creek during the spring of 1985 caused drift nets to rest at an angle in the water column, not faced fully into the current.

Table 10. Dates of peak spawner counts and fry emigration in McDonald Creek, 1981-1985.

Year	Peak of spawner counts	Peak of fry emigration	Number of days between peaks
1980-81	Oct. 22	April 21	151
1981-82	Oct. 21	June 5	196
1982-83	Oct. 27	May 4	159
1983-84	Oct. 5	April 20	197
1984-85	Oct. 17	May 17	181

held in net cages in McDonald Creek to assess mortality. Stained and unstained fry exhibited mortality rates of 16 and 18 percent, respectively, after 15 days.

Fry survival during emigration may be increased by the designated minimum flow in the main stem during the late winter and early spring before spring runoff. A steady discharge to aid passage of fry through the river system to Flathead Lake will help increase survival by decreasing migration time and predation.

Fry Food Habits and Fry Quality

Fry Food Habits

Stomach contents from 379 kokanee fry collected in 1982 were examined to determine food habits. Diptera larvae was the major item in the diet of kokanee fry in Beaver Creek, Middle Fork Flathead River, and Brenneman's Slough, while Copepoda and Cladacera had a small representation. Loftus and Lenon (1977) found that chironomidae were the most important food organisms for chum salmon fry and chinook salmon fry in the Salcha River, Alaska. Becker (1973) reported that juvenile chinook fed mainly on chironomid adults and larvae in the Columbia River, Washington. Salmon fry fed mainly on chironomid larvae in rivers of Japan and Norway (Kaeriyama et al. 1978, Lillehammer 1973).

Fry Quality

There was a relationship between kokanee fry length and water temperatures in Flathead River system spawning areas. Emigrating kokanee fry ranged from 25-51 mm in Brenneman's Slough during and after peak emergence. The warmer water temperatures in the spring fed slough coupled with the apparent longer residence time after emergence from the gravel was reflected in the relatively large length of the majority of kokanee fry emigrating from the slough. Peak time of emergence in Brenneman's Slough during 1982 was 30 March through 7 April. The mean temperature during this time was 8.9°C.

CONCLUSIONS AND RECOMMENDATIONS

Based on our findings from 1979 through 1985, we've reached the following conclusions:

1) Dewatering of kokanee redds resulted in unnaturally high mortality of incubating embryos due to desiccation and/or freezing in areas not influenced by groundwater.

2) A strong relationship existed from 1966-1984 between the average female kokanee spawner length — an indication of year class strength — and the difference in average river stage during the kokanee spawning and incubation periods. These differences in stage were primarily influenced by the operation of Hungry Horse Dam.

3) The main stem now supports only 16% of the total escapement of kokanee spawners from Flathead Lake due to past operation of Hungry Horse Dam and harvest by anglers.

4) Operation of Hungry Horse Dam for daytime power peaking would significantly reduce kokanee spawning success in the main stem Flathead River.

5) At the recommended spawning flow of 3,500 - 4,500 cfs a sufficient amount of gravel exists in the main stem to support a population of well over 165,000 post harvest spawners.

6) We could not determine any significant relationships between the timing of kokanee spawning migration and environmental variables.

7) Fry emigrate at night and require as few as 72 hours to travel 100 km downstream to Flathead Lake at moderately high levels of flow (average of 11,200 cfs at Columbia Falls).

The kokanee spawning run in the main stem Flathead River has exhibited a beneficial response to the initial recommended flow regime implemented in 1980. Egg survival has increased in response to the more consistent water levels now existing in the river during the spawning and incubation seasons. Eight times more spawners returned to the main stem in 1984 than expected, probably due mostly to the reduced harvest levels on the fishery and increase in production of fry in 1981. Assuming the carrying capacity of Flathead Lake is not limiting, increases in the number of spawners in the main stem can be expected in each quadrennial cycle with continuation of the Departments recommendations. Those recommendations are as follows:

1) Flows in the Flathead River at Columbia Falls should be between 3,500 and 4,500 cfs from October 15 through December 15 and not less than 3,500 cfs from December 15 through April 30. These flows should be maintained 24 hours per day.

2) Harvest should remain at present levels of not more than 10 percent of the main stem run until the population recovery is well underway, then be increased as the population can accommodate the additional harvest.

3) Monitoring of spawner numbers, kokanee length, and harvest should be carried out in cooperation with the regional fisheries staff to insure that the population recovery is proceeding as expected and to make necessary adjustments and recommendations in discharge regimes and harvest rates.

As kokanee escapement in the main stem increases, the population could be regulated by angler harvest. Ideally, half the main stem population could be harvested when the spawning run is back to the 1975 level of 330,000 preharvest spawners of approximately 300-330 mm in length, which is the management goal of the study.

Kokanee escapement in the main stem could also be regulated by changes in the daily and seasonal operation of Hungry Horse Dam. These changes would allow greater flexibility for the production and marketing of power. Opportunities for flexibility in operation include: 1) maintain higher maximum flows during part or all of the 15 October to 15 December period, 2) maintain the recommended flow level, but for less than the full 15 October to 15 December period, 3) maintain the recommended flows for less than the full 24 hour daily period, and 4) some combination of the first three measures. Further study may be required to establish the best possible plan for providing flexibility in flow regimes.

It is important for the Department, BPA, BOR and other interested parties to continue open discussions relative to fisheries and hydropower issues in the Flathead System. Through responsive management, we should be able to maintain the optimum number of spawners in the Flathead River through some combination of harvest level and flexibility in flow regimes.

The monitoring program for kokanee in the river system is outlined in Appendix C. Results of the monitoring program will be incorporated into the final project report in March 1988.

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APPENDIX A

VARIABLES USED IN REGRESSION WITH AERIAL COUNT DATA TO ANALYZE SPAWNER MIGRATION TIMING

Table 1. Variables used in regression with aerial count data to analyze spawner migration timing.

1) Daily mean gauge height
2) Daily mean gauge height discharge
3) Daily mean discharge
4) Daily maximum gauge height
5) Daily minimum gauge height
Hours per day between gauge heights:
6) 1.00-1.99
7) 2.00-2.99
8) 3.00-3.99
9) 4.00-4.99
10) 5.00-5.99
11) 6.00-6.99
12) 4.00-7.00
13) Maximum daily temperature
14) Minimum daily temperature
15) Mean daily temperature
16) Total daylight hours

APPENDIX B

KOKANEE REDD COUNTS IN SPAWNING AREAS ON THE MAIN STEM FLATHEAD RIVER

1979-1984

Table 1. Numbers of kokanee redds counted in late November of 1979, 1980, 1981, 1982, 1983, and 1984 in areas of the Flathead River below the South Fork. See Appendix E and Fraley and Graham (1982) for locations and descriptions of spawning areas.

Area Number	River km	Number of kokanee redds observed					
		1979	1980	1981	1982	1983	1984
1	37.0	425	136	341	180[d]	278	155
1A	37.0	—	—	—	60	0	0
2	41.42	5	0	12	0	0	16
3	42.0	7	1	0	0	0	0
4	42.2	0	25	67	9	0	0
5	42.5	0	0	14	0	0	0
6[a]	43.4	60	11	0	0	0	0
7	44.3	0	6	30	16	0	0
8	45.0	0	0	133	47	0	0
9	45.5	0	15	218	0	7	0
10	46.7	0	0	517	0	19	476
11	47.9	0	0	165	0	0	350
12	48.0	0	0	254	0	0	0
13	48.3	22	0	0	60	0	71
14	48.8	0	0	151[d]	0	0	0
15	49.0	0	0	9	0	0	34
16	49.4	119	12	106	0	0	0
17	50.0	359	0	118	0	0	550
18	50.5	10	0	0	0	2[e]	0
19	52.0	0	3	174	0	6	0
20	52.2	55	0	604	0	130[e]	38
21	52.4	0	13	226	0	24	27
22	54.4	100	0	176	17	0	69
23	55.3	100	7	31	0	0	38
24	55.5	200	1	13	0	0	0
25	59.8	290	5	363	0	124[b]	22
26	60.2	0	0	3	0	0	40
26A	60.2	0	0	0	0	—	33
27	60.3	150	0	494	0	368	115
28	60.7	0	1	51	0	60[e]	90
29[b]	60.8	250	0	375	0	197[a]	0
30	61.0	25	0	94	22	103	99[e]
31	61.5	25	0	23	0	25[a]	800
32	65.0	0	0	735[d]	0	199	137
32A	65.5	0	0	413	0	10	0
33	66.0	0	0	11	0	36[e]	0
34[a]	66.5	20	0	160	67	123	115
35	67.6	50	0	146	0	25	60
36[a]	68.5	330	231	0[c]	0	0	0
37	67.7	100	0	495	0	1302	450
38[a]	68.5	100	0	288	0	260	890
39A	69.0	—	—	—	—	30	19
39B	69.4	—	—	—	—	108	76
39[b]	69.5	0	0	1083	560	1852	1123
39[c]	70.1	—	—	—	—	742	240
40	70.6	0	0	76	0	231	2
41	70.9	0	0	92	65	8	0
41A	72.0	0	0	0	12	0	260
42	73.7	0	0	0	12	222	0
42A	73.7	—	—	—	—	192	443
TOTAL		2,802	467	7,853	1,528	6,683	7,433
Number of areas used		22	14	37	13	27	30

[a] Spring influenced.
[b] Limited groundwater or spring influence.
[c] Beaver dammed during 1981.
[d] Redds found after late November redd count.
[e] Early November count used because they exceeded late Nov. counts.

APPENDIX C

MONITORING KOKANEE SALMON ESCAPEMENT AND SPAWNING IN THE FLATHEAD RIVER SYSTEM

A plan to monitor kokanee escapement and spawning in the Flathead River System has been developed and is being implemented (Tables 1, 2, and 3). The regional management staff is being integrated into this program to continue monitoring after the contract period. Monitoring activities are prioritized into three categories. Priority one activities include: 1) kokanee redd counts, 2) snorkel counts of spawners, and 3) fish samples for length and age data. Priority two activities are: 1) fry sampling, and 2) creel census. Egg survival sampling is a priority three activity. Methods, background and justification are outlined in the 1984 monitoring report (Fraley and McMullin 1984).

Redd counts to monitor yearly trends in main stem kokanee spawning runs are recommended for 12 areas. These areas contained 60 percent of the total number of redds counted in all 50 river system spawning areas from 1979-1984 (Figure 1).

Table 1. Summary of redd count activities proposed for monitoring in the Flathead River system.

Area	Activity	Timing	Number days	Number people	Number man-days
Main stem Flathead River	Mid Oct. check	15-19 October	1	2	2
	Early Nov. check	1-5 November	1	2	2
	Final redd count	20-25 November	2	3	6
South Fork Flathead River	Final redd count	5-15 November	1	2	2
Whitefish River	Final redd count	20-28 October	1	2	2
Beaver/ Deerlick Creeks	Final redd count	25 Nov-1 Dec.	1	2	2
TOTAL			7	---	16

Table 2. Schedule for snorkel counts of kokanee spawners in McDonald Creek.

Count No.	Count date	Number[a] days	Number people	Number man-days
1	Wednesday nearest 7 September	1	3	3
2	Wednesday nearest 20 September	1	3	3
3	First Wednesday in October	1	3	3
4	Wednesday nearest 20 October	1	3	3
5	First Wednesday in November	1	3	3
	TOTAL	5	---	15[b]

a/ Field counts take approximately 0.8 days including travel time, remainder of day for data summary.

b/ Five of the man-days will be supplied by the Region 1 Information Officer.

Table 3. Sampling schedule for kokanee collections in river system spawning areas. Time requirements are for fish collection and otolith removal.

Site	Collection period		Number days	Number people	Number man-days
Flathead River, non-spring	1-15 Nov.	Back pack shocker, gill net	1	2	2
Flathead River, spring	15 Nov. - 15 Dec.	Gill net	1	2	2
McDonald Creek	5 Oct. - 25 Oct.	Gill net, dip net	Do in conjunction with mid-October snorkel counts		
Whitefish River	1 Oct. - 20 Oct.	Back pack shocker, gill net	Do in conjunction with October redd count		
TOTAL			2	---	4[a]

[a] One additional manday will be required for data entry and analysis.

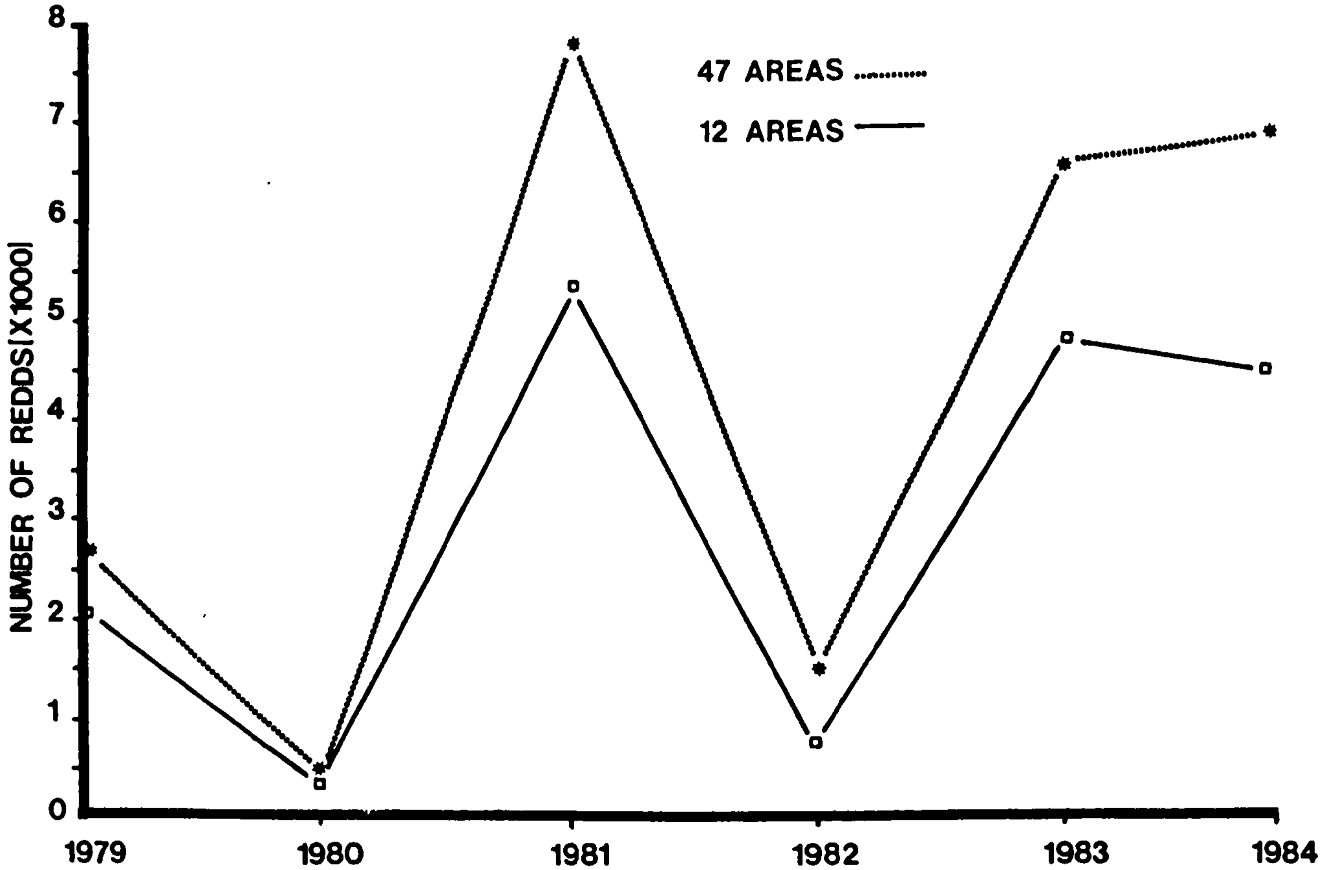

Figure 1. Yearly trends in kokanee spawner abundance in the main stem Flathead River as indicated by total redd counts in 45 areas (dotted line) and redd counts in 12 proposed monitoring areas (solid line).

FLATHEAD RIVER KOKANEE MONITORING ACTIVITY SCHEDULE

PRIORITY 1

ACTIVITY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	MAN-DAYS
REDD COUNTS		4	12										16
SNORKEL COUNT	6	6	3										15
FISH SAMPLES		2	1	1									4
MAN-DAYS	6	12	16	1									35 TOTAL

PRIORITY 2

ACTIVITY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	MAN-DAYS
CREEL SURVEY	5	5											10
FRY SAMPLING							5	4	5	1			15
MAN-DAYS	5	5					5	4	5	1			25 TOTAL

PRIORITY 3

ACTIVITY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	MAN-DAYS
EGG & ALEVIN SAMPLING					4								4
MAN-DAYS					4								4 TOTAL

Summary of activities and man-day requirements outlined in the Flathead River system kokanee monitoring report