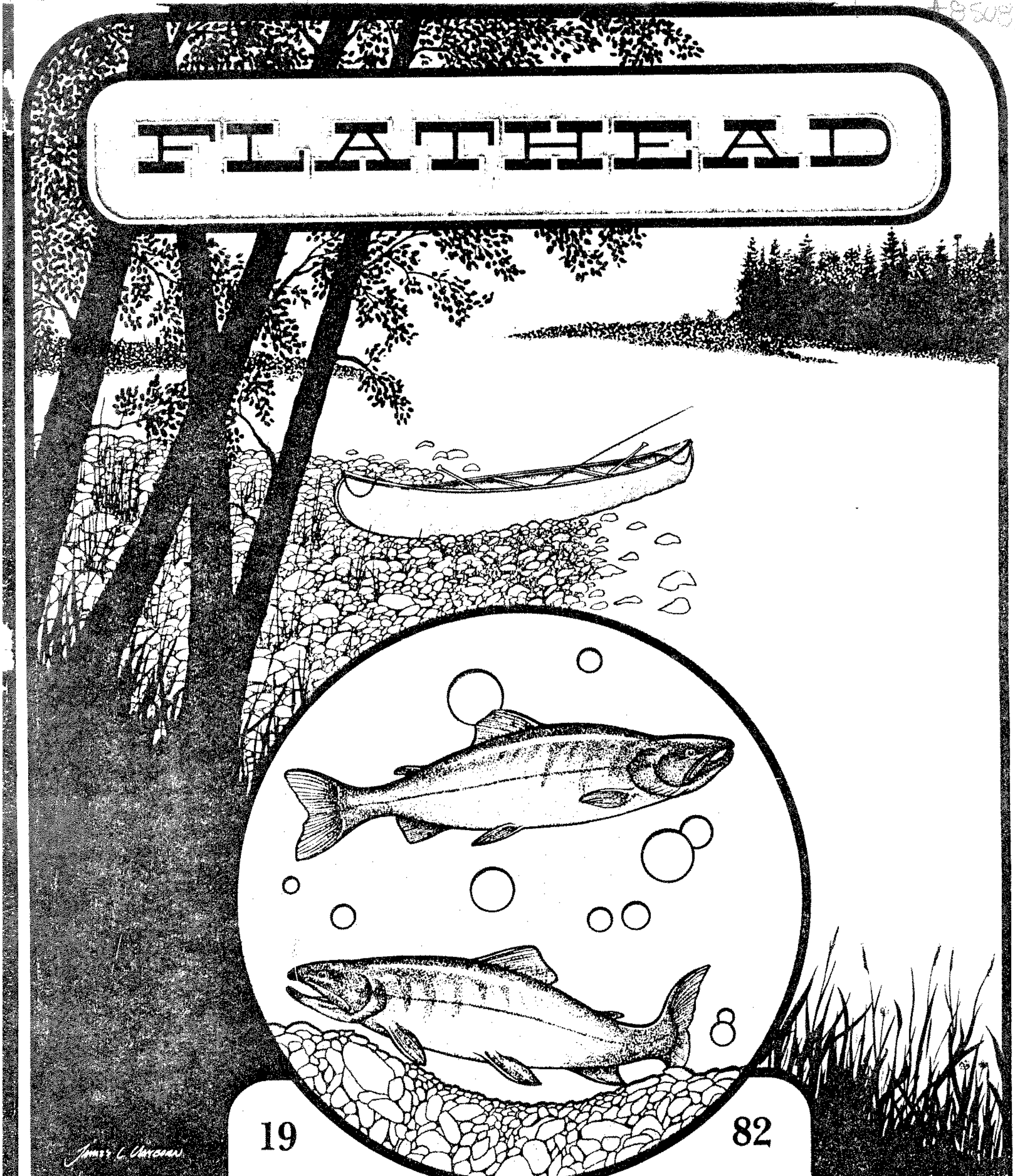
FLATHEAD



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IMPACTS OF HUNGRY HORSE DAM ON THE FISHERY IN THE FLATHEAD RIVER—FINAL REPORT

Research Conducted by: MONTANA DEPARTMENT OF FISH, WILDLIFE AND PARKS
Sponsored by: BUREAU OF RECLAMATION

The Impact of Hungry Horse Dam on the Fishery of the Flathead River - Final Report

by

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Sponsored by:

Bureau of Reclamation
Boise, Idaho
October 1982

and watered at the minimum incubation flow elevation. Eggs at these sites experienced survival rates of 0%, 25% and 90%, respectively, to the eyed stage. Egg survival was high in an area continually watered by a spring. Artificial channel experiments conducted during the 1981-82 season supported the conclusion that substantial mortality of dewatered green and eyed eggs would occur within a few hours if air temperatures were below -10°C. Incubating eyed eggs experienced less mortality than green eggs when dewatered. A moderate amount of fine material in the gravels was beneficial in delaying freezing mortality of kokanee eggs which were dewatered in artificial channels.

Kokanee year class strength as measured by spawner length and flows in the mainstem Flathead River from 1966 to 1981 were closely correlated. This indicated Hungry Horse discharges had impacted kokanee populations by providing unfavorable spawning and incubation flows. Strong relationships have existed between kokanee year class strength and several flow variables, including spawning and incubation period gauge height differences ($r^2 = .840$ $p < .001$) and average number of hours incubating eggs were dewatered per day ($r^2 = .859$, $p < .001$).

Timing and abundance of fry emergence was studied to help assess the relative recruitment of river system spawning areas to the Flathead Lake kokanee population. An estimated 12,000,000 kokanee fry emigrated from McDonald Creek from March through June of 1982. The survival rate from potential egg deposition to fry emigration was approximately 22 percent. An estimated 4.5 million fry passed the mainstem Flathead River sampling station near Kalispell in April and May. An estimated total of 429,000, 317,000, 43,000 and 11,000 kokanee fry passed sampling stations in lower Beaver Creek, the Middle Fork River near West Glacier, Brenneman's Slough and the Whitefish River, respectively. Studies in McDonald Creek indicated emigrating kokanee fry were present throughout the vertical and horizontal portions of the water column. Marking experiments of kokanee fry in Beaver Creek and observations of fry in Brenneman's Slough indicated fry have longer residence times before emigrating from spring areas.

The abundance of the mainstem kokanee spawning population was well below the level of our management objectives. We estimated that a total of 35,000 preharvest mainstem spawners were present in 1981. This was only 11 percent of the 330,000 mainstem spawners estimated for 1975, which was considered an average good year. Due to the lack of a strong mainstem run, fishermen shifted their effort almost completely to the earlier run migrating to the Middle Fork drainage. High flows during the spawning season and lower flows during the incubation season, partly in response to provisional energy deliveries from Hungry Horse Reservoir since 1967, have contributed to this decline in kokanee spawner abundance in the mainstem.

Flow recommendations of a 3,500 cfs minimum and a 4,500 cfs maximum in the Flathead River at Columbia Falls for the spawning season (15 October-

15 December) and a minimum of 3,500 cfs during the incubation season (15 December through April) were submitted to the Northwest Power Planning Council to rebuild the mainstem kokanee runs to the management objective levels similar to 1975. If these flow requests are not adopted, we expect the mainstem kokanee run to remain at the present level of only 11 percent of the management goal of 330,000 preharvest spawners.

A minimum flow request of 3,500 cfs in the Flathead River at Columbia Falls for the entire year was submitted to the Northwest Power Planning Council for the protection of overwintering and rearing habitat for west-slope cutthroat, bull trout and mountain whitefish. A stable minimum flow in the mainstem would be greatly beneficial to migration and holding of adult adfluvial cutthroat trout.

The proposed multilevel outlet or surface withdrawal system at Hungry Horse Reservoir would increase water temperatures and trout growth units by 40 percent in the Flathead River below the South Fork and would result in an overall benefit of 40 percent to the recreational trout fishery in the mainstem Flathead River.

ACKNOLWEDGEMENTS

Steve McMullin was the project biologist during the first two years of this study. Mark Gaub and Jon Cavigli participated in field activities, data summation, figure preparation and manuscript editing during the 1981-82 season. Paul Leonard provided valuable assistance in the field and office throughout the first two and one half years of the study.

Bob Schumacher, Steve McMullin, Laney Hanzel, Scott Rumsey, Bob Domrose and Joe Huston are permanent Department biologists who provided advice, equipment, information and guidance and critically reviewed the manuscript. Stewart Kienow of the Flathead Lake Hatchery provided assistance in egg dewatering experiments. Brad Shepard assisted in substrate analysis studies.

Personnel of the U.S. Park Service, U.S. Forest Service and U.S. Geological Survey were especially helpful in providing data and assistance. Gordon Pouliot and John Dalimata are landowners in the drainage who cooperated throughout the study.

Personnel of the Bureau of Reclamation and Bonneville Power Administration were helpful in providing data. Rick Prange of the Bureau of Reclamation provided valuable assistance in manuscript preparation. Rich Clark cooperated throughout the study in providing flow information and flow requests.

This study was funded by the Bureau of Reclamation.

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INTRODUCTION

Kokanee salmon (*Oncorhynchus nerka*) were first introduced to the Flathead system in 1916 (Montana Fish and Game Commission 1918) and a thriving kokanee fishery had developed by the early 1930's in Flathead Lake. Kokanee have become the most popular game fish in the drainage, supporting a summer trolling fishery in Flathead Lake and an intense fall snagging fishery in the Flathead River system. Kokanee comprised over 80 percent of the catch in the river system and over 90 percent of the catch in Flathead Lake during 1982 (Fredenberg and Graham 1982). Kokanee comprised over 80 percent of the game fish harvest in 1975 (Hanzel 1977). Anglers from most of the western United States, Alberta, and British Columbia take part in the Flathead Lake trolling and river snagging fisheries. A census of the kokanee fishery in the Flathead River was undertaken in conjunction with this study during 1981. Results of that study and related recreation studies in the Flathead will be available in the fall of 1982 (Graham and Fredenberg 1982, Fredenberg and Graham 1982a, 1982b).

Impoundment of the South Fork Flathead River began in 1948 and was completed in 1952 with the construction of Hungry Horse Dam. At that time, Hungry Horse was the fourth largest concrete dam in the world. Located eight km upstream from the mouth of the South Fork, Hungry Horse created a reservoir approximately 66 km long with a storage capacity of 3,461,000 acre feet (af).

Operation of the powerhouse altered normal discharge and temperature regimes in the South Fork and consequently in the mainstem below the South Fork. Discharge and temperature effects on the mainstem are mediated by natural flows from the North and Middle Forks.

Kokanee spawning in the South Fork and mainstem have been affected by operation of Hungry Horse Dam. Kokanee prefer to spawn in shallow areas with moderate water velocities. In large rivers like the Flathead, kokanee spawn primarily along stream margins and in side channels. Vertical water level fluctuations of over two meters in the South Fork and up to 1.4 m in the mainstem have resulted in alternate wetting and dewatering of eggs when flows were high during the spawning season. Dewatering can quickly cause death of eggs incubating in stream gravels due to freezing.

Kokanee eggs deposited in the South Fork mainstem, and Flathead Lake have all been subject to water level fluctuations. Incubation mortality could vary greatly from year to year, depending on flow conditions. Incubation mortality is probably the most important factor governing year class strength of Flathead kokanee. McNeil (1968) determined that incubation mortality was the most important factor governing year class strength of pink salmon (*Oncorhyncus gorbuscha*) in southeast Alaska streams. Stober et al. (1978) obtained similar results with sockeye salmon in Cedar River, Washington.

The Hungry Horse project is part of the Bonneville Power Administration electrical energy grid. The dam is operated primarily for flood control and hydroelectric energy production. The crest of the dam is 172 m high (1,087 m above mean sea level). Penstocks are located 75 m below the crest. At present peak capacity, the powerhouse produces 328 Mw. Present minimum flow from Hungry Horse is 145 cfs and the rated capacity is 11,417 cfs. Operation of Hungry Horse is determined in concert with the complex network of electrical energy producing systems, consumption needs, and flood control requirements throughout the Pacific Northwest. Water leaving Hungry Horse passes through 19 dams before reaching the Pacific Ocean.

To meet anticipated need for more peak power in the Northwest, many base load or existing peak power projects are being reviewed with the objective of increasing peaking power production. Several alternatives for the Hungry Horse project are presently being assessed. The alternatives include:

Alternative	Peaking Power (Mw)	Maximum Instantaneous Discharge(cfs)
1. Existing	328	11,417
2. Uprate existing generators	385	12,060
3. Powerhouse addition	383	13,367
4. Uprate and powerhouse	440	13,783

Hungry Horse alternatives are being evaluated both with and without a reregulating dam. The proposed reregulating dam would be located on the South Fork and have a storage capacity of 1,950 af. Additional peaking power capability at Hungry Horse may also result in increased total annual power production.

This study was undertaken to assess impacts of the various power alternatives and operating regimes on the fisheries of the Flathead River. Fisheries studies began in April, 1979, with the following objectives:

1. To provide the Bureau of Reclamation with the Department of Fish, Wildlife and Park's best estimate of a flow regime which will result in the most desirable level of reproduction and survival of kokanee salmon, mountain whitefish, and fish food organisms.

2. To determine the effects of reservoir discharge fluctuation on survival of incubating kokanee eggs in the Flathead River below its confluence with the South Fork.

3. To monitor delays in upstream migration of adult cutthroat trout as a result of unnatural seasonal flow and temperature regimes caused by discharges from Hungry Horse Dam.

4. To evaluate whether or not a multiple outlet discharge structure at Hungry Horse could provide desirable seasonal water temperatures to significantly benefit fish production in the Flathead River.

As the study has progressed, we have refined objective two to include:

a. Determining the relative contributions of various river system spawning areas in the Flathead drainage.

b. Determine the relationship between Flathead River flows and kokanee year class strength.

c. Assessing the capacity of Hungry Horse Dam to meet flow management criteria necessary to effect significant changes in natural reproductive success of kokanee under the various power alternatives.

Studies during the 1981-82 season have primarily addressed objectives one and two.

DESCRIPTION OF STUDY AREA

The Flathead River drains 21,876 km^2 of southeast British Columbia and northwest Montana (Figure 1). The Flathead is the northeastern most drainage in the Columbia River basin. Three forks of appoximately equal size drain the west slope of the Continental Divide.

The North Fork flows south out of British Columbia forming the western boundary of Glacier National Park. The North Fork was 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 was classified as a recreational river.

The Middle Fork was 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 was designated a recreational river. The Middle Fork forms the southwestern boundary of Glacier National Park.

The upper South Fork was 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 was classified recreational. The lower South Fork is regulated by flows from Hungry Horse powerhouse. Vertical water level fluctuations in the lower South Fork has been as much as 2.5 m daily due to peak hydroelectric energy production (Figure 2).

The mainstem Flathead River was 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 are subject to fluctuation due to the operation of Hungry Horse powerhouse downstream from its confluence with the South Fork.

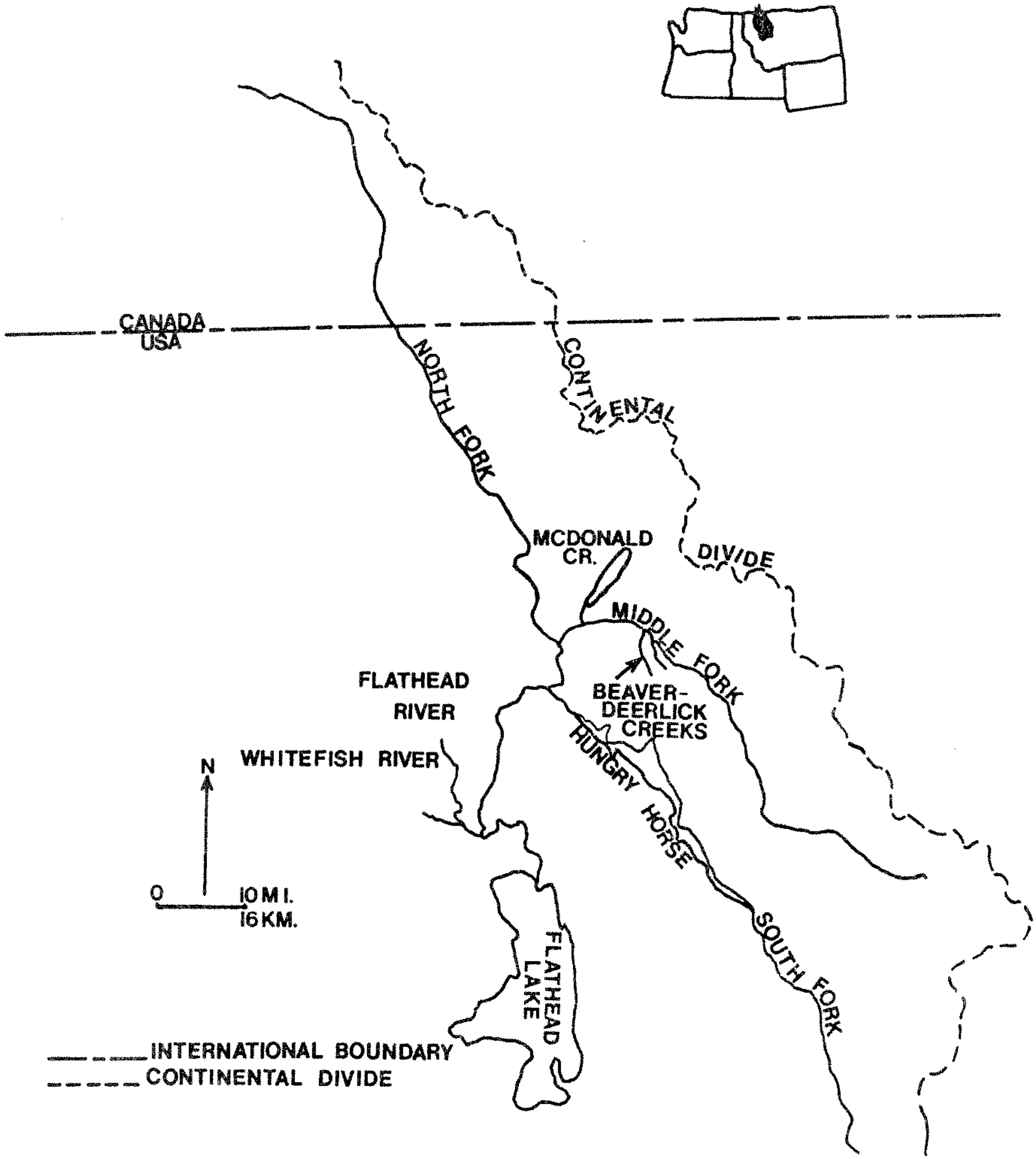

Figure 1. The upper Flathead drainage.

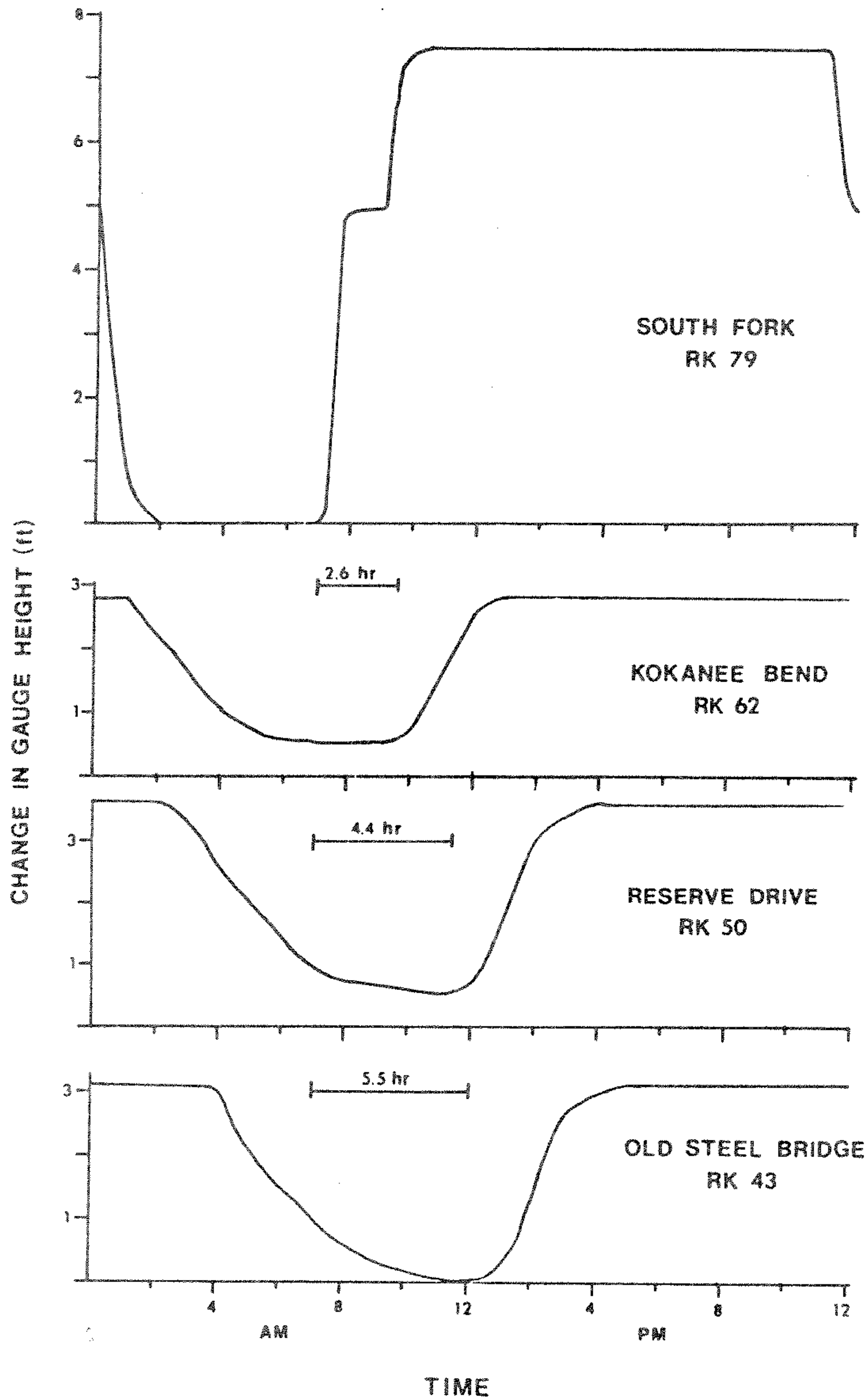

Figure 2. Vertical water level changes in the South Fork and three areas of the mainstem Flathead River as a result of generation at Hungry Horse Dam, August 2, 1979. Range of flows is 164 cfs to 9,100 cfs in the South Fork and 3,210 cfs to 12,100 cfs in the mainstem (from McMullin and Graham 1981).

Peak flows in the mainstem 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 mainstem hydrograph mirrored that of the South Fork. Daily vertical water level fluctuations in the mainstem, due to Hungry Horse operation varied up to 1.4 m (Figure 2).

Water temperature in the mainstem 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 in the mainstem (Figure 4).

Kokanee salmon, westslope cutthroat (*Salmo clarki*) and bull trout (*Salvelinus confluentis*) 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 or quinnat salmon eggs obtained from the Oregon Fish 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 populations became established in Flathead Lake and 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 (Montana Fish and Game Commission 1934). Thousands of kokanee were spawning along the shores of Flathead Lake and large runs were ascending into the Flathead River system.

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 mainstem Flathead River. The kokanee population in the mainstem 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. Kokanee were first observed spawning in the Middle Fork of the Flathead River from McDonald Creek upstream to the mouth of Deerlick Creek in 1981.

Westslope cutthroat trout (*Salmo clarki*) migrate up the Flathead River from Flathead Lake in winter and early spring (Hanzel 1966). Exact timing of migration may be affected by operation of Hungry Horse powerhouse (Huston and Schumacher 1978). Spawning occurs in May and June in tributaries of the North and Middle Fork.

Three distinct life history patterns of westslope cutthroat commonly occur throughout their native range (Behnke 1979). Adfluvial cutthroat reside in small streams for one to three years before emigrating to a lake. Growth is generally more rapid in lakes than in streams. After a period of one to three years in a lake, adfluvial cutthroat mature and ascend tributary streams to spawn. Westslope cutthroat probably evolved as

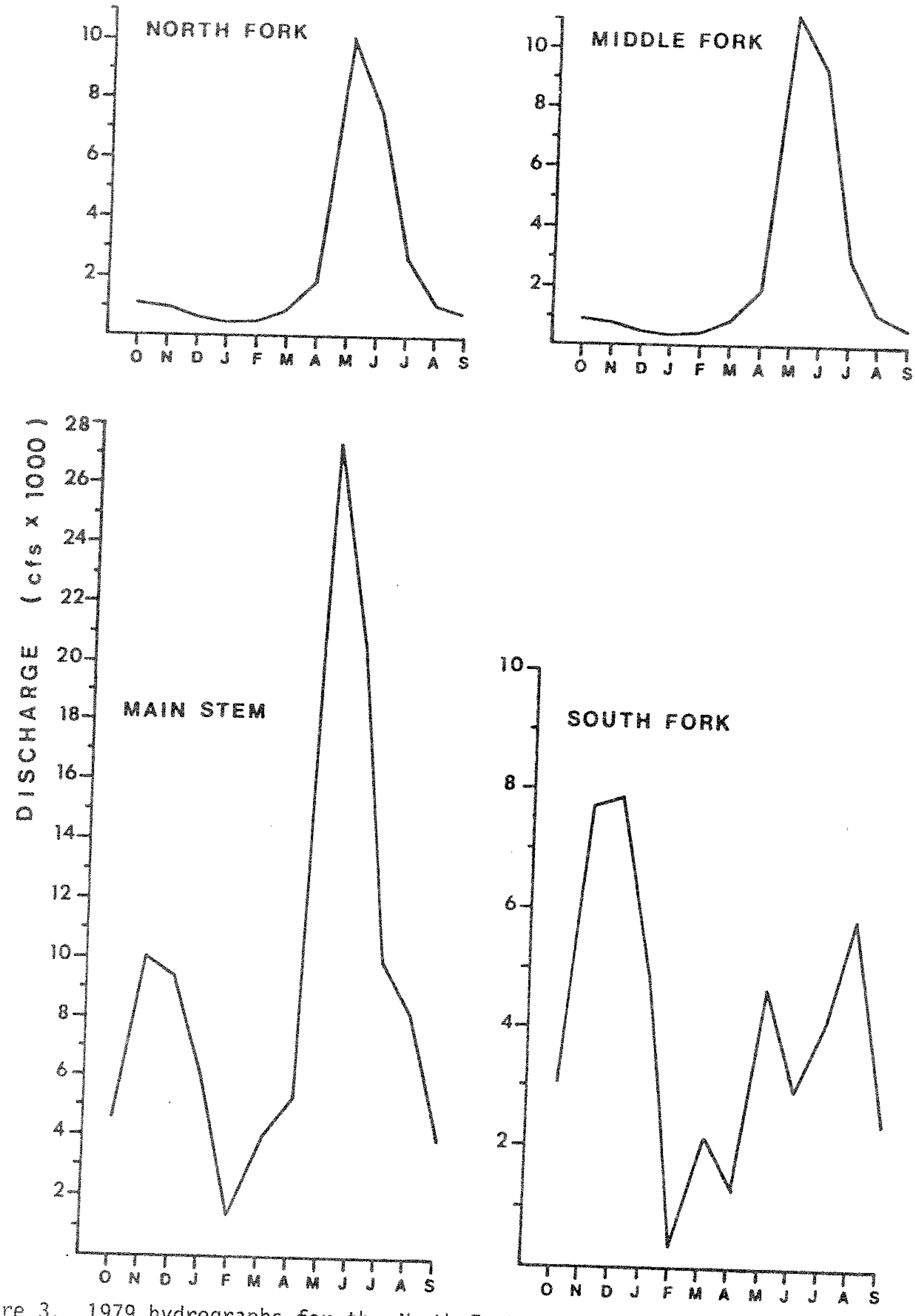

Figure 3. 1979 hydrographs for the North Fork near Canyon Creek, Middle Fork near West Glacier, South Fork near Hungry Horse and Flathead River at Columbia Falls (from McMullin and Graham 1981).

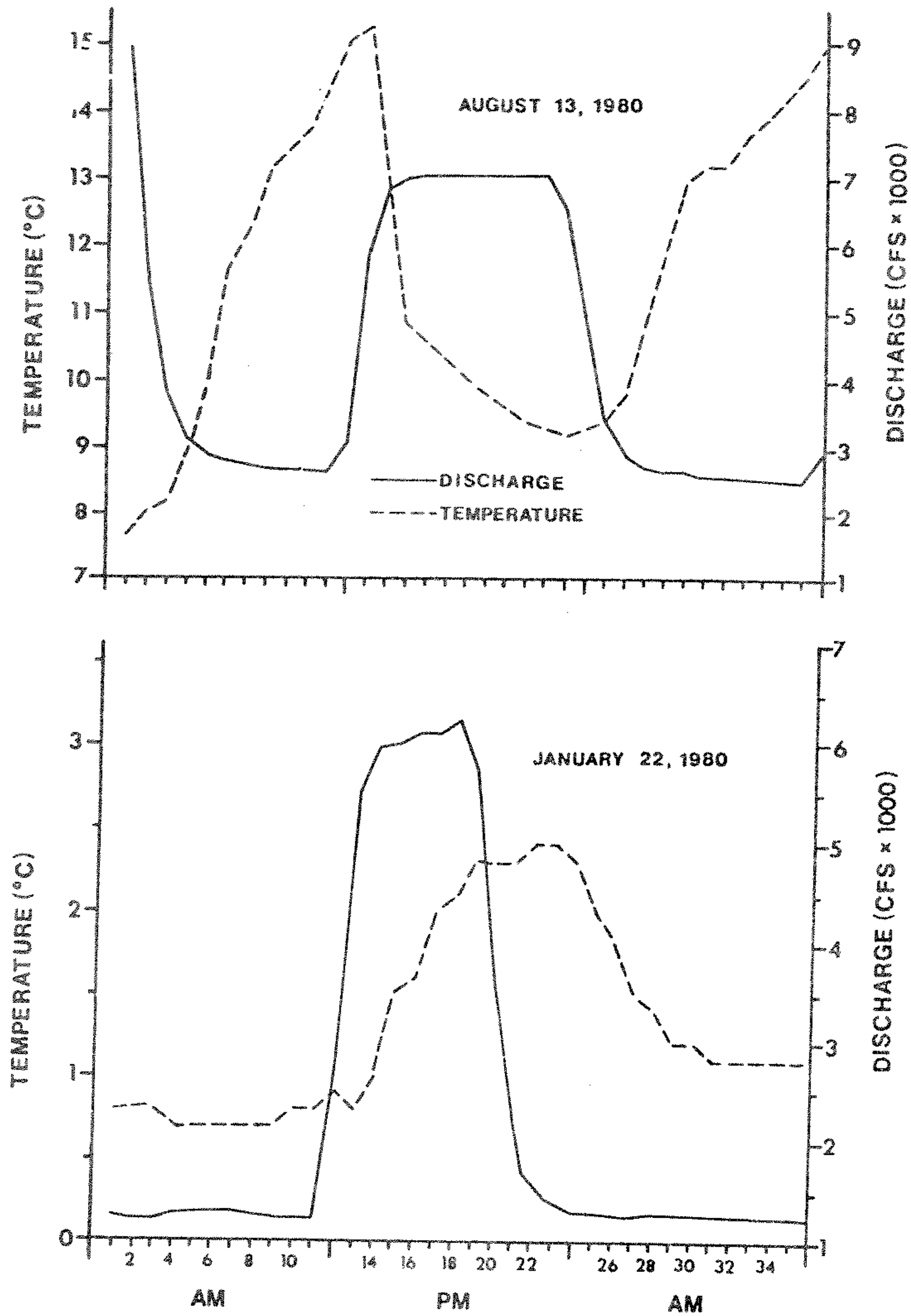

Figure 4. Flow-related temperature fluctuations in the mainstem Flathead River at Columbia Falls on a winter day and a summer day (from McMullin and Graham 1981).

adfluvial fish in Glacial Lake Missoula (Wallace 1979). Fluvial westslope cutthroat follow a life history pattern similar to adfluvial fish except maturation occurs in a large river. Spawning typically occurs in smaller tributaries. Resident westslope cutthroat spend their entire lives in small headwater streams.

All three forms of cutthroat are found in the Flathead drainage. The upper South and Middle Forks support fluvial populations. Fluvial cutthroat are occasionally found in the North Fork and mainstem. Resident cutthroat are found in nearly all tributaries of all three forks. Adfluvial cutthroat support the bulk of trout fishing in the North Fork and mainstem Flathead River. Anglers harvest adult adfluvial cutthroat on their spawning migration and juvenile cutthroat as they migrate downstream in summer and fall.

Bull trout (*Salvelinus confluentus*) begin migrating up the Flathead River in spring (Block 1955). Spawning occurs in North and Middle Fork tributaries during September and October. Migrating bull trout provide an important trophy fishery in the Flathead River system from May through October (Hanzel 1977). They provide a year round fishery in Flathead Lake. Regulations forbid taking of bull trout less than 457 mm (18 inches) in length. Anglers commonly harvest bull trout weighing two to five kilograms and occasionally up to 10 kilograms.

Other fish species are probably affected by Hungry Horse operations during at least a portion of their life histories. Other species commonly found in the Flathead River include rainbow trout (*Salmo gairdneri*), mountain whitefish 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*), longnose whitefish (*Prosopium coulteri*), 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 MIGRATION AND ABUNDANCE

The migration and abundance of kokanee spawners was monitored by snorkeling, aerial census, and fisherman tag returns of marked fish. Kokanee were observed by snorkeling in the North and Middle Fork drainages. Aerial census was the major method used in determining distribution and abundance in the mainstem Flathead and the lower Middle Fork. Tag return information was utilized to assess distribution and harvest throughout the drainage.

Snorkeling surveys were conducted in selected areas of the Middle Fork above McDonald Creek and the North Fork from Kintla Creek to Canyon Creek in late September, 1981. Snorkeling counts were made on the entire length of McDonald Creek and the Middle Fork below McDonald Creek in late

September, and again in late October, 1981.

Aerial counts were made as part of a fisherman census on the Flathead River from the mouth of the Stillwater River 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 flew the observer at the lowest practical elevation (150m) 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 4 September to 29 October, 1981. One count was made on 8 November. Gibson (1973), Neilson and Geen (1981) and Church and Nelson (1963) successfully used aerial counting methods to enumerate salmon.

Counts of spawners were also made during redd surveys by observing the fish from the jet boat and canoe.

SPAWNING SITE INVENTORY

An inventory of spawning sites or redds was conducted in five major spawning areas in the Flathead River system, including the mainstem Flathead, Middle Fork of the Flathead, Beaver-Deerlick creeks, Whitefish River and South Fork of the Flathead. The inventories were made when spawning was considered approximately 90 percent completed in each area.

Experimental spawning and incubation flows in the Flathead River below the South Fork were provided during the 1981 water year through agreement with the Bureau of Reclamation and the Bonneville Power Administration. A maximum spawning flow of approximately 4,000 cfs at Columbia Falls was to be maintained during the estimated hours of peak kokanee spawning activity (1700-2300 hours) in the month of November. The request allowed flows to be increased for power peaking during daylight hours. However, operators provided the preferred spawning flow of 4,000 cfs 24 hours per day throughout November.

Kokanee redd counts were made in mid-October, and early and late November in the Flathead River below the South Fork. All areas which had suitable spawning gravel were checked from a jet boat or by wading.

Surveys of spawning activity in McDonald Creek were made while snorkeling in September and October, 1981. Actual counts of redds were not made due to the density of spawners and redd superimposition.

Kokanee redd counts were made in the Middle Fork River above McDonald Creek on 20 and 22 October, 1981. The Middle Fork below McDonald Creek was surveyed on 21 October.

Redd counts were made in both Beaver and Deerlick Creeks in the Middle Fork drainage above McDonald Creek on 4 December. The South Fork of the Flathead and the Whitefish River were surveyed for kokanee redds on 29 and 19 October, respectively.

Four major spawning areas in the Flathead River below the South Fork were mapped during the late winter and early spring 1982. A transit and stadia rod were used to map spawning gravels and measure depth contours. Elevation of redds in these areas was measured relative to the 4,000 cfs spawning flow.

The 4.3 km section of McDonald Creek below McDonald Lake was floated by canoe on 31 March and 1 April, 1982, and the substrate material was mapped using an expanded aerial photo and measuring tape. The wetted substrate was divided into unsuitable, poor, medium, and good quality spawning gravel based on substrate composition. This classification was based on observations of substrate selection by kokanee spawners throughout the drainage. If the area of substrate had a large proportion of fine or very large materials, it was considered unsuitable for kokanee spawning.

Lengths, widths, and water depths of selected kokanee redds were measured in the mainstem Flathead and Middle Fork rivers. Substrate cores were analyzed for 20 redds in the mainstem Flathead. Geometric means (Platts et al. 1979), percent of material less than 0.85 and 9.5 mm, and fredle indices (Tappel 1981) were calculated for the samples.

EGG INCUBATION AND ALEVIN DEVELOPMENT

Experimental incubation flows of approximately 2,300 cfs (24 hours per day) at Columbia Falls were maintained during the November through April study period, except for several days during the winter when the flow dropped to 2,200 cfs. Survival and development of kokanee eggs and sac-fry alevins was monitored in natural redds throughout the winter in the Flathead River to evaluate the effects of the experimental spawning and incubation flows. A hydraulic egg sampler (Graham et al. 1980, McNeil 1963) and kick net were used to sample natural redds.

Incubation and development in the lower Flathead River were also evaluated with experimental egg plants. Eggs were put in fiberglass bags and buried in gravel at four water levels in three spawning areas on the river. Bags were harvested monthly from each spawning area to evaluate development and survival. Egg bags were also planted to test survival in three mainstem areas where suitable spawning gravel was present, but had not been utilized by kokanee throughout the three year study period. A total of 140 bags containing 100 eggs each were planted during 1981.

Survival and development of eggs and alevins in natural redds was monitored at spawning areas in the Middle Fork Flathead River and McDonald Creek. Two areas of the Middle Fork, one below and one above McDonald Creek, were sampled in mid-December and again in mid-March with the hydraulic egg sampler and kick net. A 2 km portion of McDonald Creek was sampled with the hydraulic egg sampler and kick net to estimate the density of live eyed eggs and sac fry alevins in the gravel. A total of 36 samples were taken at randomly selected points and total production and survival were calculated (McNeil 1964). Random sampling was conducted to determine production in four areas in the mainstem Flathead. Production was calculated by multiplying the live egg and alevin density times the total area (m^2) of spawning gravel at each site.

Eggs were planted in artificial channels at Somers Hatchery to test the effects of sediments on egg survival during periods of dewatering. Six bags, each containing 50 eggs, were planted in each of four channels containing 12, 21, 27 and 40 percent fine sediment mixtures, respectively. Dewatering was simulated by shutting off the water source and survival was monitored by collecting egg bags every two hours and counting live and dead eggs. The experiment began at dark and continued for 12 hours. Two green egg experiments (December and January) and two eyed egg experiments (January and March) were conducted. In mid-March, 300 eggs were planted in each channel to evaluate survival from egg to fry in the four sediment levels.

STREAMFLOW - YEAR CLASS RELATIONSHIP

Relationships between year class strength of kokanee spawners and flows during the spawning and incubation seasons which produced them were analyzed (Graham et al. 1980, McMullin and Graham, 1981). Length of kokanee spawners was used as the measure of year class strength, assuming fish size was inversely related to fish numbers in Flathead Lake. Other workers have reported this density dependent relationship in sockeye salmon populations (Foerster 1944, Johnson 1965, Goodlad 1974, Stober et al. 1978).

The majority of kokanee spawners entering the river system in a particular year were mostly of one age class (Hanzel 1976). However, interactions with other year classes of kokanee can affect their growth. To account for year class interactions, a three-year moving average of flow conditions was used in the calculations (Graham et al. 1980, McMullin and Graham 1981).

FRY EMERGENCE AND MOVEMENTS

Timing and abundance of emerging fry was evaluated using $0.5m^2$ drift nets suspended in the water column and fry emergence traps placed over the spawning gravel.

Drift nets were used in all river system spawning areas to filter swimming fry from the water column. Net sets were made weekly from early March through June in McDonald Creek, Beaver Creek, and Deerlick Creek in the Middle Fork drainage and Brenneman's Slough on the mainstem Flathead. Sampling began in early April in the Flathead River near the Old Steel Bridge and the Whitefish River near Highway 2. Drift nets were suspended in the water column overnight at each area. Fry were counted and the volume of water filtered by the net was calculated.

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. Nets were placed at several different depths and water velocities and were harvested every two hours.

Fry emergence traps (.12m^2) were designed, constructed, and tested (Figure 5). The traps consisted of a nylon net and metal frame with a nylon sock and screen fyke to capture emerging fry. Frames were attached to the stream bottom with rebar. Timing and number of emerging fry were evaluated using 29 of the traps. Seventeen traps were placed in four mainstem spawning areas, 8 were placed in McDonald Creek, and four were placed in Beaver and Deerlick creeks. Phillips and Koski (1969) used similar traps in Oregon river systems to capture salmonid fry.

Groups of kokanee fry were dyed with Bismark Brown stain (Ward and VerHoeven 1963) during experiments to evaluate fry movements. Approximately 2,000 fry captured in Beaver Creek were dyed and released. Drift nets were then set downstream near the confluence of the creek and the Middle Fork and maintained for ten consecutive days. Groups of dyed and undyed fry were kept in net bags in the stream as controls for the experiment to evaluate mortality and dye retention. A similar experiment was conducted in Deerlick Creek where approximately 3,000 hatchery fry were dyed and released.

RESULTS AND DISCUSSION

KOKANEE ABUNDANCE AND MIGRATION

Kokanee Abundance

An assessment of the relative contributions of various segments of the river system to kokanee recruitment is required to determine the effects of discharge from Hungry Horse Dam on the fisheries of the Flathead River. Abundance estimates of spawners were made by a combination of direct observations and redd counts made after spawning was completed. Assessing the abundance of kokanee in areas not influenced by Hungry Horse Dam provided an estimate of the relative contribution of the impacted portions of the river system. These unaffected areas such as McDonald Creek, the Middle Fork of the Flathead River, Whitefish River and mainstem spring areas provide a reference to monitor natural fluctuations in the kokanee populations.

The number of spawners in the mainstem Flathead River remained small although spawner abundance was greater in 1981 than in the two previous years of the study (Table 1). The total redd count in 1981 was several times larger than the 1979 count and about fourteen times larger than in 1980. The estimated 18-20,000 spawners (estimated from redd counts) in the mainstem in 1981 is quite small when compared to the numbers of spawners which were present during previous years.

The number of redds counted in spring areas was much more consistent

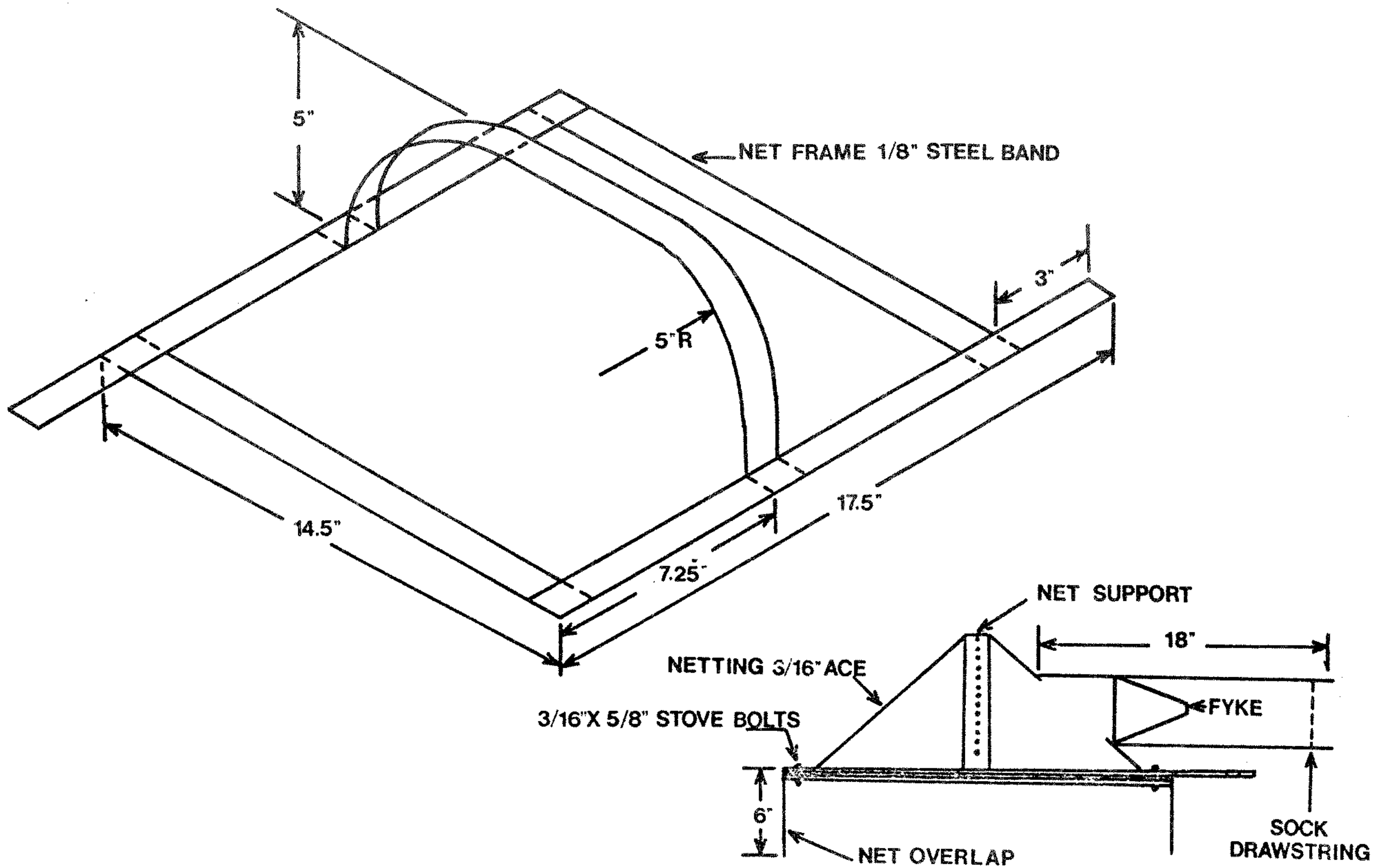

Figure 5. Fry emergence trap design.

Table 1. Numbers of redds observed in the Flathead River system in 1979, 1980 and 1981.

River Section	Year 1981	1980	1979
Flathead River below the South Fork			
total	6,952	467	2,802
non-spring	5,961	77	1,861
spring	991	390	941
South Fork River	300	1/	1/
Middle Fork River	2,300	1/	1/
Beaver Creek	516	1/	0
Deerlick Creek	202	1/	1/
Whitefish River	416	426	1/

1/ Spawning probably occurred but no redd surveys were conducted.

among the three years, probably because of more stable environmental conditions. These areas were not significantly affected by discharges from Hungry Horse Reservoir.

Larger numbers of kokanee spawners were also counted in McDonald Creek in 1981 than in either of the two previous years of the study (Table 2). It is probable that survival conditions in the year of development of the 1981 year class were more favorable than for the 1979 and 1980 year classes. A median estimate of 97,000 kokanee was obtained in the 21 October survey. An estimated 5,000-7,000 dead kokanee were also counted.

Snorkel counts in the Middle Fork Flathead River above and below McDonald Creek also indicated larger numbers of kokanee in the Middle Fork drainage in 1981 as compared to the two previous years of the study. No kokanee were observed in the North Fork drainage in 1981.

The 300 kokanee redds counted in the South Fork of the Flathead below Hungry Horse Dam were concentrated in the Devil's Elbow area (Table 1 and Appendix C). More than half of the redds in the South Fork were subject to dewatering during periods of low discharge from Hungry Horse Dam. Huston and Schumacher (1978) reported that kokanee spawned in similar areas of the South Fork during the 1970's.

A total of 2,300 redds were counted on 20-22 October in the Middle Fork (Table 1 and Appendix C). Approximately 1,000 of these redds were located above McDonald Creek and 1,300 were located below McDonald Creek. Spawning began in mid to late September in the Middle Fork, and was estimated to be 80-90 percent completed by the 20-22 October redd count.

Counts of 516 and 202 kokanee redds were made in Beaver and Deerlick Creeks, respectively, on 4 December, 1981 (Table 1 and Appendix C). Spawning had begun in early October in these streams and was virtually completed by the date of the redd count. A few fish remained in Deerlick Creek, but no fish were observed in Beaver Creek on 4 December. A beaver dam prevented spawning in Beaver Creek in 1979 (Graham et al. 1980). Some spawning occurred in 1980 (McMullin and Graham 1981), but no redd count was made.

The 416 redds counted in the Whitefish River on 19 October were concentrated between Hodgson and Rose Crossings (Table 1 and Appendix C). McMullin and Graham (1981) reported 426 redds in this section of the river in 1980 (Table 2).

Spawning in McDonald Creek and the Whitefish River appears to be more than one month earlier than reported in the 1950's (Stefanich 1954). This temporal shift may be a result of better survival of progeny from earlier spawning kokanee.

Based on direct observations of spawners and total redd counts, an estimated 140,000 kokanee spawners reached spawning grounds in the Flathead River system during 1981. An estimated 60,000 and 100,000 spawners reached spawning grounds in the river system in 1980 and 1979, respectively, based on more limited data. Spawner abundance in the Flathead River below the South Fork from 1979-1981 followed the same pattern recorded for McDonald Creek, indicating natural environmental fluctuations affecting survival as well as Hungry Horse discharge have influenced kokanee abundance. This demonstrates the critical importance of monitoring portions of the river system unaffected by Hungry Horse operations.

Kokanee Migration

Timing, rate of migration and distribution of kokanee spawners may be influenced by river discharge and temperature. Recreational potential of the fisheries may be influenced by the rate of movement and density of spawners in the river. Aerial counts of spawners and tag return information proved to be valuable tools in assessing kokanee migration patterns.

The first large concentration of kokanee spawners in 1981 was recorded in the Flathead River near Kalispell during an aerial count on 4 September (Appendix A). Smaller groups of adult spawners were as far upstream as Columbia Falls on this date. By 8 September, large schools of kokanee had reached the Middle Fork of the Flathead River near McDonald Creek, 56 km upstream from Kalispell. A similar pattern of migration occurred in 1979 (Graham et al. 1980). In 1980, large groups of kokanee spawners did not appear in the Kalispell area until mid-September (McMullin and Graham, 1981).

Aerial counts made in the river system indicated kokanee migration occurs in several "waves" or "runs" (Figure 6). Several peaks of kokanee abundance were recorded in the mainstem Flathead below Blankenship Bridge. Peaks of spawner abundance in this area occurred in mid-September, late September, and early October as they migrated upstream. No large peaks of spawners were observed in the mainstem after early October. We believe this later portion of the run makes up the majority of fish that spawn in the mainstem Flathead River. As a result of a third consecutive poor year in the mainstem, the river was closed to snagging of kokanee on 28 October by order of the Fish and Game Commission.

A moderate peak of spawner abundance was recorded in mid-September in the Middle Fork River from Blankenship Bridge to West Glacier (Figure 6). Kokanee were abundant in this section of the river throughout September and most of October with major peaks occurring in late September - early October, and mid-October. Numbers of spawners declined sharply in late October because the majority of the fish had moved into McDonald Creek or farther upstream in the Middle Fork River.

Water temperature has affected kokanee migration timing in this river section. Comparisons of late September and late October snorkel counts in McDonald Creek indicated kokanee moved into the stream earlier than observed in 1979, but later than observed in 1980 (Table 2). The temperature pattern of McDonald Creek affected the rate and time of movement of kokanee into the stream during the three years. Temperatures of McDonald Creek in

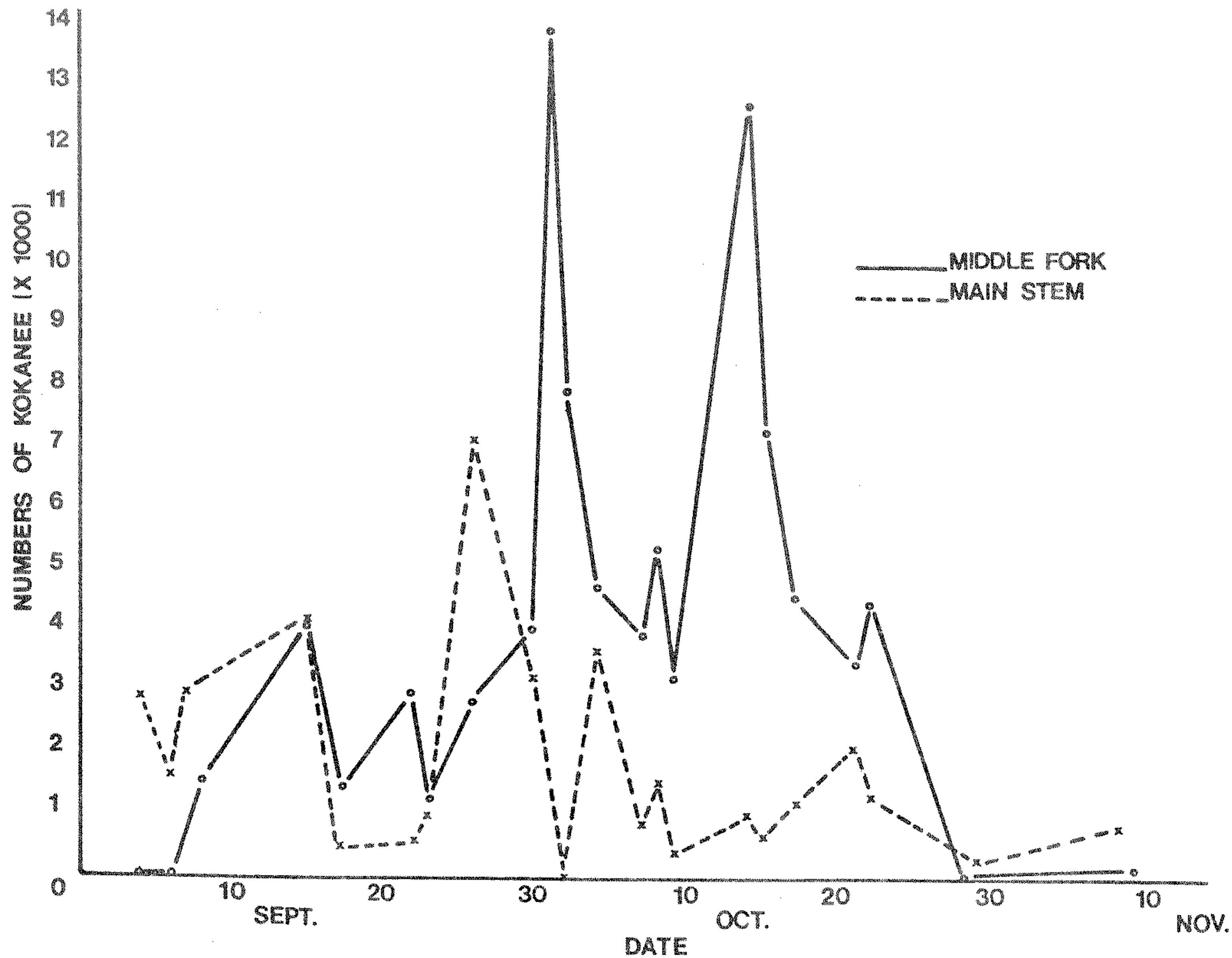

Figure 6. Aerial counts of kokanee spawners during 1981 in the Flathead River from Blankenship Bridge to the mouth of the Stillwater River and the Middle Fork of the Flathead from Blankenship Bridge to West Glacier.

bridge to West Glacier.

Table 2. Numbers of kokanee salmon adults counted by snorkeling in the Flathead River system above the confluence of the North and Middle Forks.

Date	Kokanee counts			
	McDonald Creek	Middle Fork below McDonald Creek	Middle Fork above McDonald Creek	North Fork from Kintla Creek to Canyon Creek
9/23-25/81	12,434-15,834	19,917-24,297	2,785-3,350	0
9/23-25/80	28,700-43,300	350-550	0	0
9/19-21/79	1,200- 1,500	7,000-12,000	0	175-225
10/21/81	84,000-111,000 (+5,000-7,000 dead kokanee)	11,000-15,000	---	---
10/22/80	37,000-54,000 (+4,000 dead kokanee)	450-500	---	---
10/17/79	60,000-70,000	6,500-9,500	---1/	---1/

1/ Counts were not made in the North or Middle Fork drainages in October.

late September ranged from 17° to 19° centigrade during 1979, and from 13° to 14° centigrade during 1980 (McMullin and Graham 1980). During 1981 temperatures in McDonald Creek ranged from 14° to 16° centigrade during late September. Kokanee remained in the Middle Fork until temperatures in McDonald Creek dropped to levels below approximately 16°C. Foerster (1968) found water temperatures affected migration of sockeye salmon.

The pattern of kokanee migration indicated that successive runs of spawners were moving through the river system with early runs spawning in upriver areas and the late run spawning in areas generally influenced by Hungry Horse Dam. The phenomenon of late and early runs was discussed in Graham et al. (1980) and McMullin and Graham (1981). Merrell (1960) found pink salmon runs into Sashin Creek, Alaska, occurred in several waves or peaks during a period of approximately one month. Jeppson (1960) reported similar migration patterns in kokanee salmon tributaries of Pend Oreille Lake, Idaho. Eaton and Meehan (1966) reported two peaks of sockeye salmon migration in the Frazer Lake system, Alaska.

Tag return information supported the concept of successive runs of kokanee spawners through the migration season. The greater average rates and distances of movement exhibited by fish tagged in early September indicated these fish were part of one of the earlier waves of fish bound for more upstream spawning areas of the river system. Almost one-fourth (23 percent) of the returns of fish tagged in early September were reported from the Middle Fork drainage, while only 7 percent of the returns from the fish tagged in late September were reported from the Middle Fork. Tag returns of kokanee by fishermen have averaged 12 percent in the three years of the study (Table 3).

Fishermen returned 38 (23 percent) of the 162 adult kokanee tagged in the Flathead River near Kalispell on 6 September (Appendix B). Six were caught in the area where they were tagged within a few days of release. The remaining 29 spawners which were caught exhibited an average upstream movement of 21.1 km at an average rate of 2.1 km/day. Killick (1955) reported an average migration rate of 30 km/day for sockeye salmon in the Fraser River, Washington. The greatest rates of movement were by fish caught on 9 September near Columbia Falls (8.2 km/day) and a fish caught on 13 September in the Middle Fork near McDonald Creek (8.0 km/day). A total of nine returns were reported from the Middle Fork River. One fish was caught near Nyack in the Middle Fork River, 111 km upstream from Kalispell.

A total of 15 returns (6.7 percent) were reported by fishermen of the 227 kokanee tagged on 29 September in the Flathead River near Kalispell (Appendix B). Five fish were caught near Kalispell within one week. One fish was caught near the point of release 28 days after it was tagged. The maximum rate of movement (5.8 km/day) was exhibited by a fish caught on 3 October near Columbia Falls. Only one return was reported from the Middle Fork.

Table 3. Tag returns by anglers from kokanee tagged near the Old Steel Bridge in September 1979-1981.

	Date	Number tagged	Number returned	Percent return
1981	9/6	162	38	23.4
	9/29	224	15	6.7
1980	9/15	302	29	9.6
1979	9/4	104	14	13.5
	10/4	59	6	10.2
1979-1981		851	102	12.0

SPAWNING SITE INVENTORY: FLATHEAD RIVER

Redd Counts

Spawning in the Flathead River below the South Fork began on 8 October, 1981, when 16 redds were counted in mainstem spawning areas of the lower Flathead River. On 2-5 November, 3566 redds were counted (Table 4). A final, complete redd count was conducted on 23-25 November when 6,767 redds were observed in 37 spawning areas. An additional 886 redds were discovered in early December in two areas not previously checked during the study. Spawning continued into mid-December in a number of the spawning areas. Approximately 90-95 percent of all spawning which occurred took place between mid-October and mid-December.

Spawning began earlier and extended later into the winter in 1981 than in 1979. About one-third of the total redds were constructed by the end of the early November count in 1979 compared to 50 percent by the same date in 1981. In 1979, spawning during December was observed only in Brenneman's Slough (Area 1) while in 1981 spawning was observed in many mainstem river areas in December. Spawners were still entering Brenneman's Slough in early January, 1981. The extended spawning season in 1981 probably resulted in a substantial amount of observed redd superimposition.

Complete descriptions and map locations of all 42 mainstem spawning areas utilized by kokanee during the three years of the study are presented in Appendix C.

Distributions of Redds Relative to Spawning and Incubation Flows

The relationships among river elevations, number of watered redds and area of wetted gravel at major spawning areas in the mainstem Flathead were measured to assess the distribution of redds relative to spawning and incubation flows.

A survey of the drop in water elevations between the 4,000 cfs spawning flow (SF) and the 2,300 cfs minimum incubation flow (IF) was conducted on 8-13 October at 13 areas of the mainstem Flathead considered representative of spawning sites in the river (Appendix D). The drop between SF and IF ranged from 0.5 feet to 1.3 feet and averaged 0.8 feet. The difference in water elevation between SF and IF was 1.2 feet at the Columbia Falls gauge site.

Relationship between flow and water elevation at most major spawning areas were then developed to help determine the number of redds wetted and area of gravel wetted at various flows between SF and IF.

Distribution of Redds

When the 2-5 November redd count was made in the mainstem Flathead, 943 redds of the 3,568 counted were located above the spawning flow water elevation of 4,000 cfs. These redds had been constructed in mid to

Table 4. Numbers of redds counted in early and late November in spawning areas utilized by kokanee salmon on the Flathead River below the South Fork in 1981.

Area number[1/]	Date: November 2-5, 1981	November 23-25, 1981
1	339	341
2	2	12
4	62	67
5	10	14
7	20	30
8	7	133
9	69	218
10	166	517
11	165	165
12	254	254
15	9	9
16	43	106
17	0	118
19	124	174
20	132	604
21	60	226
22	51	179
23	2	31
24	10	13
25	139	363
26	3	3
27	255	494
28	11	51
29	225	375
30	68	94
31	8	23
33	4	11
34	78	160
35	55	146
37	310	495
38	78	288
39	703	1,083
40	72	76
41	33	92
42	1	2
TOTAL	3,568	6,967

1/ See Appendix C for descriptions and map locations of spawning areas.

late October at higher flows of approximately 10,000 cfs during peaking operations of Hungry Horse Dam. The spawning flow was not exceeded during the rest of November and the remainder of the redds were constructed below the SF water level. Meekin (1967) found that fluctuating flows early in the spawning period of chinook salmon resulted in redd construction above later flow levels in the Columbia River below Chief Joseph Dam.

A survey of major spawning sites in early December, when the mainstem was flowing at the minimum incubation flow of 2,300 cfs, showed approximately 25 percent of the redds constructed below the 4,000 cfs SF level were dewatered. More detailed surveys during the winter of 1982 at four major spawning sites subject to dewatering (Areas 10,27, 32 and 39) showed that an average of 50 percent of all redds constructed at the 4,000 cfs spawning flow were dewatered at the 2,300 cfs incubation flow (Figure 7). These areas were chosen for study because they contained approximately 30 percent of all redds found in the mainstem and are considered high quality, traditional kokanee spawning areas. Kokanee were concentrated in shallower gravel areas and spawned in water as shallow as one inch. When the river was dropped to the 2,300 cfs incubation flow later in the winter, subsequent dewatering occurred. The percent of redds dewatered in the mainstem as a whole would be somewhat lower because some areas are not subject to dewatering. Kokanee salmon spawned in Washington streams at depths averaging 0.6 feet and ranging from 0.2 to 1.8 feet (Hunter 1973). Mean water depth of kokanee spawning was 0.7 feet in several Oregon streams (Smith 1973).

Distribution of Spawning Gravel

Spawning gravel and water elevations at various flows were mapped for the three major spawning areas (Appendix D). The average loss of wetted spawning gravel (70 percent) from 4,000 cfs to 2,300 cfs was even larger than the loss of redds (Figure 8). A smaller percentage of redds than gravel were dewatered or lost at these sites because an egg depth of 0.2 feet was assumed when evaluating redd dewatering. Based on redd excavation, 0.2 feet appeared to be a good estimate of minimum egg burial depth. Ground-water flow was also found to keep some redds watered, even though the river was not flowing over them.

The large reduction of wetted spawning gravel and kokanee redds occurred in the lower Flathead because spawners concentrated in spawning sites with gently sloping gravels along the margins of the stream. A small drop in water elevation resulted in a large loss of wetted spawning area.

Microhabitat Measurements of Kokanee Redds

Kokanee redds averaged longer and wider in the mainstem Flathead than in the Middle Fork River (Appendix E). Depths of water over the redds ranged from one inch to more than 20 feet in both areas. The majority of the redds in the mainstem Flathead were in water depths less than 1 m at the 4,000 cfs spawning flow, while the majority of redds in the Middle Fork River were in water depths greater than 1 m. Most redds were observed in water

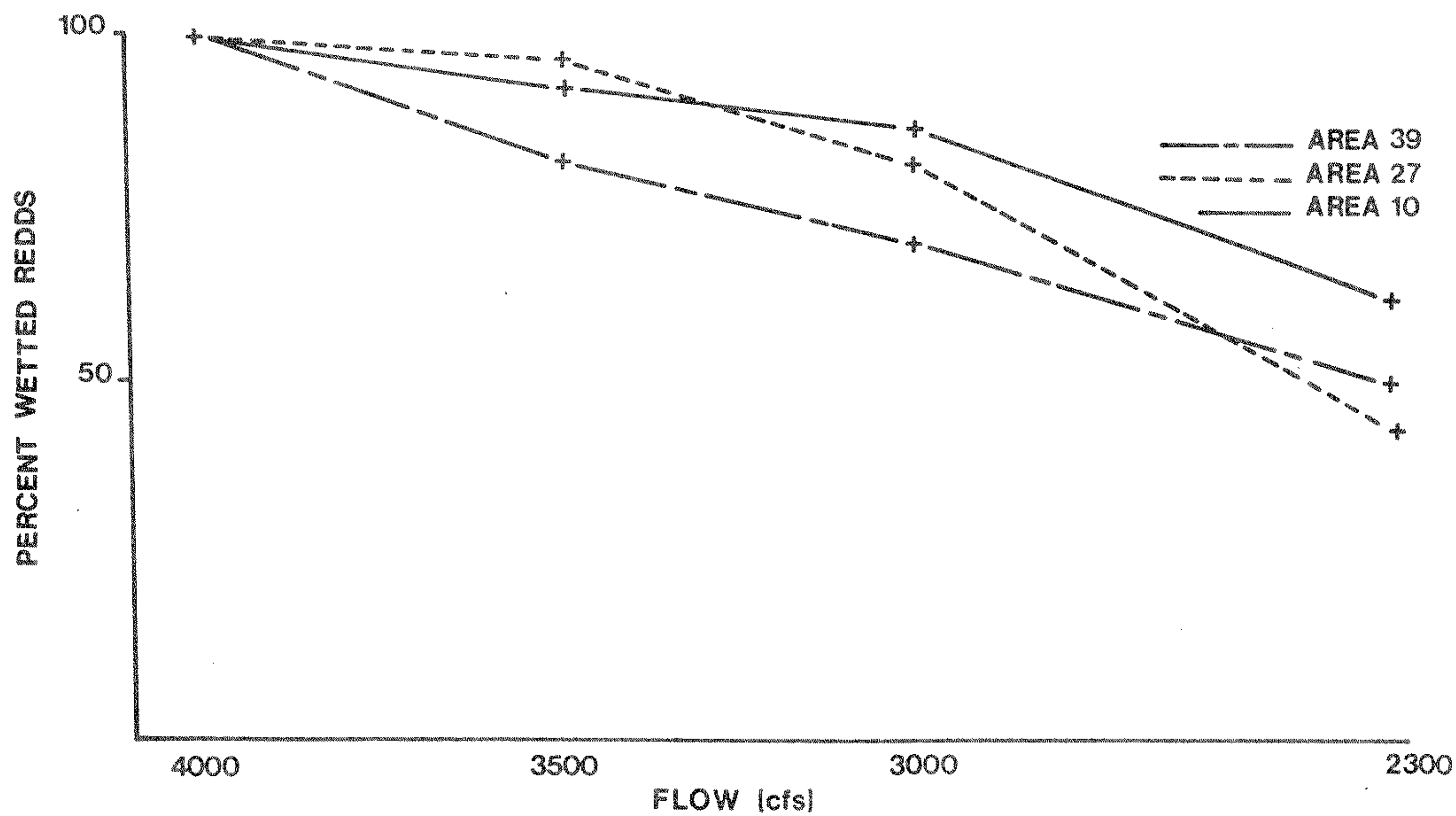

Figure 7. Percent of kokanee redds which were constructed at the 4,000 cfs spawning flow wetted at various flows in the mainstem Flathead River.

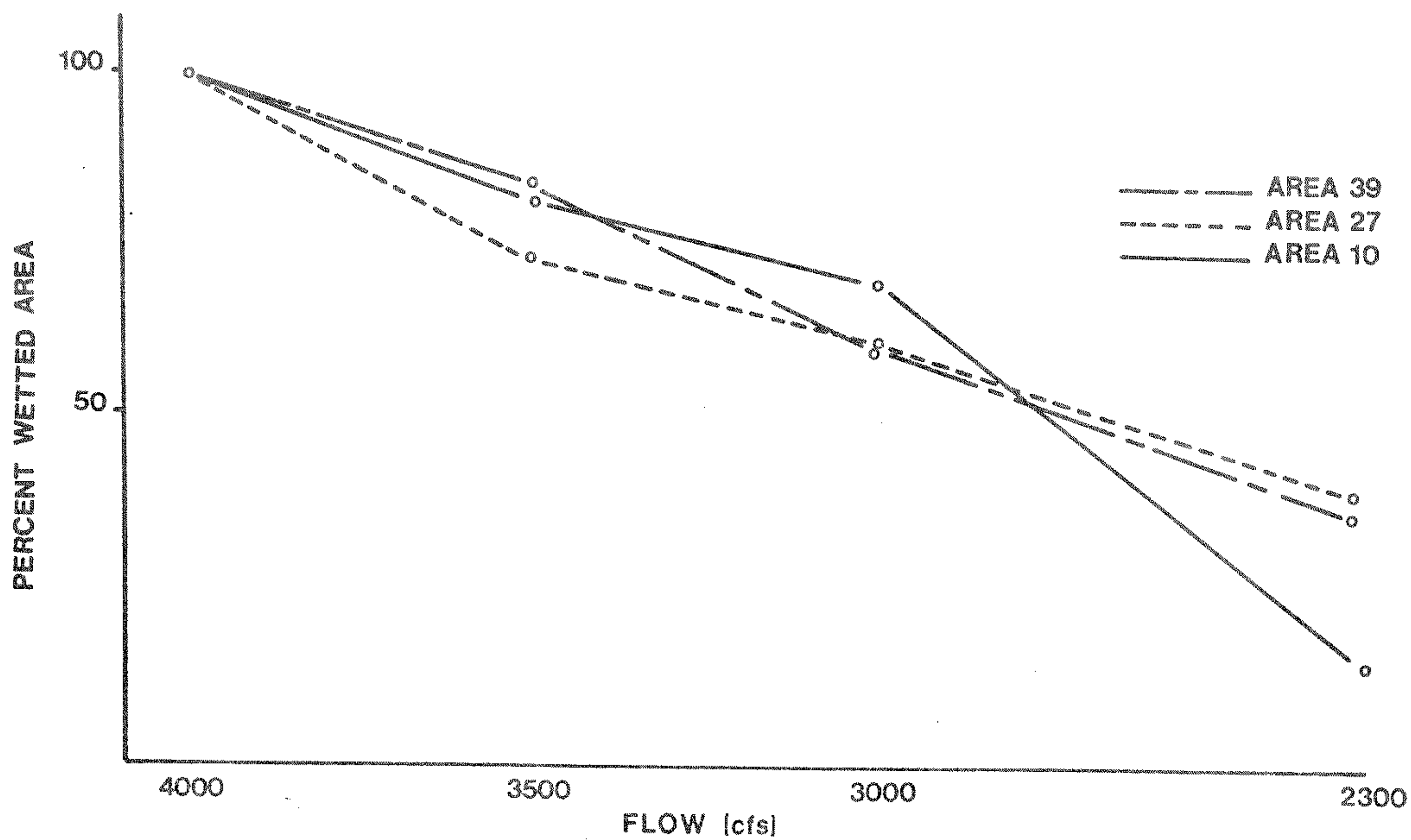

Figure 8. Percent of wetted spawning area at various flows in three spawning areas in the mainstem Flathead River.

velocities less than 2 feet/second. Graham et al. (1980) reported a similar velocity distribution of redds.

Substrate composition in redds of five major spawning areas in the mainstem Flathead varied in the size compositions of materials (Figure 9 and Appendix E). The average percent of materials less than 6.35 mm in diameter was 20, 27, 29, 30 and 23 in areas 10, 12, 27, 32 and 39, respectively. Graphs of cumulative percents of substrate sizes indicated the materials were generally lognormally distributed. Areas 10 and 12 departed most from lognormality. Platts et al. (1979) reported stream bed materials were lognormally distributed.

EGG INCUBATION AND DEVELOPMENT

Egg and Alevin Survival

Survival of kokanee embryos through incubation and emergence was assessed under a variety of natural and artificial conditions to evaluate impacts of dewatering and assess potential production. Some factors which influenced egg survival included length of dewatering, air temperatures and quality of spawning bed material. Determining the potential recruitment of kokanee at a given spawning and incubation flow requires an understanding of those interrelationships.

Natural Redds

Survival of kokanee eggs in natural redds in the mainstem Flathead River averaged 22 percent during the green egg stage at a nonspring site (Area 27) in late December (Appendix F). This area was subject to dewatering during the incubation period. Survival of eggs in natural redds averaged 78 percent on the same date at a spring influenced site (Area 38).

Survival in the late eyed-egg and alevin stages (March) averaged 62 percent and ranged from 16 to 88 percent in the mainstem. These survival values may be high due to disappearance of dead eggs from spawning gravels prior to sampling (McNeil 1964, Graham et al. 1980). However, McNeil et al. 1964 reported a slow disappearance of dead eggs from spawning gravels in Susan Creek, Alaska.

Analysis of substrate quality indicated nonspring mainstem areas experienced much lower survival than the potential predicted by three measures of substrate quality based on salmon and steelhead studies (Table 5, Figures 10-12). This decreased survival was probably due in part to dewatering mortality resulting from fluctuations in Hungry Horse discharge. Predicted potential survival was lower (Figure 13, Table 5) in studies conducted on kokanee in Idaho channels (Idaho Coop. Fish. Unit. unpublished data).

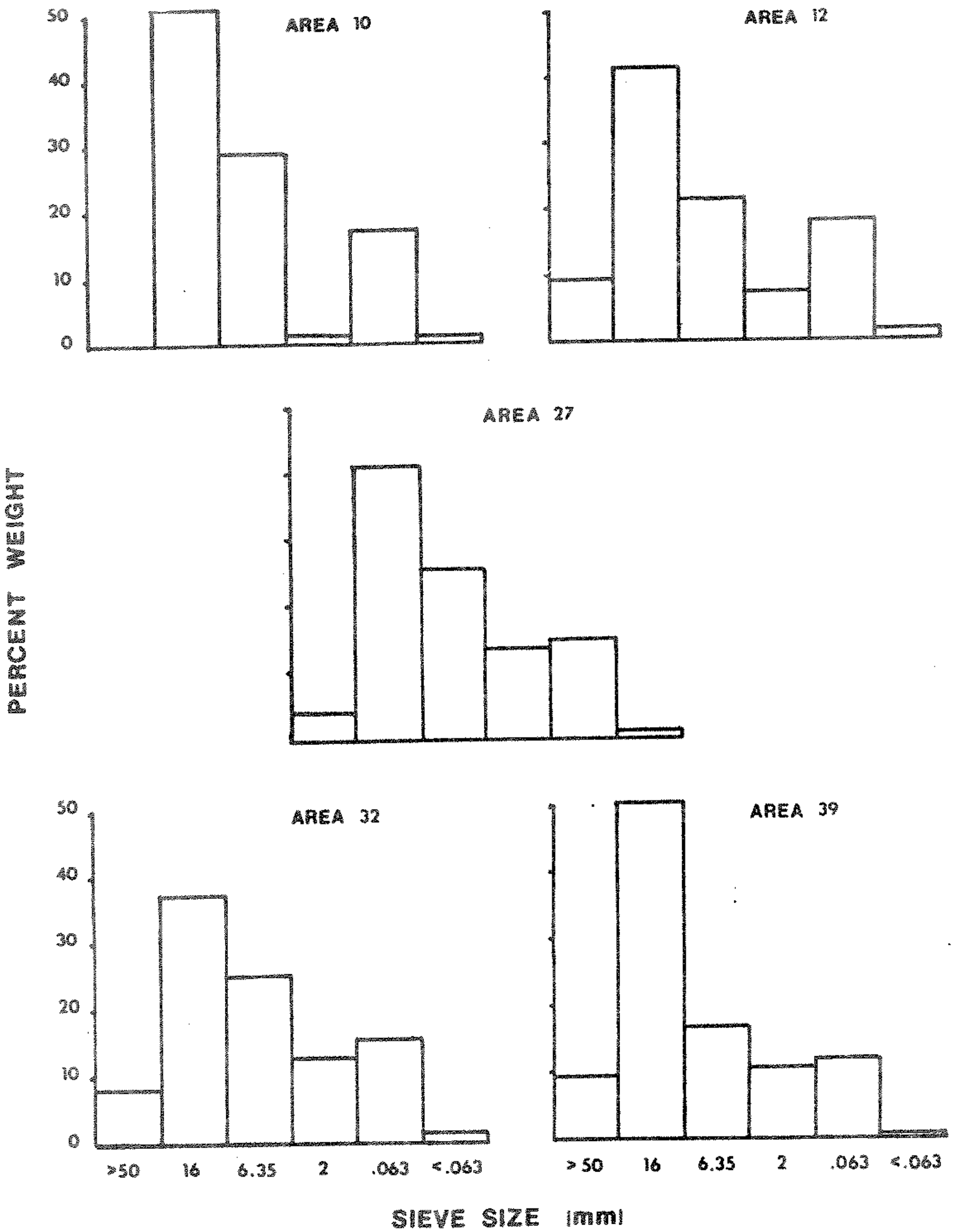

Figure 9. Substrate material composition in kokanee redds of five spawning areas in the Flathead River below the South Fork.

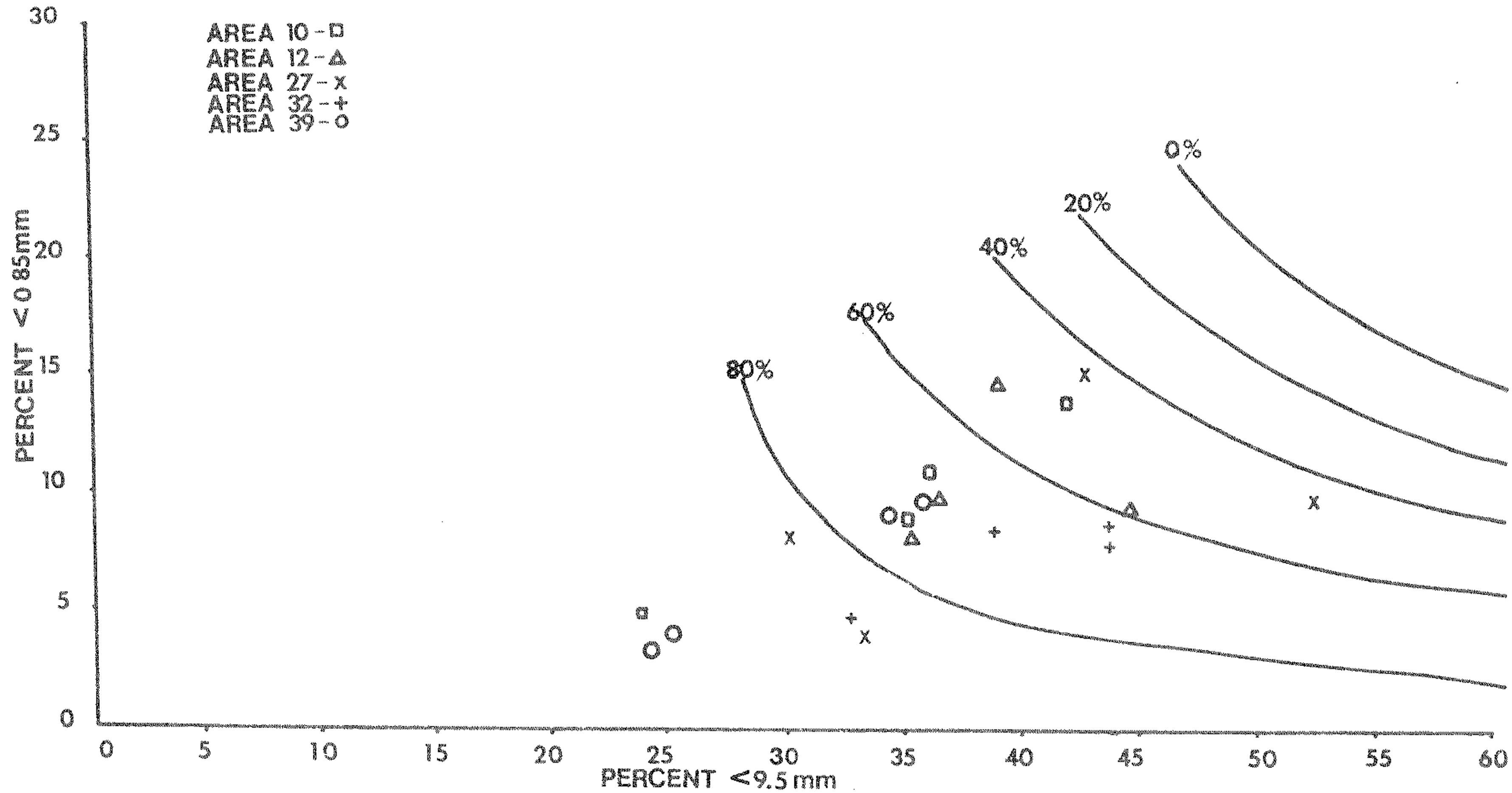

Figure 10. Predicted kokanee egg survival in spawning areas of the Flathead River based on substrate quality. Survival bands are based on salmon studies conducted in Idaho by Tappel (1981).

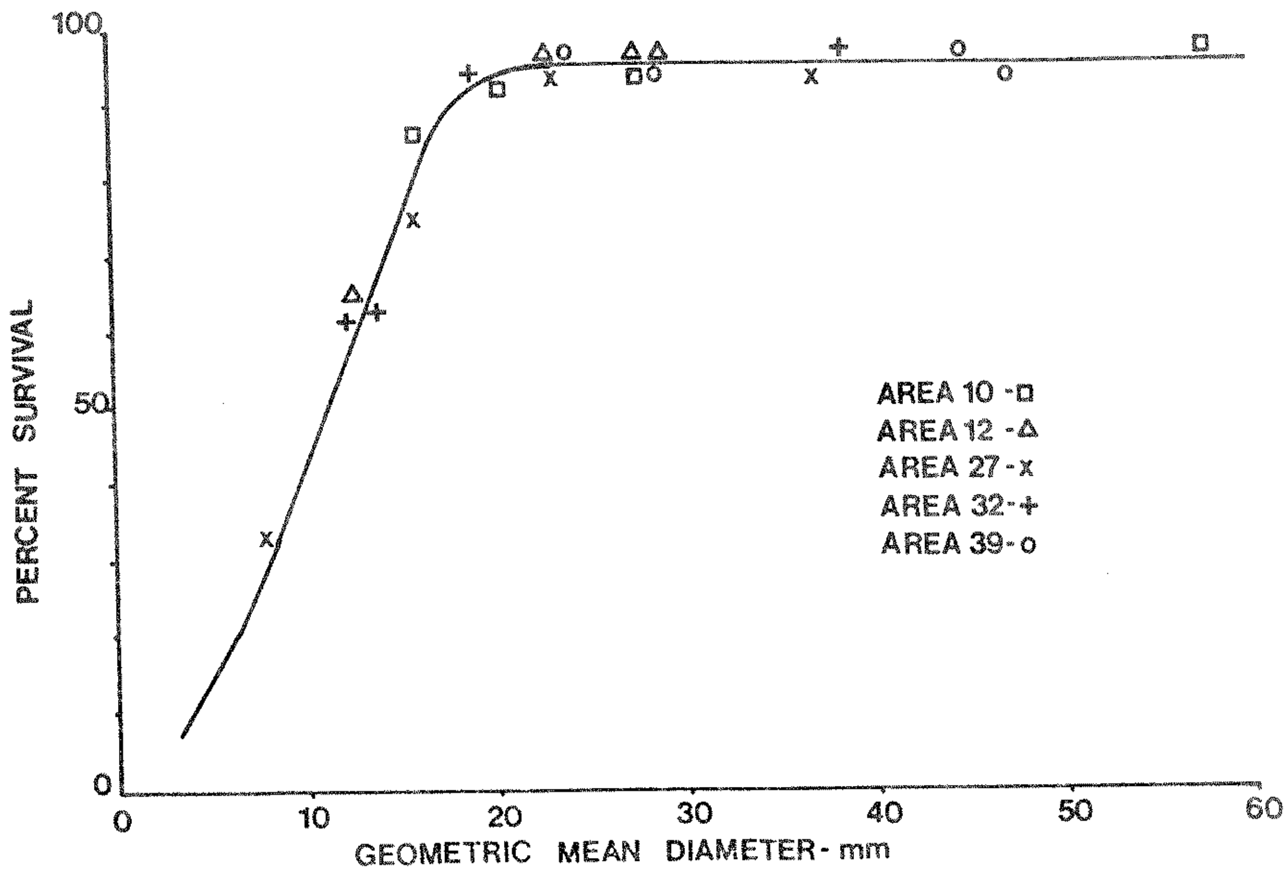

Figure 11. Predicted survival of kokanee eggs in areas of the Flathead River based on geometric mean of substrate particles. Survival curve was based on salmon and steelhead studies (Platts et al. 1979 and Shirazi and Seim 1981).

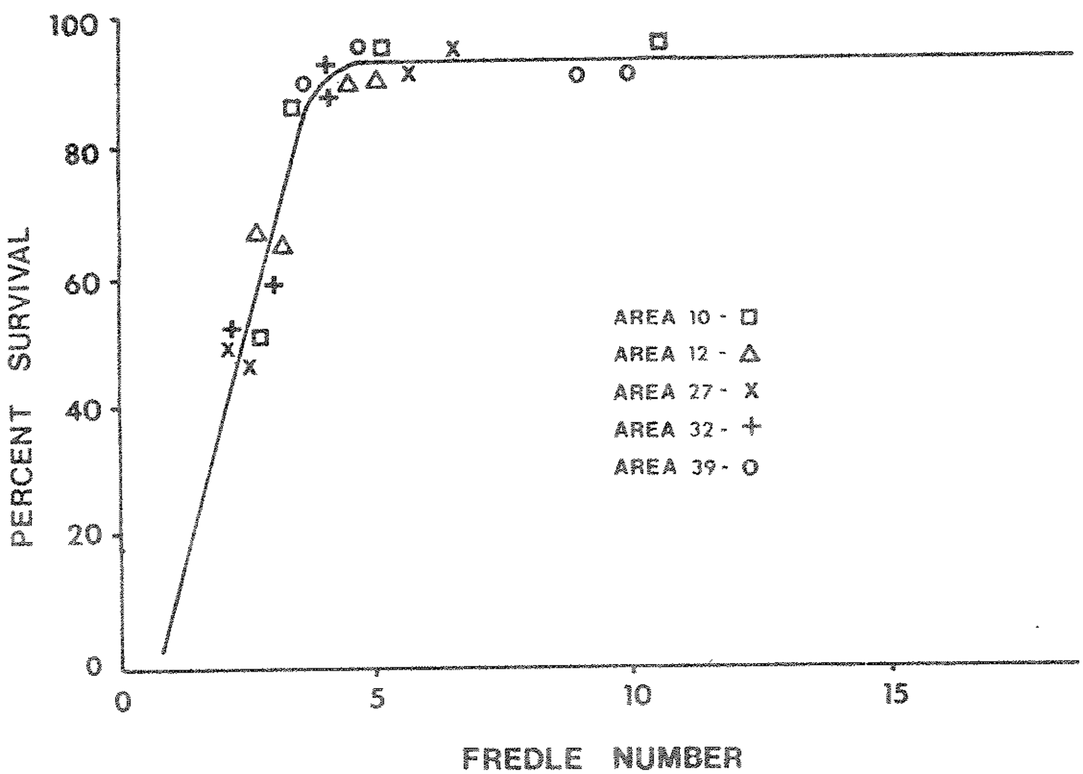

Figure 12. Predicted kokanee egg survival in spawning areas of the Flathead River based on fredle indices calculated from substrate samples. Surv'val curve was based on salmon and steelhead studies conducted in Idaho (Tappel 1981).

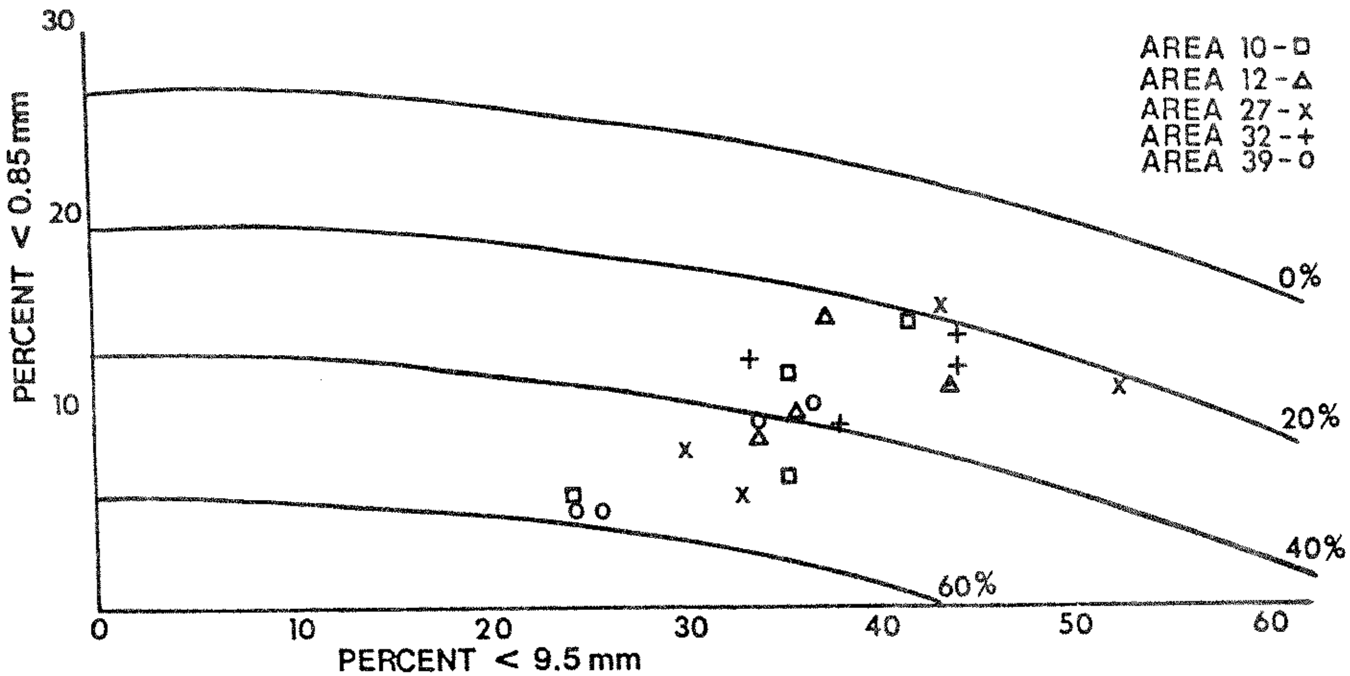

Figure 13. Predicted survival of kokanee eggs in spawning areas of the Flathead River based on substrate quality. Survival bands are based on kokanee salmon fry emergence studies conducted in Idaho (Idaho Coop. Fish. Unit unpublished data).

Table 5. Predicted percentage of survival potential based on measures of substrate quality in five nonspring spawning areas in the Flathead River. Values are mean and range from four samples from each area.

Measure of Substrate Quality	Spawning Area Number				
	10	12	27	32	39
%<.85 mm, %<9.5 mm (Tappel 1981)	74 (50-90)	64 (50-75)	61 (40-85)	70 (60-85)	81 (70-90)
%<.85 mm, %<9.5 mm (Irving 1982)	40 (22-56)	34 (25-44)	35 (19-52)	30 (22-40)	48 (37-58)
Geometric Mean (D_{50})	92 (85-95)	88 (65-92)	74 (32-95)	78 (62-95)	95 (95-95)
Fredle Number	80 (50-92)	78 (65-92)	70 (47-92)	74 (52-91)	91 (90-92)

The three substrate analysis methods gave generally similar results. Tappel (1981) suggested the method utilizing the percent of material less than 0.85 and 9.5 mm better typified the distribution of critical materials in the substrate. Shepard and Graham (1982) used similar methods to analyze substrate in bull trout redds in the Flathead drainage.

The percent of fine materials less than 6.35 mm in the mainstem areas averaged 25 percent. Shirazi (unpublished data) reported these levels of fines should result in salmonid egg survival levels near 80 percent.

Survival of eyed eggs and sac fry alevins in samples taken in McDonald Creek in mid-February averaged 72 percent. Survival of eggs and alevins averaged 74, 66, and 52 percent respectively in good, medium and poor gravels. Graham et al. (1980) reported survival rates of 70 to 85 percent for eyed kokanee eggs in McDonald Creek in January and February, 1979. Stober et al. (1978) found 60-70 percent survival of sockeye salmon eggs in spawning gravels in the Cedar River, Washington by late winter.

Experimental Egg Plants

Survival of eggs planted in fiberglass screen bags in mid-November in three continuously watered areas of the mainstem Flathead River (Kokanee Bend, Eleanor Island, and below Kalispell), was generally high through the green egg stage (Appendix F). An average of 98 percent of the eggs had survived to the eyed egg stage in three of the four areas when they were sampled on 14 January. Egg survival through the late eyed stage in March averaged 98 percent in these three areas. Survival through the early sac fry alevin stage averaged 70 percent. It appeared that these three gravel areas were highly suitable for kokanee spawning and egg incubation.

Egg survival through the various stages was much lower in a continuously wetted gravel area in the mainstem Flathead River near the county bridge in Columbia Falls (Appendix F). Survival was 92 percent through the green egg state (December), but fell to 20 percent by the eyed egg stage (January) and finally to 0.4 percent by the late eyed stage in early March. This heavy mortality may have been due to low oxygen levels in the gravels and indicated this gravel area may not be suitable for successful kokanee spawning. Further study of gravel conditions will be conducted in this area during the 1982-83 season.

Eggs were planted in fiberglass screen bags in areas 27, 31 and 38 to test the effects of dewatering on egg survival in the mainstem Flathead River. As a control, eggs were planted 0.2 and 0.4 feet below the level of minimum incubation flow which kept them continuously wetted. Survival was high in the control bags at the two nonspring areas, averaging over 90 percent to the eyed stage and 75 percent to the sac fry stage (Figure 14). Egg survival was much lower in eggs planted at the upper water level of the incubation flow, averaging 25 percent through the eyed egg stage, and 0 percent to the sac fry stage. These egg bags were assumed to be partially wetted, although not spring influenced. Survival of eggs at 0.2 feet above incubation flow level (dewatered) was near 0 percent by the first egg bag harvest in mid-December at the two nonspring areas. Significant mortality occurred early in December when discharge was reduced to minimum incubation flows for a forty hour period when air temperatures reached a minimum of -12° centigrade.

Survival was relatively high and similar at all water levels at area 38, a spring influenced site (Figure 14). Graham et al. (1980) and Domrose (1968, 1975) documented good survival of kokanee eggs in dewatered areas influenced by springs. Sampling of natural redds at elevations above and below incubation flow level indicated similar survival patterns to those observed for planted eggs in all three areas.

Egg and Alevin Development

Kokanee eggs planted in bags in the mainstem Flathead River required more temperature units to reach each developmental stage in the spring area than in the nonspring area (Table 6). Developmental requirements of kokanee eggs in Beaver Creek and Flathead Lake Hatchery were similar to that of the mainstem spring area. Temperature requirements for development of sockeye salmon eggs and alevins in various areas was similar to that found in Flathead kokanee studies. Stober et al. (1978), Hunter (1973), Graham et al. (1980), and Alderdice and Velsen (1978) reported more temperature units were required for development of kokanee or sockeye salmon eggs at higher incubation temperatures.

Incubating eggs and alevins remained in the gravel for a longer period of time in mainstem, nonspring spawning areas because of lower incubation

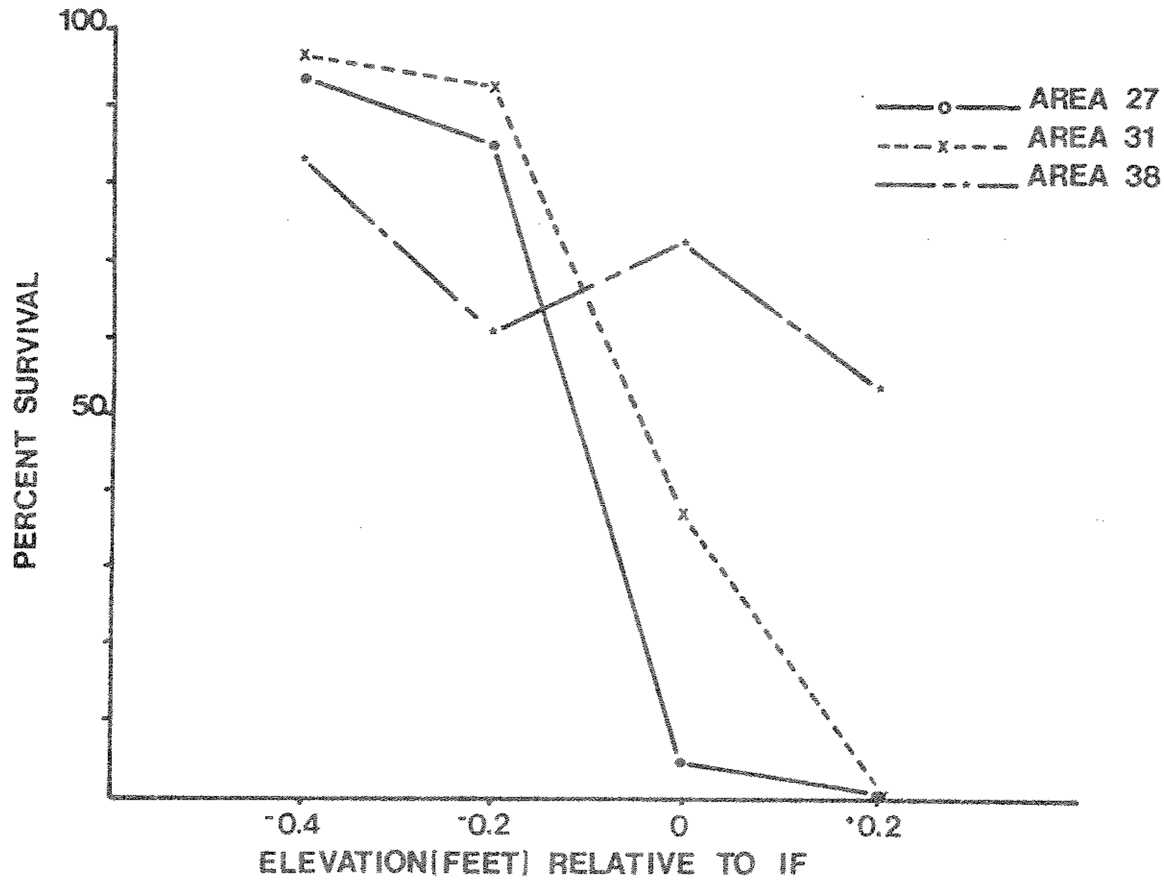

Figure 14. Percent survival of kokanee eggs planted in fiberglass screen bags at various water elevations in two nonspring areas (Area 27 and Area 31) and a spring influenced area (Area 38) in the Flathead River.

Table 6. Calculated number of temperature units (°C) and days required for developmental stages of kokanee salmon eggs.

Area	Stage of development					
	Eye up		Hatching		Yolk sac absorption	
	Units	Days	Units	Days	Units	Days
Flathead River						
Non-spring	280	66	480	138	700	195
Spring	300	45	540	104	850	154
Beaver Creek (Graham et al. 1980)	260	46	525	101	700	145
Flathead Lake[1/]	331	82	526	143		
Flathead Lake [2/] Hatchery	300	41	580	110	800	145
Sand Point, Idaho Hatchery (Jeppson 1960)	---	---	555	100	805	136
Odell Lake (Lewis 1972)	---	---	643	204	800	251
Average (sockeye salmon) (Foerster 1968)	286	55	590	107	760	138
Cedar River Washington(sockeye salmon) (Stober et al. 1977)	263	38	620	90	950	140

1/ Decker-Hess and Graham (1982)
2/ Montana Fish, Wildlife and Parks (unpublished data)

temperatures resulting in slower development. The longer incubation time and duration of the sac fry stage resulted in a later emergence period which increased their susceptibility to fluctuations in environmental conditions such as extremely low or high flows. Becker et al. (1981) found that sac fry and pre-emergent alevins were highly susceptible to dewatering mortality even when air temperatures are above freezing.

Egg and Alevin Densities and Production

Live kokanee and alevin densities averaged $563/m^2$ in McDonald Creek spawning gravels in mid-February, 1982 (Table 7). Average densities were $14/m^2$ in poor, $470/m^2$ in medium and $965/m^2$ in good gravels. A total of 61 percent of the stream bed was found to be suitable for spawning.

Extrapolating the mean egg and alevin density for the entire spawning area yielded a total production estimate of 46,000,000 live eggs and alevins. The calculated potential deposition (number of female spawners times average fecundity of 924 eggs/female) was 52,000,000 eggs if a 50:50 sex ratio was assumed. This would yield an 88 percent survival rate from egg deposition to late eyed egg and sac fry alevin stage. Netting of spawners near the Apgar Bridge in early October indicated there may have been more females than males during 1981, but the sample size was (93 fish, 67 percent females). If a 60:40 female:male ratio was assumed, the estimate of potential deposition was 62,000,000 eggs and the survival from deposition to late eyed or sac fry stage was 74 percent.

McNeil (1964) reported lower survival rates from egg deposition to late stages of development using these methods of calculation. Snorkel counts of spawners in McDonald Creek in mid-October were primarily for yearly trend purposes. It was likely that fish had already spawned, died, and floated out of the stream, or were consumed by eagles at the time of count. Also, kokanee which were holding in the Middle Fork of the Flathead River probably moved into McDonald Creek after the count was made. Both of these factors would result in an underestimate of the total number of spawners that used McDonald Creek and the potential egg deposition. Neilson and Geen (1981) described the importance of residence time of spawners in calculating their total numbers.

Egg and alevin densities were smaller in McDonald Creek near Apgar in 1981-82 than in the two previous years of the study (Table 8). This occurred despite the larger estimated number of spawners in 1981, indicating substantial mortality may have occurred due to superimposition. The percent survival of eggs and alevins in the samples was also lowest in 1981-82. The largest egg and alevin densities were recorded in 1980-81 when the smallest estimated number of spawners entered McDonald Creek. McNeil (1964) reported that egg survival and numbers of spawners may be inversely related. The inverse relationship of egg densities and numbers of spawners in McDonald Creek may be related to less crowding of adult spawners resulting in egg deposition occurring mainly in prime areas and less superimposition of redds.

Table 7. Analysis of samples taken from random points in kokanee spawning areas of the mainstem Flathead River and McDonald Creek during the winter of 1982 with a 0.11 m^2 hydraulic egg sampler. See Appendix C for descriptions and locations of mainstem spawning areas.

Spawning area description	Date	Spawning gravel area (m^2)	Number of samples	Percent survival	Percent sac fry	Mean number of live eggs and sac fry per m^2	Calculated total production of area (nearest 1000)
McDonald Creek							
All gravel combined	2/3/82-2/11/82	82,476	36	72	21	563	46,434,000
good gravel		46,860	16	74	----	965	45,219,000
medium gravel		22,767	10	66	----	470	10,665,000
poor gravel		12,849	10	52	----	14	262,000
Flathead River							
Spawning Area 27	3/3/82	1,333	12	88	4	202	229,000
Spawning Area 10	3/5/82	809	8	16	93	18	15,000
Spawning Area 39	3/2/82	2,023	10	74	55	765	1,550,000
Spawning Area 32	2/19/82 & 3/1/82	1,578	10	70	1	414	653,000

Table 8. Comparison of live kokanee egg and alevin densities in McDonald Creek near Apgar during the 1979-80, 1980-81 and 1981-82 incubation years.

Sampling dates	Number of samples	Mean number of live eggs and alevins per m^2	Percent survival
2/8 and 2/9/82	12	896	72
12/12/80, 1/13/81	11	1,313	91
12/21/79, 1/14, 2/1 and 2/22/80	21	1,195	86

Live egg and alevin densities in four major spawning areas in the main-stem Flathead River ranged from 18 to 765/m^2 (Table 7). Total calculated production of the four areas was 2,447,000. A total of 2,146 kokanee redds were counted in the same area during the late November redd count. If one female per redd and 924 eggs per female are assumed, the potential calculated deposition was 1,983,000 eggs. The measured surviving deposition was 19 percent higher than the total potential deposition calculated from redd counts. This could have been due to more redd construction after the redd count, and redd superimposition.

Artificial Channel Experiments

Green Egg Experiments

Survival of green eggs in channel 1 (12 percent fine material) was 0 percent four hours after dewatering during the 29, 30 December experiment (Figure 15). Survival averaged 10 percent ten hours after dewatering in channels 2 (21 percent fines), 3 (27 percent fines) and 4 (40 percent fines). Green eggs in channels 2 and 3 experienced the best survival indicating moderate amounts of fine material in spawning gravels allows increased survival of kokanee eggs subject to dewatering during periods of cold air temperatures. Reiser (1980) reported sediments operated to retain moisture in spawning gravels.

Mortality resulted from freezing in channels 1 and 2, as gravel temperatures were near or below 0° centigrade after 4 hours of dewatering. Gravel temperatures 10 cm deep in channel 3 barely reached freezing during the experiment, indicating freezing, oxygen stress, and desiccation have all contributed to mortality. In channel 4, gravel temperatures never reached freezing, indicating mortality was due to oxygen stress. Alderdice and Velson (1978) reported that pre-eyed salmon eggs were extremely sensitive to oxygen stress. Fine sediments have increased mortality related to oxygen stress in spawning gravels (Wickett 1954, Peters 1962).

Air temperatures during the 5, 6 January dewatering experiment were much colder (Figure 16). Survival of green eggs was 0 percent after 4 hours of dewatering in channels 1 and 2 and after 6 hours in channel 3. Survival was 0 percent after 8 hours in channel 4. Gravel temperatures reached 0° centigrade in channels 1,2, and 3 after 4 hours of dewatering but did not reach freezing until 8 hours in channel 4. This experiment clearly showed the rapid mortality of green eggs when dewatered during periods of extremely cold air temperatures.

Eyed Egg Experiments

Survival of eyed eggs was higher than green eggs during dewatering experiments. During the 19, 20 January experiment, survival averaged 50 percent after 8 hours of dewatering although minimum air temperatures reached -18° centigrade (Figure 17). Survival of eyed eggs was highest in channels 3 and 4, indicating higher sediment levels may have reduced

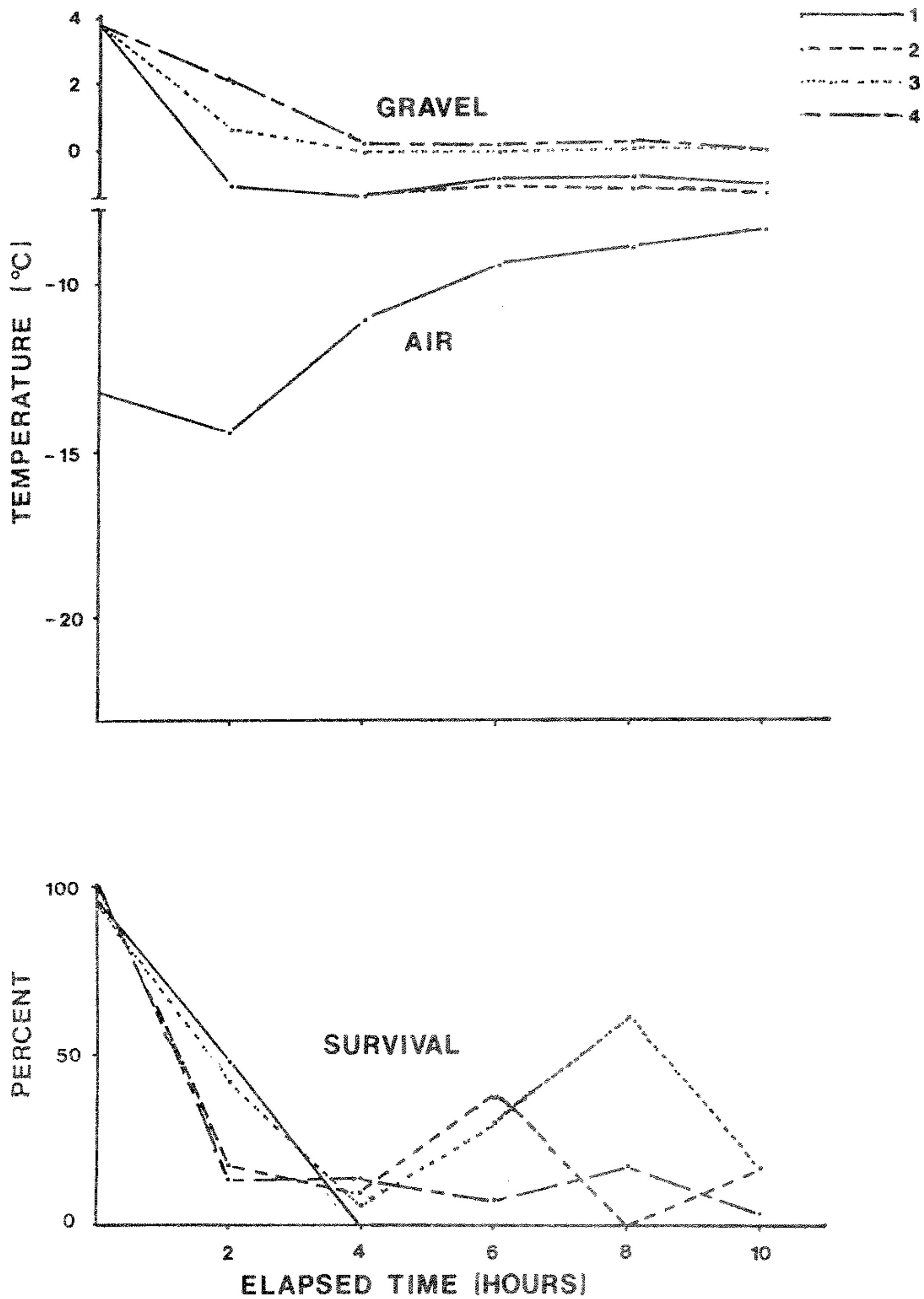

Figure 15. Gravel, air temperatures and percent kokanee green egg survival in artificial channels 1, 2, 3 and 4 after dewatering on 29 and 30 December, 1981.

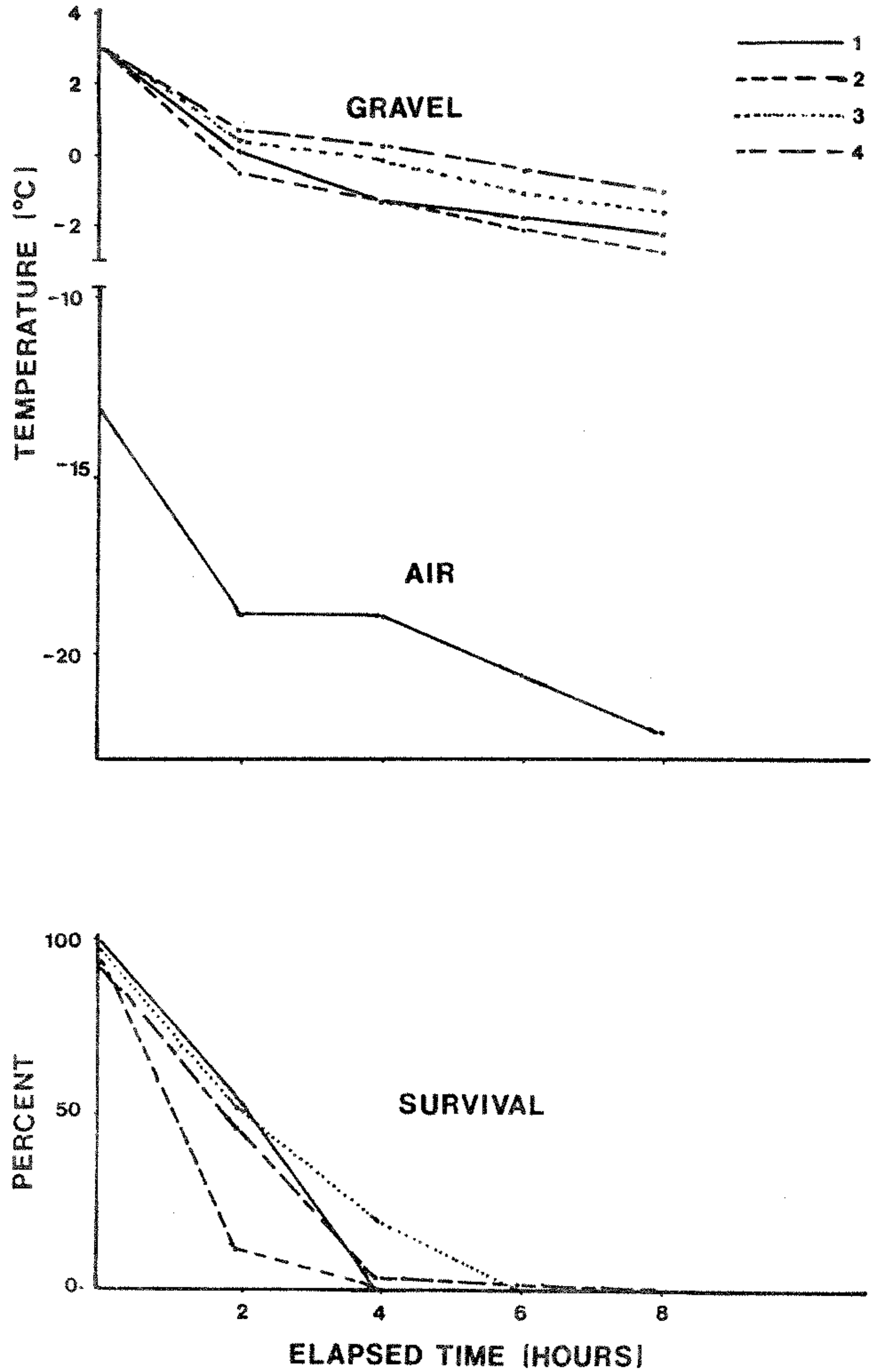

Figure 16. Gravel, air temperatures and percent kokanee green egg survival in artificial channels 1, 2, 3 and 4 after dewatering on 5 and 6 January, 1982.

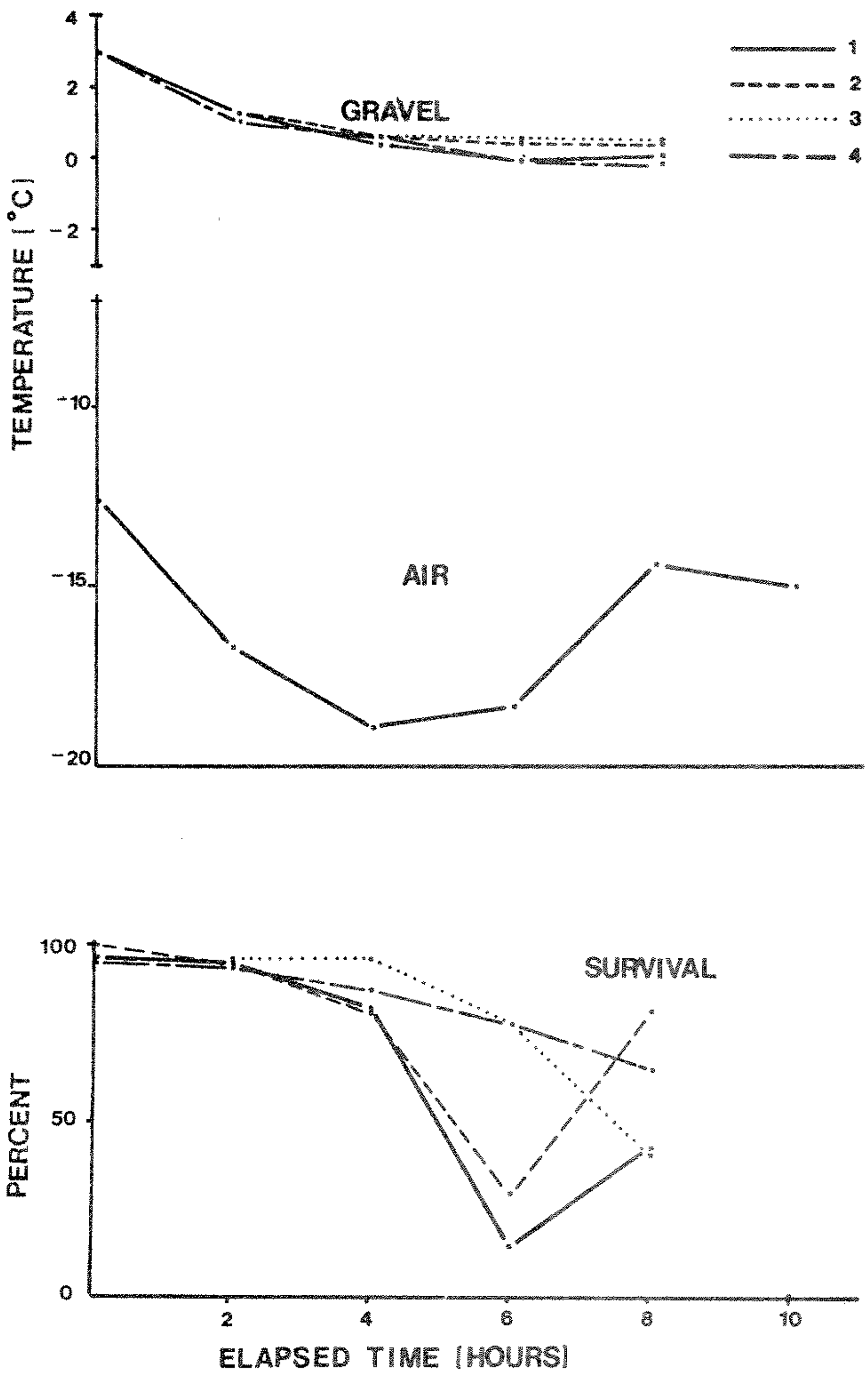

Figure 17. Gravel, air temperatures and percent kokanee eyed egg survival in artificial channels 1, 2, 3 and 4 after dewatering on 19 and 20 January, 1982.

freezing mortality.

Eyed egg survival was above 90 percent in all channels after 12 hours of dewatering during the 11, 12 March experiment (Figure 18). This experiment illustrated the resistance of eyed eggs to dewatering during periods of less severe winter air temperatures (-5° centigrade).

Experiments conducted by McMullin and Graham (1981) indicated eyed kokanee eggs could withstand a period of dewatering if winter air temperatures were not severely cold. However, the cumulative effects of repeated dewatering of eggs resulted in nearly complete mortality in a long term experiment. Reiser (1980) also reported eyed eggs were more tolerant than green eggs to dewatering. However, sac fry and pre-emergent alevins were highly sensitive to dewatering mortality. Hawke (1978) found that quinnat salmon eggs can tolerate dewatering into the eyed stage, but must be rewatered before hatching to survive.

A total of 246 (82 percent), 152 (52 percent) and 125 (42 percent) fry emerged from channels 2, 3 and 4 respectively (Figure 19), indicating a substantial increase in egg to fry emergence success in gravel mixtures containing less fine materials. Channel 1 was eliminated from the experiment due to an interruption of the water supply. Survival to emergence in the artificial channels (Figure 20) was similar to that predicted by survival studies of salmon and steelhead based on the percent of materials in the substrate less than 0.85 mm and 9.5 mm (Tappel 1981). Survival in channels 2, 3 and 4 were higher (Figure 21) than that predicted by survival studies of kokanee in Idaho (Irving 1982).

Fry emergence in channel 2 occurred earlier than in channels 3 and 4. McCuddin (1977), (Bjorn 1969), Phillips et al. (1975), and Tappel (1981) reported an inverse relationship between the amount of fine sediment in gravels and emergence success of salmon and steelhead fry. Hausle and Coble (1976) found greater proportions of sand in spawning gravel slowed emergence and reduced emergence success of brook trout fry. A moderate amount of fine material (15 to 25 percent) is probably best for survival of kokanee eggs in spawning gravels of the mainstem Flathead River.

The artificial channel experiments indicated moderate amounts of fine sediments in the gravel can reduce freezing mortality of kokanee eggs during periods of dewatering at severe winter air temperatures. Channel experiments also indicated gravel temperatures remained above freezing much longer at 10 cm depth than at 5 cm depth at all sediment levels (Figure 22). Low compaction of bed materials at spawning sites would allow kokanee to deposit eggs deeper into the substrate, reducing their susceptibility to mortality related to dewatering.

Large amounts of sediment increase mortality of eggs and alevins due to oxygen stress and reduce emergence success. Large amounts of fines act to reduce permeability in spawning gravels (McNeil and Ahnell 1964, Shirazi and Seim 1981, Platts et al. 1979).

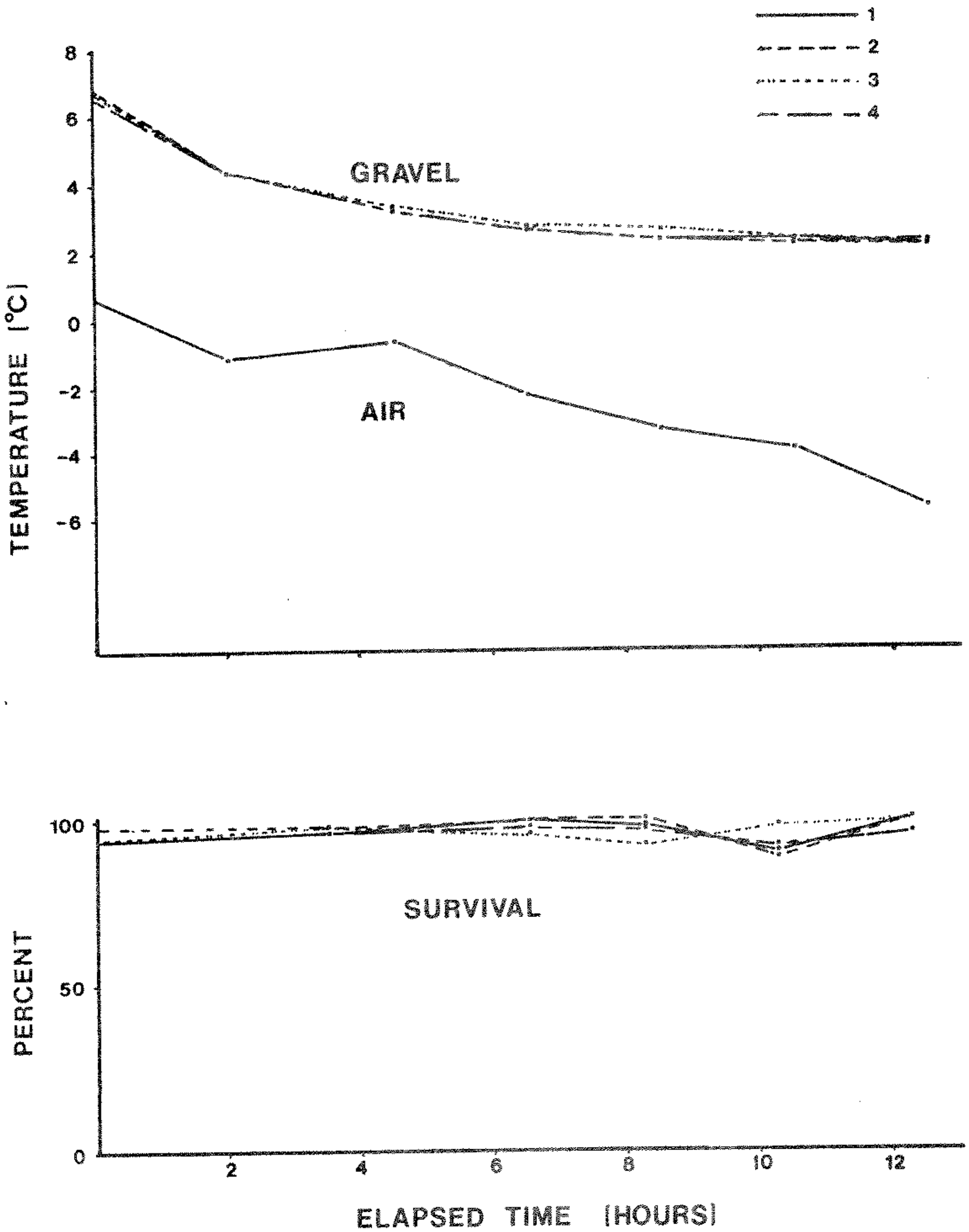

Figure 18. Gravel, air temperatures and percent kokanee eyed egg survival in artificial channels 1, 2, 3 and 4 after dewatering on 11 and 12 March, 1982.

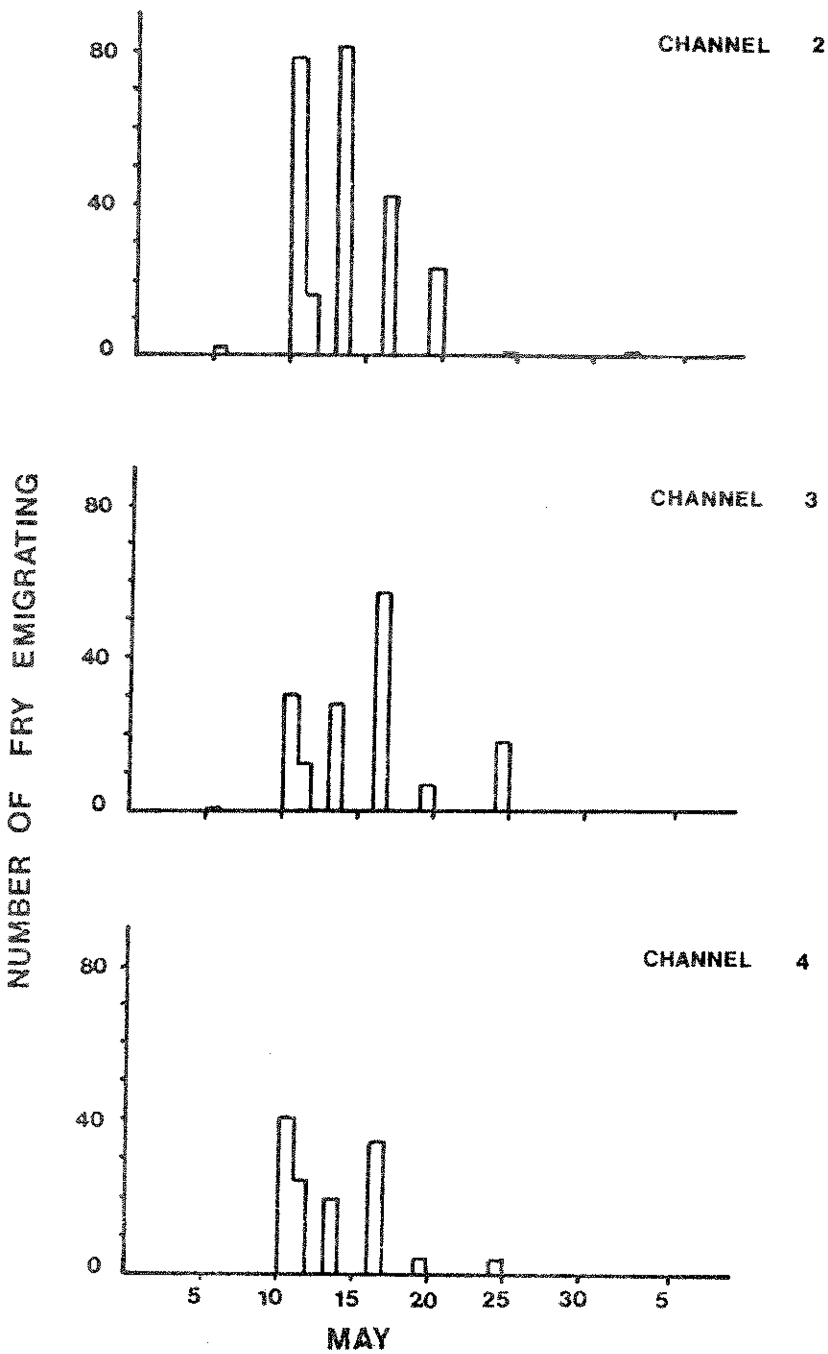

Figure 19. Number of kokanee fry emerging and emigrating from artificial channels 2, 3 and 4 during May, 1982.

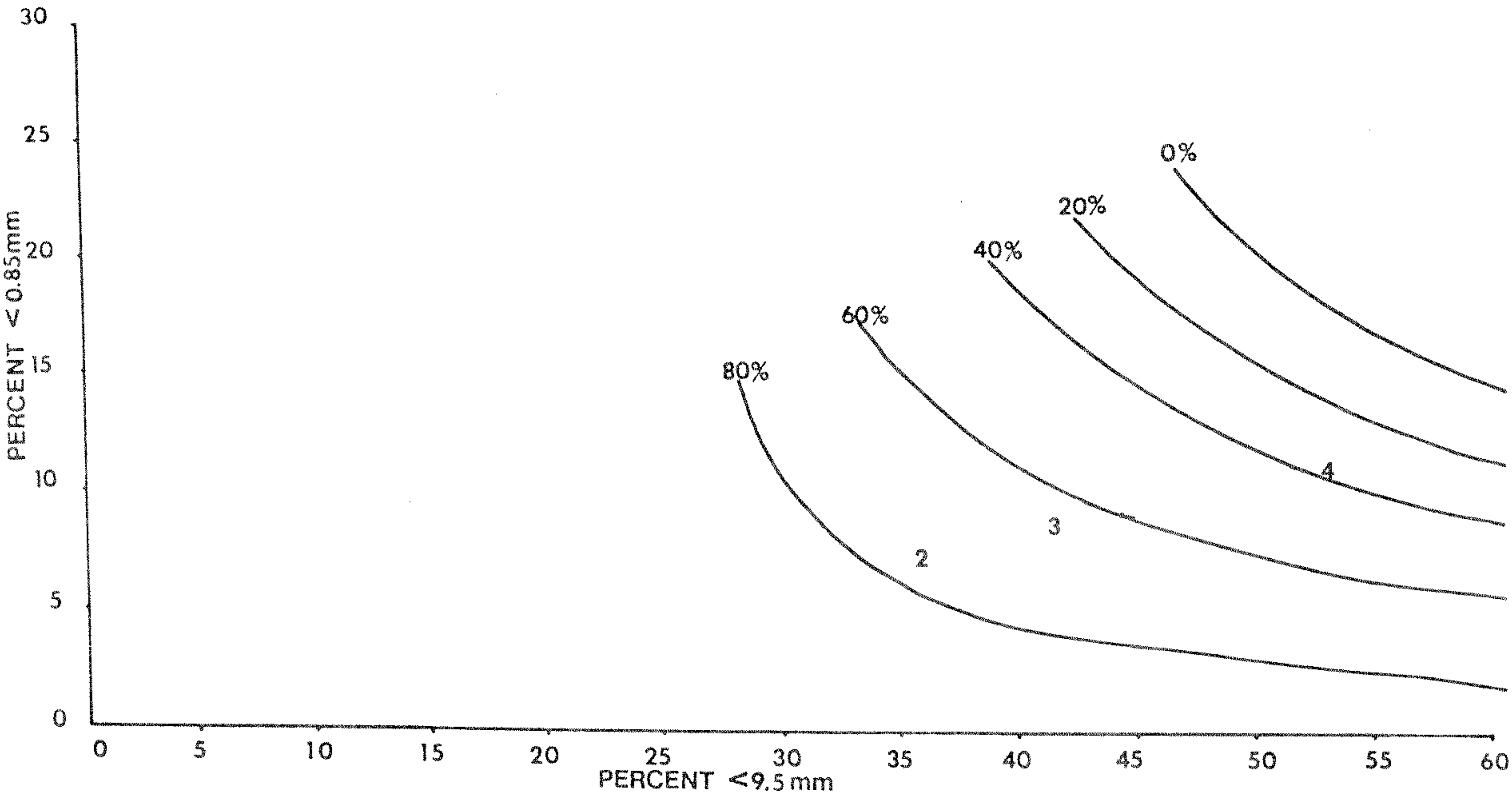

Figure 20. Predicted survival to emergence of kokanee eggs in artificial channels 2, 3 and 4 based on substrate quality analysis. Survival bands were based on coho salmon and steelhead studies (Tappel 1981).

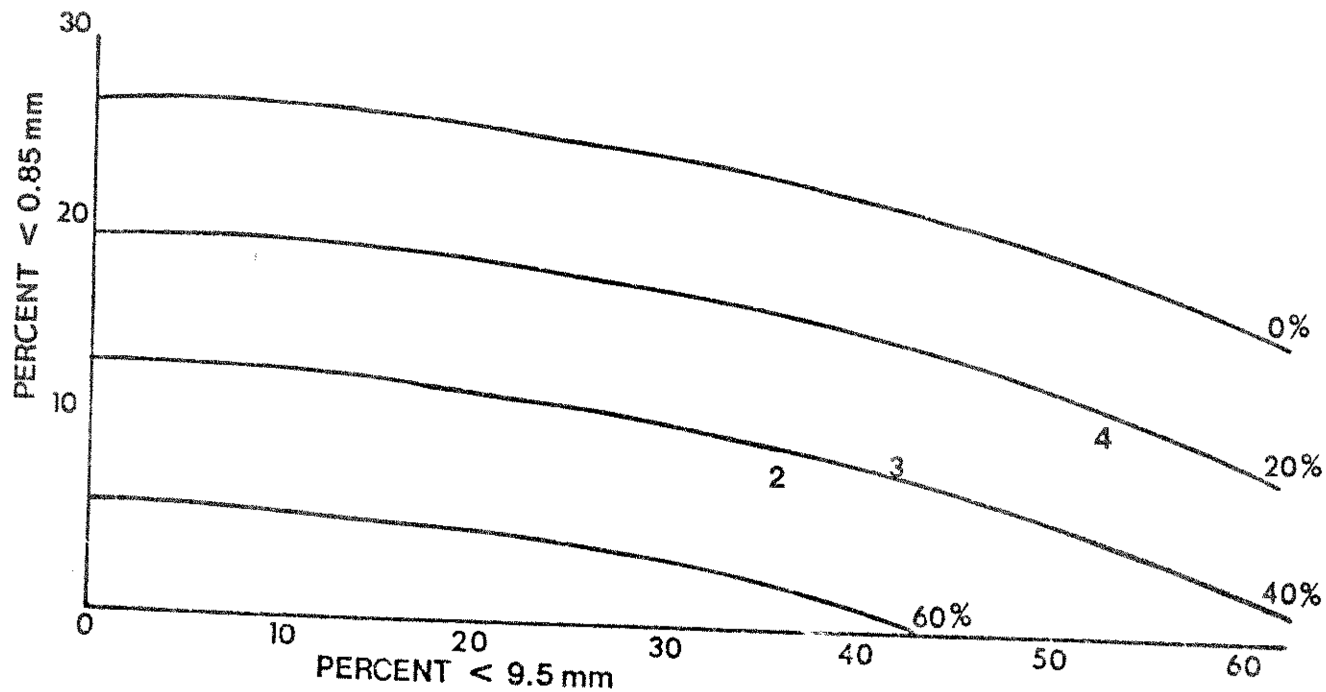

Figure 21. Predicted survival of kokanee eggs in artificial channels 2, 3 and 4 based on substrate quality. Survival bands are from kokanee salmon fry emergence studies in Idaho (Idaho Coop. Fish. Unit. unpublished data).

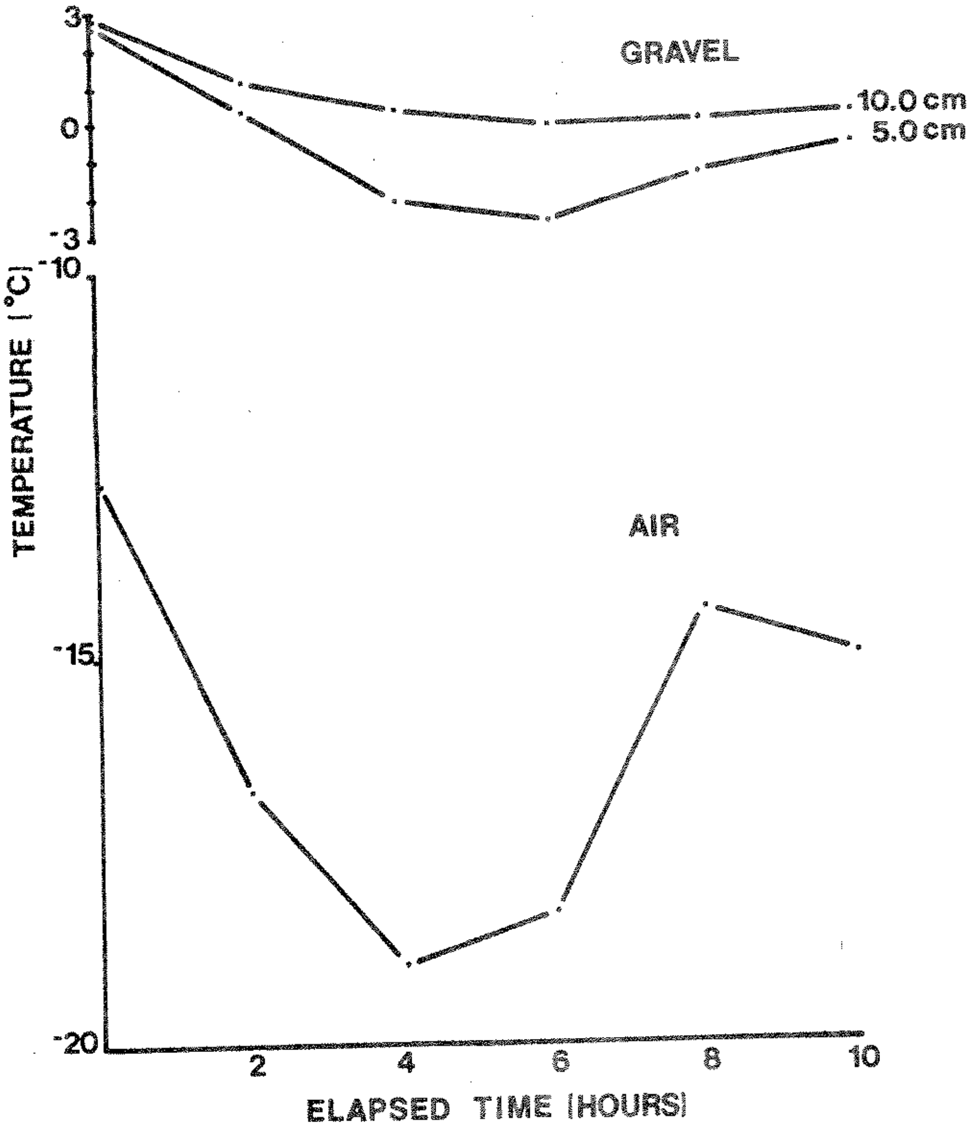

Figure 22. Air temperatures and gravel temperatures at 5 and 10 cm after dewatering in artificial channels on 19 and 20 January, 1982.

STREAM FLOW - KOKANEE LENGTH RELATIONSHIPS

Graham et al. (1980) and McMullin and Graham (1981) developed several models using three year weighted moving average flow conditions to explain the variations in kokanee year class strength from the 1966 through 1980 spawning years. The measure of year class strength was kokanee spawner length (male and female combined), which was assumed to be inversely related to population density.

Strong relationships were indicated between kokanee spawner lengths from 1966 through 1981 and flow conditions in years which produced them (Table 9, Figure 23). The correlation between kokanee lengths and spawning and incubation period gauge height difference was highly significant (r^2 = -.840 p<.001). There was also a very strong correlation (r^2 = .859, p<.001) between spawner lengths and the average number of hours kokanee eggs were dewatered during the incubation season.

The relationships indicated kokanee year class strength, was highly dependent upon incubation success as affected by discharges from Hungry Horse Reservoir. The predicted lengths of 1981 spawners from the gauge height relationship (354 mm) and the hours dewatered relationship (352 mm) were somewhat smaller than the actual length (371 mm) of 1981 kokanee spawners. The larger size and numbers of spawners than predicted may be due to variations in survival or growth due to fluctuating environmental conditions. The early closing of the 1981 fishing season may also have increased the numbers of kokanee spawners in the Flathead River. Small numbers of spawners in the 1981 lakeshore spawning population (Decker-Hess and Graham 1982) may have affected spawner length due to density dependent interactions.

Mean minimum air temperatures (on days when dewatering occurred) was added to the models because of its effects on incubation mortality (McMullin and Graham, 1981). The addition of air temperature slightly improved the fit of the hours dewatered model (Table 10), but had little effect on the gauge height model (Table 11). McMullin and Graham (1981) suggested winter air temperatures were always cold enough to cause significant incubation mortality during periods of dewatering.

Unexplained variation in kokanee year class strength as indicated by spawner length may be related to other environmental factors. These factors may affect incubation success (Wickett 1962), growth of kokanee in the lake (Goodlad et al. 1974), or differential recruitment from other spawning areas to the lake population. There does not appear to be a strong consistent relationship between the proportion of older fish in the run (IV+) and spawner length (Figure 24). Correlations between spawner length and the percent of age IV+ fish in the run from 1970 to 1981 were not significant. Age class variation in the population does affect spawner length.

Flow conditions in the Flathead River for the years that will produce

Table 9. Flathead River flow and kokanee length variables used in assessing stream flow-year class strength relationships.

Water year	Water years used in 3-year mean	Incubation-spawning gauge height difference (ft)	Weighted 3-year moving average (ft)	Total hours dewatered	Weighted 3-year moving average	Hours/day dewatered	Weighted 3-year moving average	Spawn year	Kokanee tot. length (mm)
1954		-0.68		1,504		12.43		1957	294
1955	1954-56	1.21	0.56	277	689	2.29	5.69	1958	---
1956	1955-57	0.94	1.03	423	535	3.47	4.47	1959	312
1957	1956-58	0.96	-0.30	941	1,251	7.97	10.41	1960	348
1958	1957-59	-3.22	-0.96	2,491	1,488	20.59	12.36	1961	330
1959	1958-60	0.15	-1.22	697	1,512	5.75	12.62	1962	330
1960	1959-61	-1.06	-0.42	1,621	858	13.78	7.24	1963	330
1961	1960-62	-0.15	0.13	0	502	0	4.27	1964	317
1962	1961-63	1.68	1.09	53	21	0.44	0.18	1965	306
1963	1962-64	1.53	2.06	0	16	0	0.13	1966	287
1964	1963-65	3.16	2.44	0	12	0	0.10	1967	272
1965	1964-66	2.39	2.20	40	297	0.33	2.45	1968	286
1966	1965-67	0.99	0.65	936	906	7.74	7.49	1969	313
1967	1966-68	-1.54	-0.36	1,732	1,423	14.31	11.73	1970	323
1968	1967-69	-0.14	-0.29	1,498	1,338	12.28	11.01	1971	334
1969	1968-70	0.76	-0.14	730	1,415	6.03	11.66	1972	338
1970	1969-71	-1.35	0.22	2,244	1,118	18.55	9.24	1973	330
1971	1970-72	1.78	0.23	4	1,006	0.03	8.31	1974	320
1972	1971-73	-0.27	0.41	1,104	899	9.12	7.43	1975	324
1973	1972-74	-0.04	0.06	1,522	1,208	12.58	9.99	1976	316
1974	1973-75	0.52	-0.43	894	1,484	7.39	12.26	1977	327
1975	1974-76	-2.07	-0.97	2,231	1,576	18.44	13.00	1978	341
1976	1975-77	-0.97	-0.87	1,384	1,675	11.34	13.80	1979	353
1977	1976-78	0.46	-0.48	1,507	1,603	12.45	13.22	1980	367
1978	1977-79	-1.22	-0.94	1,950	1,757	16.12	14.52	1981	371
1979	1978-80	-1.97	-2.31	1,749	2,099	14.45	17.29	1982	
1980	1979-81	-3.86	-2.06	2,715	1,658	22.25	13.63	1983	
1981	1980-82	0.25	-0.91	159	884	1.31	7.24	1984	
1982	1981-83	0.49	-	18	-	0.15	-	1985	

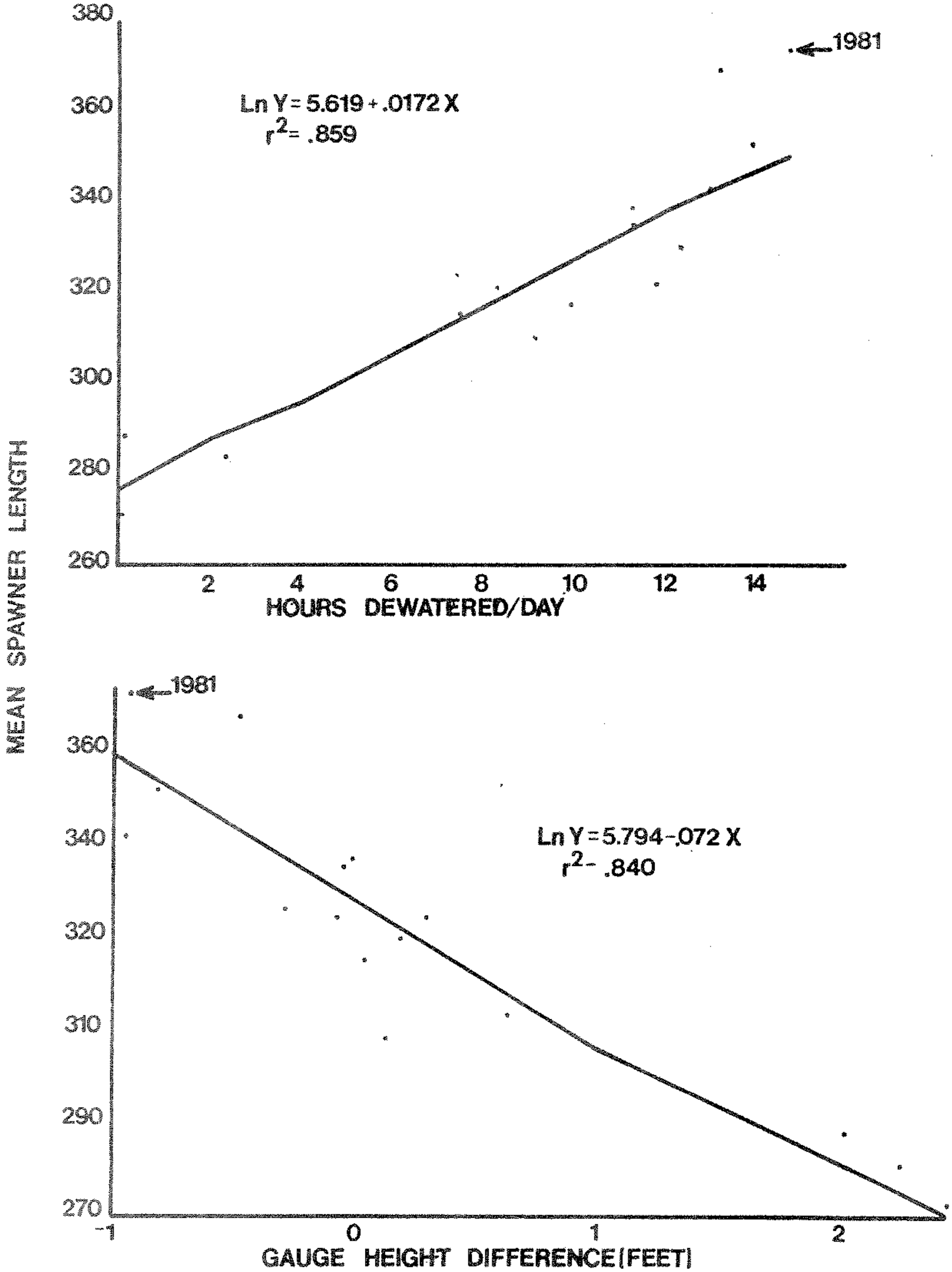

Figure 23. Relationships between kokanee spawner length and flow conditions in the years that produced them from 1966 to 1981. A three year weighted moving average was used to calculate the gauge height difference and number of hours/day kokanee eggs were dewatered.

Table 10. Mean hours per day kokanee redds were dewatered (three year moving average), mean minimum temperature on days when dewatering occurred (three year moving average), predicted kokanee lengths, actual lengths and residual errors for the model $\ln Y = 5.585 + 0.0183X_1 - 0.00313X_2$. Y = kokanee length, X_1 = hours per day dewatered, X_2 = temperature, $r^2 = 0.880$, $n = 16$.

Spawn year	Hrs/day dewatered	Air temperature	Actual kokanee length	Predicted kokanee length	Residual error
1966	.13	-23.02	287	287	0
1967	.10	- 4.25	272	270	2
1968	2.45	- 6.69	286	285	1
1969	7.49	- 5.54	313	311	2
1970	11.73	- 5.26	323	336	-13
1971	11.01	- 5.55	334	331	3
1972	11.66	- 7.85	338	338	0
1973	9.23	- 9.15	308	324	-16
1974	8.31	- 8.93	320	319	1
1975	7.44	- 6.18	324	311	13
1976	9.99	- 5.46	316	325	- 9
1977	12.26	- 6.71	327	340	-13
1978	13.00	- 7.83	341	346	- 5
1979	13.80	- 7.42	353	351	2
1980	13.22	- 6.69	367	346	21
1981	14.52	- 9.08	371	357	14
1982	17.29	-10.26	---	377	---

Table 11. Incubation-spawning gauge height differences (three year moving average), mean minimum temperature on days when dewatering occurred (three year moving average), predicted kokanee lengths, actual lengths and residual errors for the model $\ln Y = 5.783 - 0.0735X_1 - 0.00136X_2$. Y = kokanee length, X_1 = gauge height difference, X_2 = temperature, $r^2 = 0.844$, $n = 16$.

Spawn year	Gauge height difference	Mean minimum air temperature(C°)	Actual kokanee length	Predicted kokanee length	Residual error
1966	2.06	-23.02	287	288	- 1
1967	2.44	- 4.25	272	273	- 1
1968	2.20	- 6.69	286	279	7
1969	0.65	- 5.54	313	312	1
1970	-0.36	- 5.26	323	336	-13
1971	-0.29	- 5.55	334	334	0
1972	-0.14	- 7.85	338	332	6
1973	0.22	- 9.15	308	323	-15
1974	0.23	- 8.93	320	323	- 3
1975	0.41	- 6.18	324	318	6
1976	0.06	- 5.46	316	326	-10
1977	-0.43	- 6.71	327	338	-11
1978	-0.97	- 7.83	341	352	-11
1979	-0.88	- 7.42	353	350	3
1980	-0.48	- 6.64	367	340	27
1981	-0.94	- 9.08	371	353	18
1982	-2.31	-10.26	---	390	---

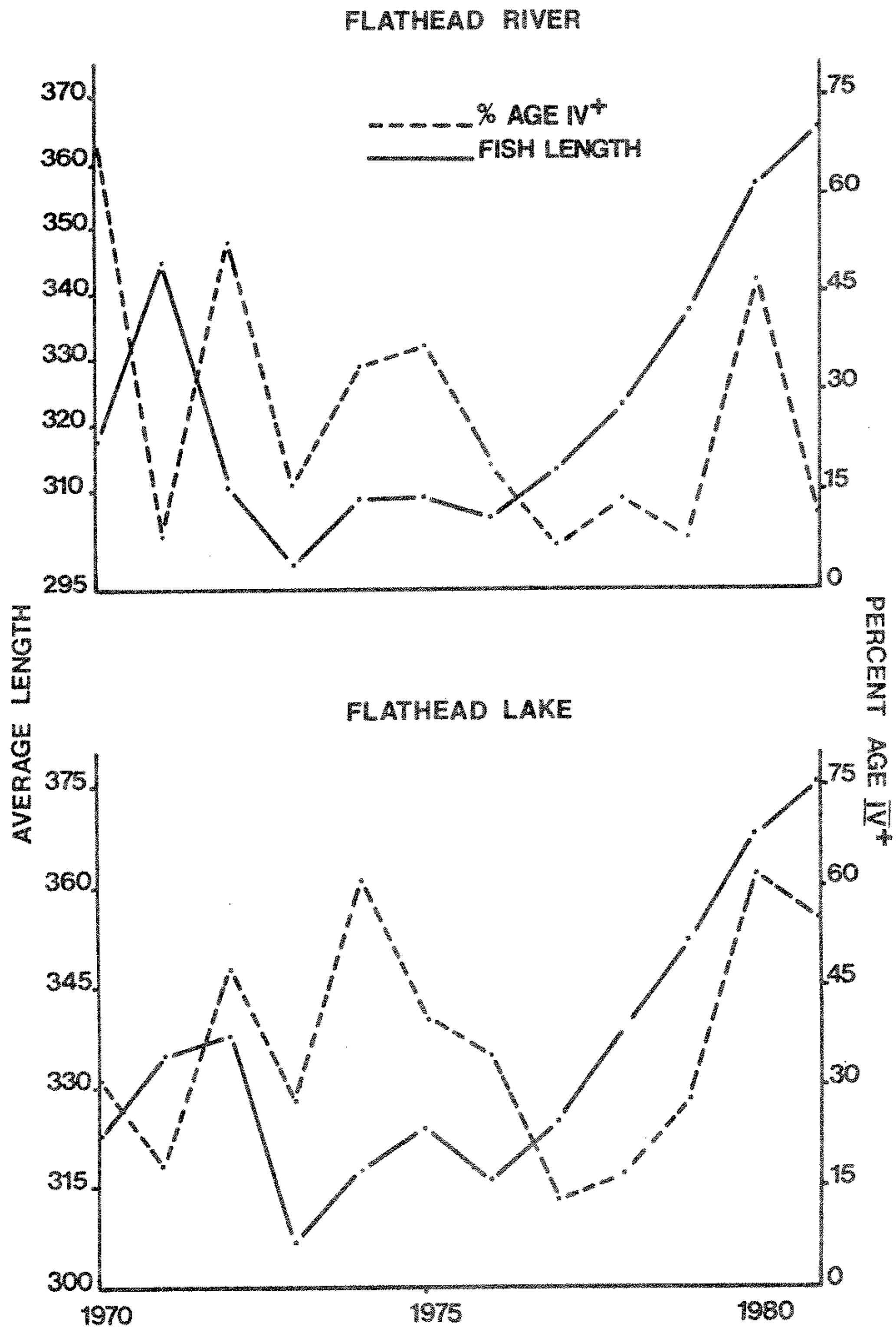

Figure 24. The average length of kokanee spawners and percent of older fish (Age IV+) in the Flathead River and Lake populations from 1970 to 1981. Average lengths are male and female combined.

the 1982 kokanee spawners were very poor. Predicted lengths for the 1982 fish by the four models range from 371 to 390 mm and average 381 mm.

Quadrennial or cyclic dominance in the four year cycle of kokanee and sockeye populations may also be a factor in year class strength variation (Killick and Clemens 1963). Correlation of kokanee lengths and number of hours dewatered/day within the four year cycles indicated that effects of quadrennial dominance may be occurring in the Flathead system kokanee population (Figure 25). The 1966-78 cycle appears less affected by dewatering mortality than other cycles. The 1969-81 cycle appears to be composed of larger fish than the other cycles. A larger data base is needed before any conclusions can be made about cyclic dominance in the Flathead system. Merrel (1960) and McNeil (1968) suggested population cycling was a controlling factor in year class strength fluctuations in pink salmon. They reported that fish in odd year runs spawned earlier than fish in even year runs and their progeny experienced better incubation and emergence success. Ossiander (1968) reported differences in population cycles of sockeye salmon in Alaska. Ward and Larkin (1964) presented conclusive evidence of year class strength variations resulting from quadrennial dominance in sockeye populations of the Adams River, British Columbia.

FRY EMERGENCE

Abundance and Timing

Emergence and emigration of kokanee fry in McDonald Creek during 1982 extended from early March to late June (Figure 26). Peak emigration of fry occurred in late May and early June, with a smaller peak occurring in late April. The time period of emigration was similar in 1978 when peak emigration occurred in late May and early June (Hanzel and Rumsey, Montana Department of Fish, Wildlife, and Parks unpublished data). Peak emigration occurred approximately one month earlier in 1977 and 1981 (McMullin and Graham 1981, Hanzel and Rumsey unpublished data). Nelson (1966) and Stover and Hamalainen (1980) reported that sockeye fry emigration occurred in a series of peaks.

Peaks of fry emigration coincided with increasing flow and water temperature in McDonald Creek during 1982. There was a significant correlation between fry numbers and flow ($r=.64$ $p<.01$) and fry numbers and water temperature ($r=.75<p.01$). Stober and Hamalainen (1980) and Brannon (1972) reported that water temperature and flow influenced fry emigration timing.

The estimated total numbers of fry emigrating from McDonald Creek were approximately 12,000,000 in 1982 and 15,000,000 in 1978. The total number of fry emigrating in 1982 were 26 percent of the total estimated egg deposition in McDonald Creek gravels and 22 percent of the total potential egg deposition based on spawner counts and fecundity estimates. These figures represent a relatively high egg to fry survival rate when compared to other areas (Table 12). Jeppson (1960) reported a 7 percent survival rate from potential kokanee egg deposition to emigrating fry in

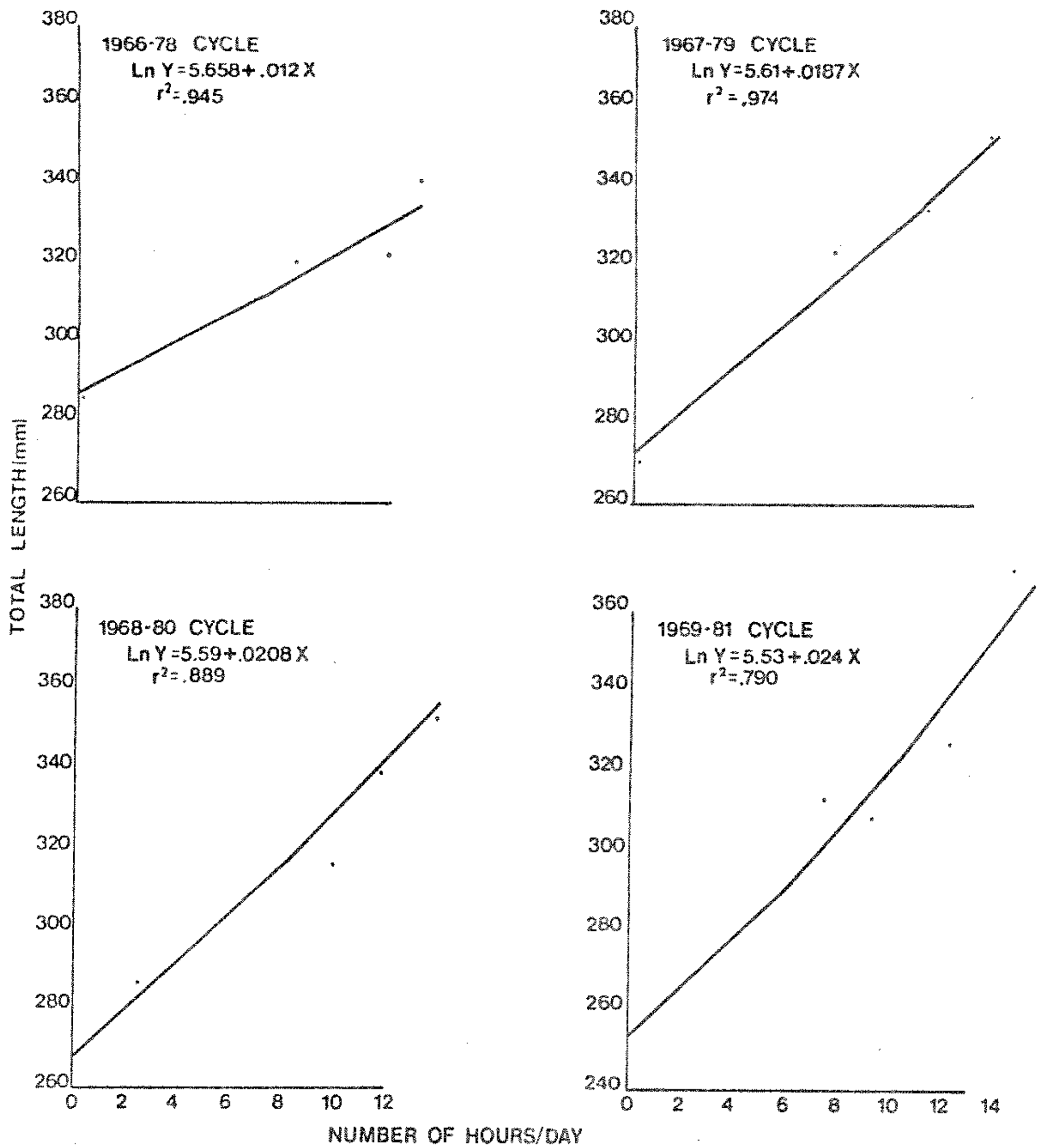

Figure 25. Relationships between mean kokanee spawner length and weighted three year moving average mean number of hours/day kokanee eggs were dewatered during the incubation period for each of four spawning cycles.

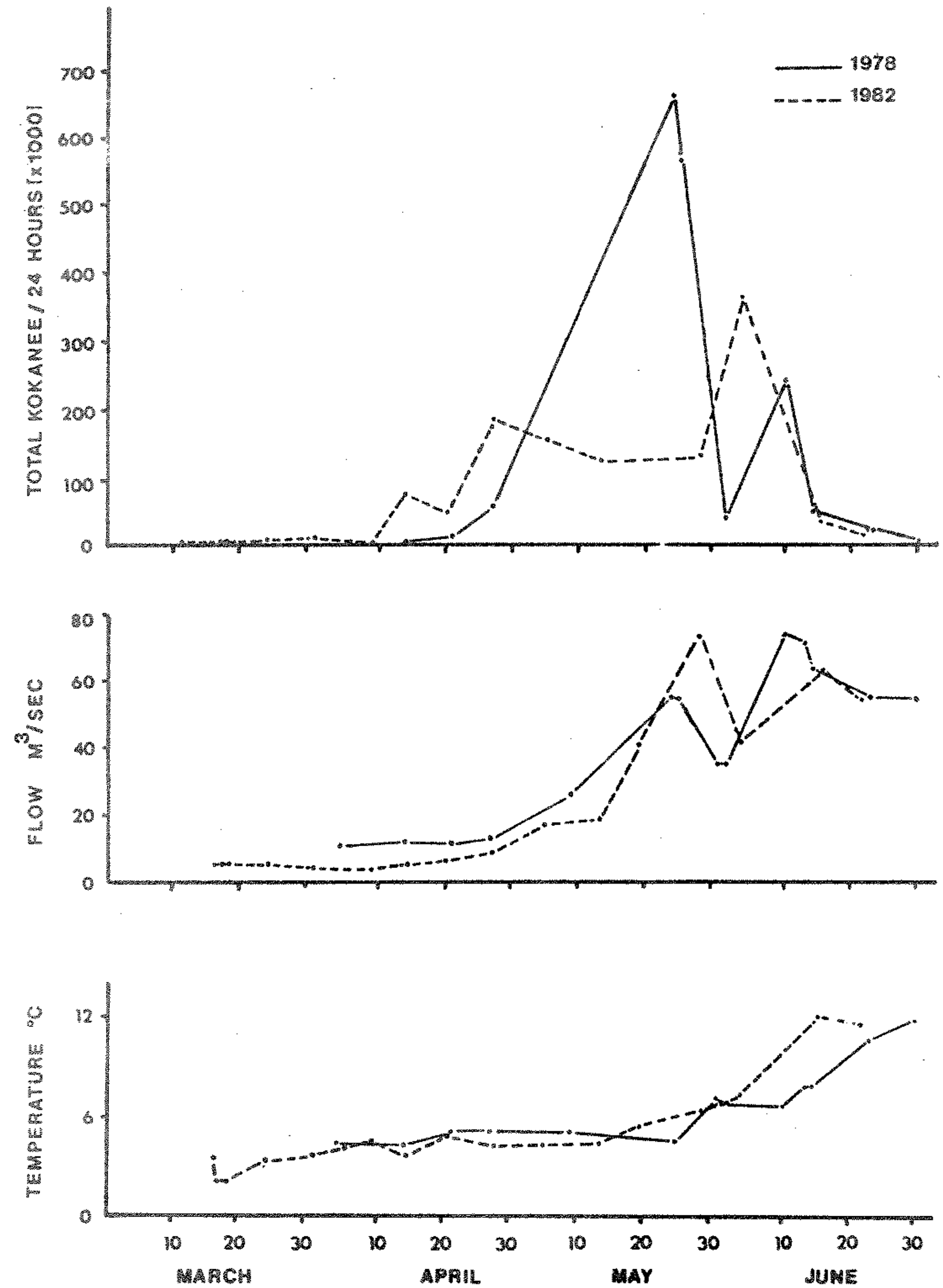

Figure 26. Estimated number of kokanee fry emigrating, flow and water temperature in McDonald Creek, 11 March to 30 June, 1982. The 1978 comparison data are from Hanzel and Rumsey (unpublished).

Table 12. Egg to fry survival of kokanee and sockeye salmon in various waters.

Area	Species	% egg to fry survival	Study
McDonald Creek	Kokanee	22	This study
Sullivan springs, Idaho	Kokanee	7	Jeppson 1960
O'dell Lake, Oregon	Kokanee	20	Lewis 1974
Cedar River, Washington	Sockeye	1-8	Stober and Hamalainen 1980
Sashin Creek, Alaska	Sockeye	7	McNeil 1968
Pitt River, Weaver Creek, British Columbia	Sockeye	11-19	Mead and Woodahl 1968
Average, several areas	Sockeye	11	Foerster 1968

Sullivan Spring Creek, Idaho. He considered the site to be near optimum spawning habitat with relatively constant flows and water temperatures.

Survival figures were calculated from fry emergence trap data from good gravel in McDonald Creek. An average of 288 fry /m^2 were caught in the traps, which was 29 percent of the number of eyed eggs and sac fry /m^2 estimated in good gravel during February sampling with the hydraulic egg sampler.

Kokanee fry emergence in Beaver Creek occurred from early March to late May, and peaked during late March during 1982. (Figure 27). Emergence occurred during a similar time period in 1981 (McMullin and Graham 1981). Peak emergence of kokanee fry occurred earlier in Beaver Creek than in any other river system spawning area during 1982, due to early spawning time and warm winter water temperatures. An estimated total of 429,000 fry emigrated from Beaver Creek during 1982.

Fry emergence in Deerlick Creek occurred from mid April to mid May, based on fry catches in emergence traps attached over the substrate. An estimate of total emigration was not obtained because algal growth limited fry drift net efficiency.

The majority of the kokanee fry captured in the Middle Fork of the Flathead River near West Glacier probably emigrated from Beaver Creek (Figure 28). Even though kokanee spawn early in the Middle Fork (October), peak emergence probably doesn't occur until late May due to very low winter water temperatures approaching 1°C. Fry sampling was terminated in mid May because of high flows and debris movement. An estimated 317,000 fry passed the Middle Fork sampling station from 1 March to 19 May.

Fry emigration in Brenneman's Spring Slough in the lower Flathead, peaked in mid April (Figure 29). The period of emigration extended from early March to early June. An estimated total of 43,000 fry emigrated from Brenneman's Slough during 1982. McMullin and Graham (1981) reported peak emergence in Columbia Falls Spring Slough in the lower Flathead, peaked in mid April during 1981.

Fry emigration in the mainstem Flathead near Kalispell was monitored from 6 April through 3 June (Figure 30). An estimated total of 4.5 million fry passed the sampling station during that period. The majority of the fry captured in the mainstem probably emigrated from McDonald and Beaver creeks in the Middle Fork drainage and mainstem Flathead Spring areas. Only a few fry were captured in 13 fry emergence traps attached over the substrate in mainstem non-spring areas as of 8 May. After this date, flows in the mainstem prevented checking of traps. Based on temperature unit calculations, most fry emergence in non-spring, mainstem areas occurred from mid May to mid June.

The total number of fry passing the mainstem sampling site was 48 percent of the estimated fry which emigrated from upstream spawning areas

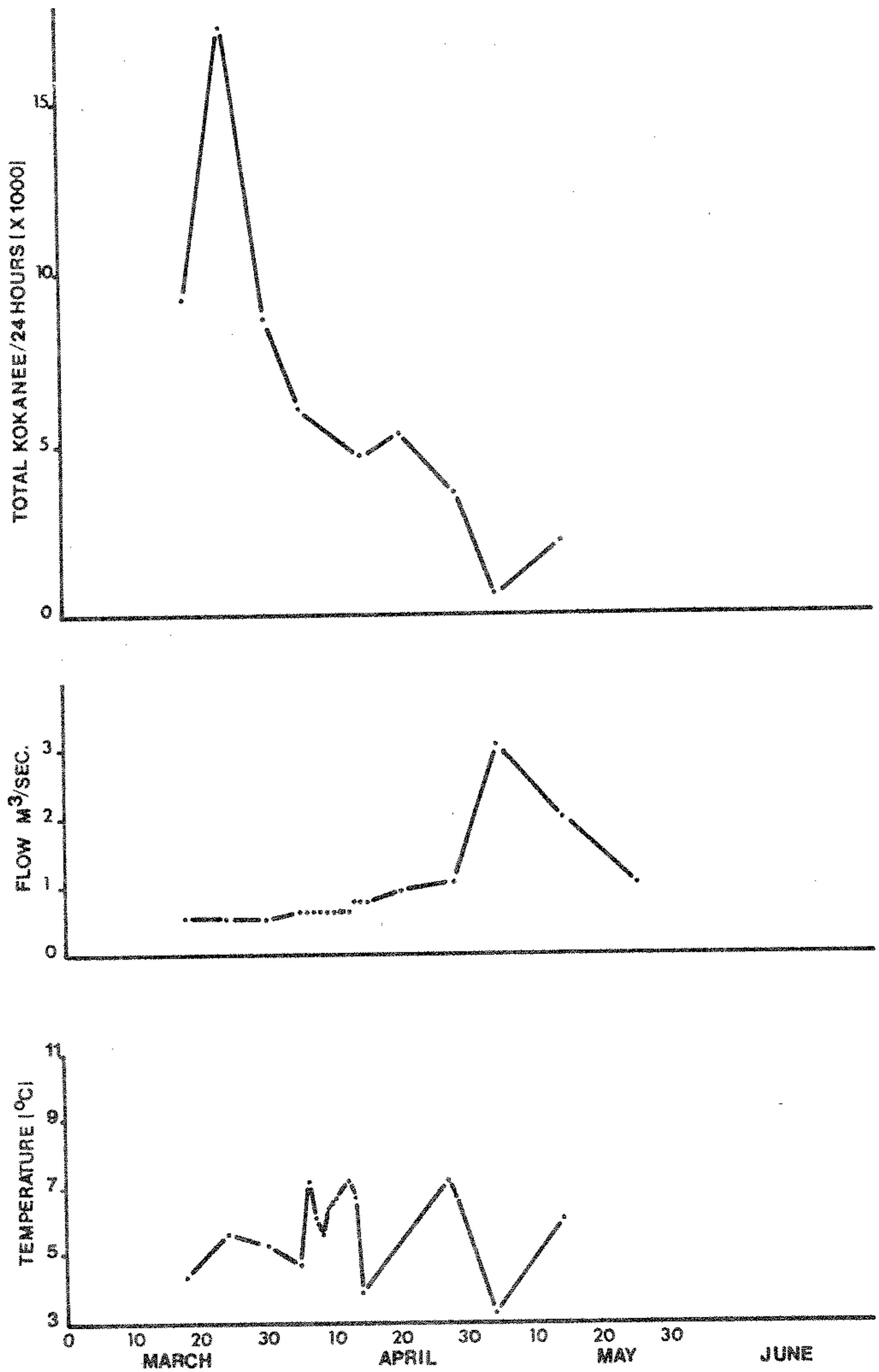

Figure 27. Number of kokanee fry emigrating, flow and water temperature in Beaver Creek from 18 March to 25 May, 1982.

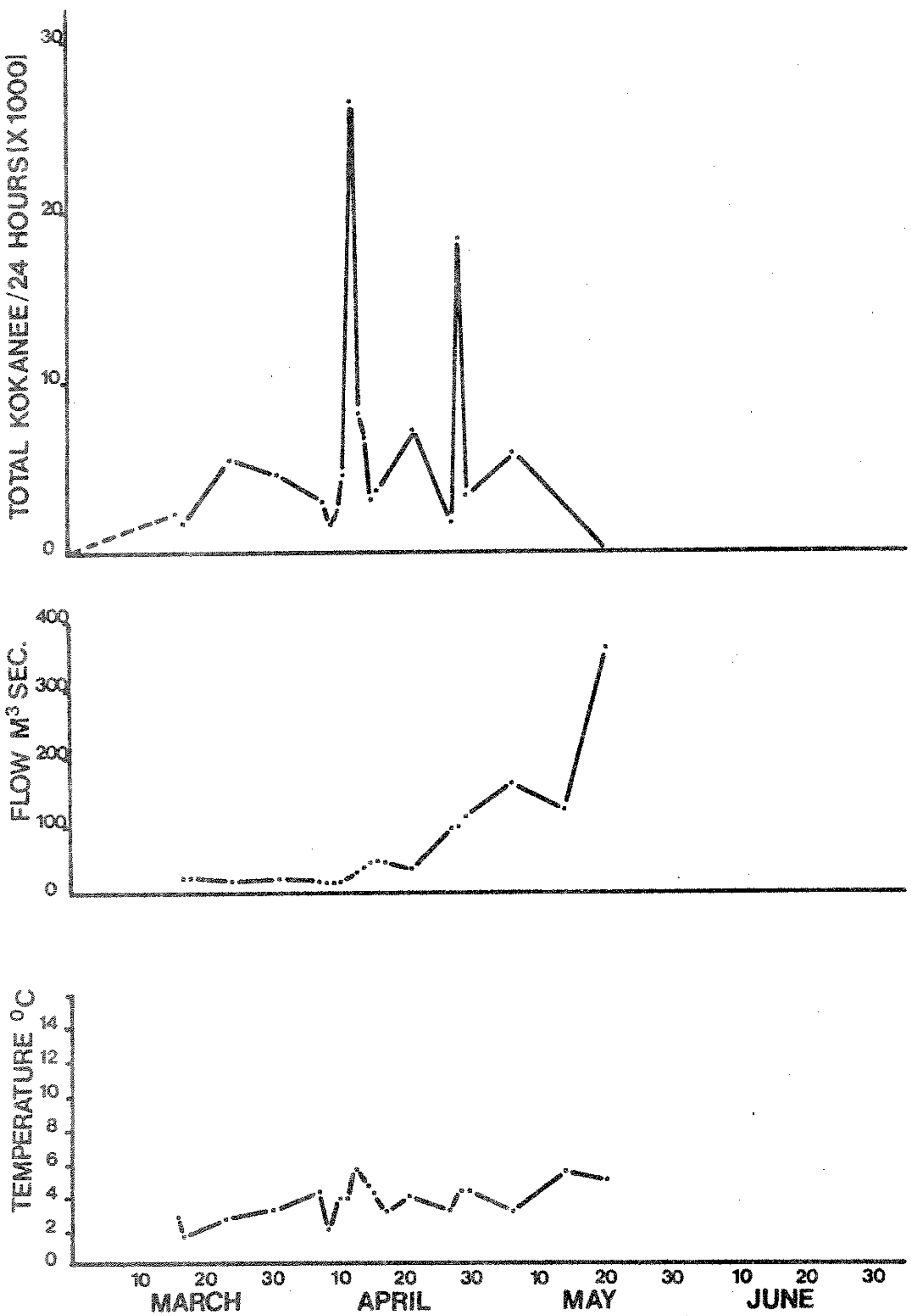

Figure 28. Number of kokanee fry emigrating, flow and water temperatures in the Middle Fork of the Flathead River near West Glacier from 1 March to 19 May, 1982.

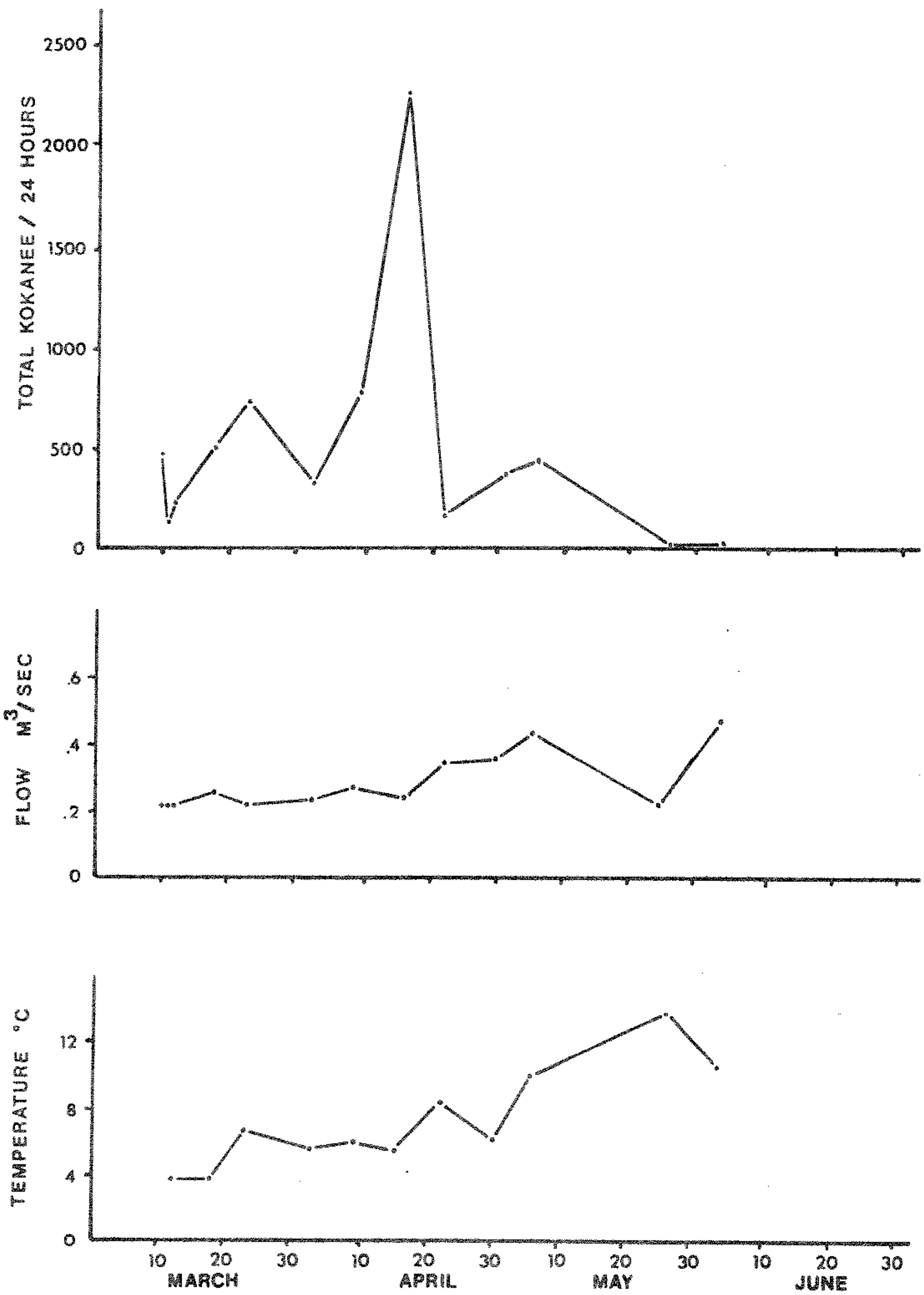

Figure 29. Number of kokanee fry emigrating, flow and water temperatures in Brennemans spring slough in the lower Flathead River from 10 March to 3 June, 1982.

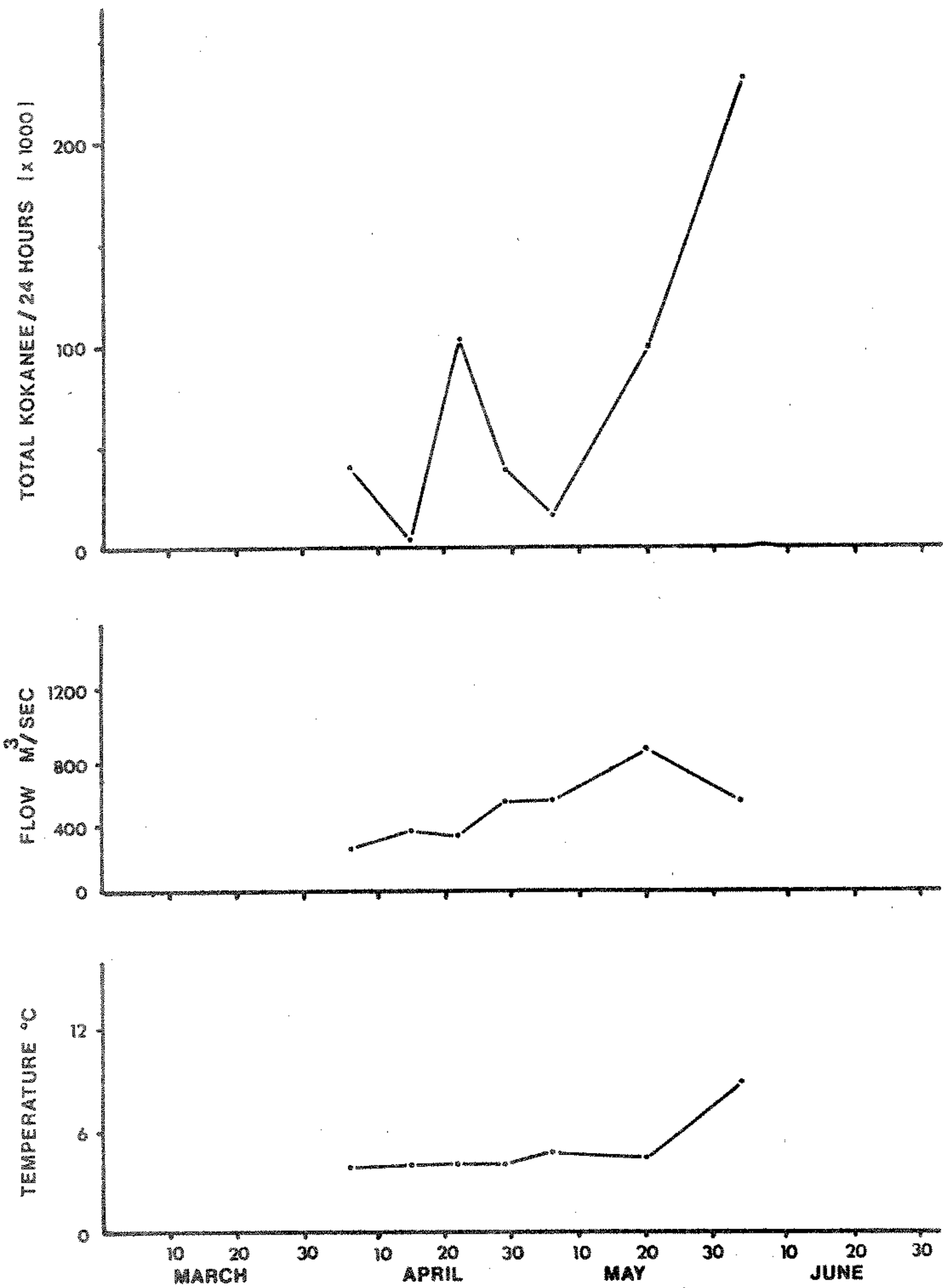

Figure 30. Number of kokanee fry emigrating, flow and water temperatures in the Flathead River near Kalispell from April to June, 1982.

in the Middle Fork drainage. Stober and Hamalainen (1980) reported an average survival rate of 50 percent for sockeye fry during downstream emigrating from the Cedar River, Washington.

Fry emigration in the Whitefish River was recorded from 6 April through 14 June (Figure 31). Peak emigration was recorded in late April. An estimated 11,000 fry emigrated over the period sampled. Sampling efficiency was probably poor due to low water velocity.

Fry Distribution in the Water Column

Experiments conducted in McDonald Creek on 13 May 1982 indicated significant numbers of emigrating kokanee fry were distributed throughout the moving portion of the water column. Nets placed near the water surface horizontally across the stream channel captured 29.0, 28.0 and 21.3 kokanee fry per 100 m^3 of water filtered near the left bank, middle and right bank, respectively. There was no relationship between water velocity and numbers of fry captured per 100 $m^3$of water filtered in nets set in a wide range of water velocities (0.05-0.60 m/sec.).

Fry net catches from the stream bottom vertically to the water surface indicated no clear relationship between water depth and distribution of emigrating kokanee fry. Top, middle and bottom net sets captured 25.8, 66.3 and 38.6 kokanee fry per 100 m^3 water filtered during peak emigration hours. During hours of lower emigration, 1.0, 2.8 and 4.3 fry per 100 m^3 water filtered were captured in the top, middle and bottom net sets. In top and bottom sets made overnight on 27 April, nearly identical numbers of fry per 100 m^3 were captured (29.0 and 27.0, respectively). Nets set near the top of the water column collected more fry per 100 m^3 water filtered than nets in the middle or bottom of the water column on 5 May (27.0, 7.0 and 5.0, respectively).

The majority of fry emigrated from McDonald Creek from 2300 to 0200 hours in experiments conducted in 1982 and 1978 (Figure 32). Brannon (1972), Stober and Hamalainen (1980) and Nelson (1965) reported most sockeye fry emigration occurred during a similar time period. Nelson (1965), however, found that although emigration always occurred at night, the exact hours or peak emigration varied from the early to late portion of the fry emigration season and from year to year. Hanzel and Rumsey (unpublished data) found that peak emergence occurred during periods of darkness in spawning areas in the Flathead River system.

Fry Behavior and Movements

Movements of stained kokanee fry in Beaver Creek indicated the majority of fry remained in the stream at least two weeks before entering the Middle Fork of the Flathead River and moving towards Flathead Lake. A total of 13 stained fry were recaptured near the outh of Beaver Creek, 3.5 km below the point of release, from one to nine days after staining. Rates of movement of the stained fry ranged from 0 to 3.5 km/day. Water velocities

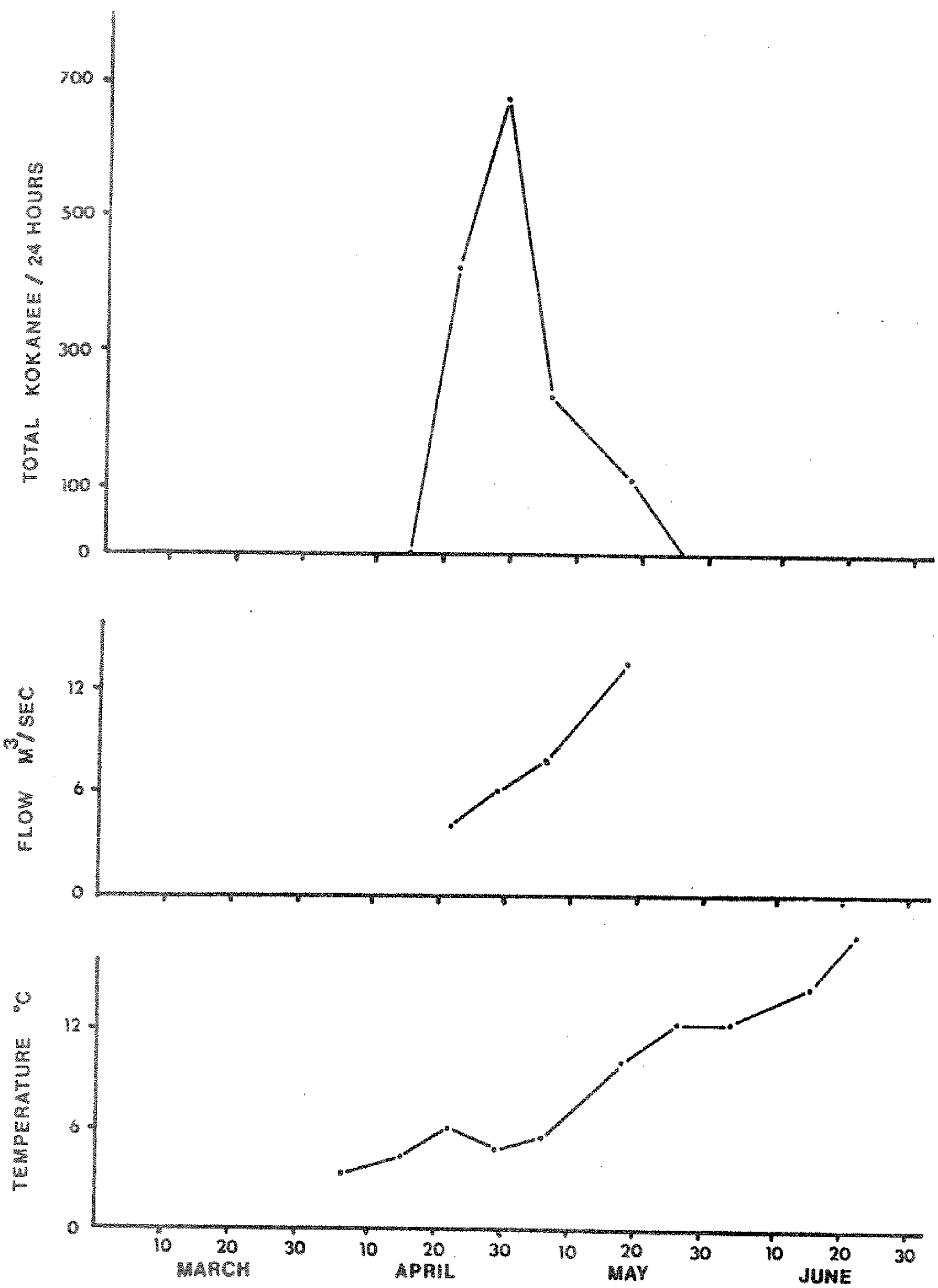

Figure 31. Number of kokanee fry emigrating, flow and water temperatures in the Whitefish River near Kalispell from April to June, 1982.

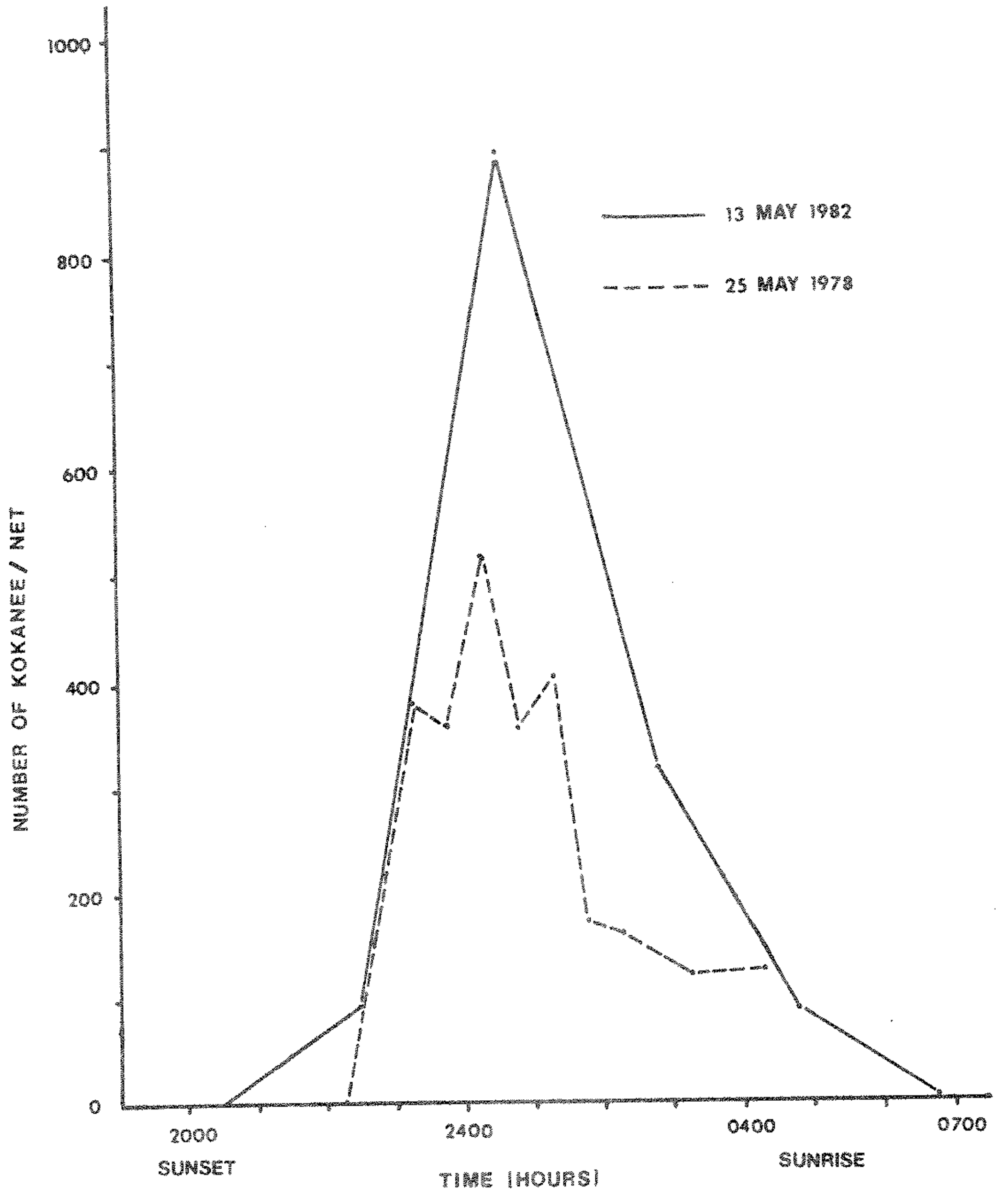

Figure 32. Number of kokanee fry captured per net in McDonald Creek during May, 1982 and 1978 from 2000 to 0700 hours. The 1978 data is from Hanzel and Rumsey (unpublished).

in this spring creek were very low in some sections during this time period, so these figures probably represent active swimming rates.

It appeared that a proportion of the fry were slowly moving downstream in Beaver Creek, taking refuge along the stream margins during daylight hours. The larger size (greater than 30 mm) of some of the fry captured near the mouth also indicated the fry had remained in the stream for some time after emergence. Extended residence time of kokanee fry was also noted in Brenneman's Spring Slough in the lower Flathead River. Stober and Hamalainen (1980) reported most stained sockeye fry released in the Cedar River, Washington emigrated in only one to three days after emergence from the gravel.

Control groups of stained fry kept for two weeks in net bags in Beaver Creek suffered 30 percent mortality while unstained fry suffered 5 percent mortality. Ward and Verhoeven (1963) and Stober and Hamalainen (1980) reported much lower mortality rates (1-5 percent) for stained sockeye fry.

Only three of the 2,700 stained hatchery fry placed in Deerlick Creek were recaptured. All were recaptured less than 1 km below the point of release, from four to five days after release. No stained fry were captured in nets set 5 km downstream. These results indicated extended residence time for the released fry before emigration, or very low survival rates. Groups of stained and unstained fry kept in net bags in the stream for 30 days suffered 80 percent mortality. The hatchery fry may not have been able to acclimate to the water conditions in Deerlick Creek. Beaver dams between the point of release and the downstream net station may also have hindered fry movements. Mead and Woodall (1968) found hatchery fry were inferior to naturally propagated fry in characteristics important in survival, such as photonegative behavior.

It was determined the Bismark Brown biological stain in concentrations of 1:30,000 and exposure times of 0.75 to 1.5 hours resulted in satisfactory short-term marks for kokanee fry. The exposure time of 0.75 hours appeared to result in lower mortalities of stained fry. Fry which were immersed in Bismark Brown for 1.5 hours and held in net bags in the stream retained traces of the dye from 15 to 30 days. Fry immersed for 0.75 hours retained traces of dye for up to 20 days.

FLOW RECOMMENDATIONS FOR FLATHEAD RIVER BELOW THE SOUTH FORK

KOKANEE REPRODUCTION

The flow recommendations outlined in this section were developed to provide for an optimum, not a maximum, number of kokanee in the Flathead River system. Optimum conditions would consist of a balanced number of spawning age fish approximately 13 inches (330 mm) in length available to the angler (Graham et al. 1981). Recruitment of large numbers of kokanee would result in spawners size of less than optimum because of the density dependent relationship in the lake. Poor recruitment would result in larger fish, but too few kokanee would be available for harvest and reproduction.

In the following discussion, we will describe the present condition of the kokanee fishery and estimate future fishery conditions as effected by discharges from Hungry Horse Dam. Future fishery conditions will be estimated without power additions or the construction of a reregulating dam and with and without the adoption of recommended fish flows submitted to the Northwest Power Planning Council.

Present Conditions of the Kokanee Fishery

Presently, kokanee reproduction in the regulated portion of mainstem Flathead River contributes less than 20 percent of the recruitment to Flathead Lake. McDonald Creek contributes the majority of kokanee, while spawning on the lakeshore was limited to about one percent of the total during 1981, the first year or record on the lake (Decker-Hess and Graham 1982).

The postharvest kokanee spawner abundance counts in the entire river system during the study period for 1979, 1980 and 1981 are considered reliable and were 100,000, 60,000 and 145,000, respectively. The harvest of 152,000 river system kokanee spawners in 1982 (Fredenberg and Graham 1982) yields a total preharvest figure of 304,000 fish in the entire river system. The mainstem run was stronger in 1981 than in 1979 or 1980, but was composed of only 35,000 preharvest spawners, based on redd counts and a harvest figure of 15-17,000 fish from the mainstem run (Fredenberg and Graham 1982). The total estimated numbers of mainstem preharvest spawners for 1979 and 1980 were 12,000 and 2,200 respectively.

Seasonal and daily discharge patterns from Hungry Horse Reservoir have contributed to these weak year classes of kokanee. Poor flow conditions, measured by a spawning-incubation flow relationship, were the result of high flows due to power peaking during the fall spawning season and subsequent lower flow during the incubation period.

Kokanee year class strength was most affected by incubation mortality during these years of high spawning and low incubation period flows. Because most spawning occurs in areas of gently sloping gravel bars along the margin of the river, the water drop between spawning and incubation flows exposed much of the area when the eggs were deposited (Figure 33).

Artificial channel and on-river experiments in 1979, 1980 and 1981 have verified high kokanee egg mortality when redds are dewatered (Figure 34). Unfavorable flow conditions for egg survival appear to be correlated to operation of the Hungry Horse project to provide provisional energy. Provisional energy deliveries at Hungry Horse in water years 1956 to 1982 and associated flow conditions related to kokanee reproduction are shown in Table 13. During the period 1967-1980, provisional energy was provided in nine of the years. In 8 of the 9 years, poor flow conditions for egg survival resulted. From 1956 through 1977, in 10 or 13 years when provisional energy deliveries were not made, highly favorable flow conditions resulted. Provisional energy deliveries typically produce higher flows and high bank spawning due to power peaking during the fall. This condition is often followed by lower flow releases during egg incubation.

Future Conditions of the Kokanee Fishery

Providing favorable flows for kokanee in the Flathead River below the South Fork requires management of seasonal and daily flow levels. If spawning flows average nearly the same or slightly higher than incubation flows, a positive spawning incubation gauge height relationship will result. The following are the Department of Fish, Wildlife and Parks estimates of flows in the Flathead River at Columbia Falls required to maintain the kokanee fishery at the level consistent with management goals. These flows were submitted to the Northwest Power Planning Council on November 15, 1981 under the Pacific Northwest Electric Power and Conservation Planning Act.

Period	Minimum Flows (cfs)	Maximum Flows (cfs)
15 October-15 December (spawning) 24 hours/day	3,500	4,500
15 December-15 April (incubation) 24 hours/day	3,500	none

The kokanee spawning and incubation flow requests for the Flathead River are based on a mid-October to mid-December spawning season and an incubation period that extends into June. Natural runoff conditions in the unregulated river segments usually exceeds the requested minimum flows by mid-April. The request minimizes the dewatering of eggs by restricting maximum flows during the spawning season and minimum incubation flows. These recommendations allow for a higher spawning flow than incubation flow to provide increased flexibility to power managers although there is no biological

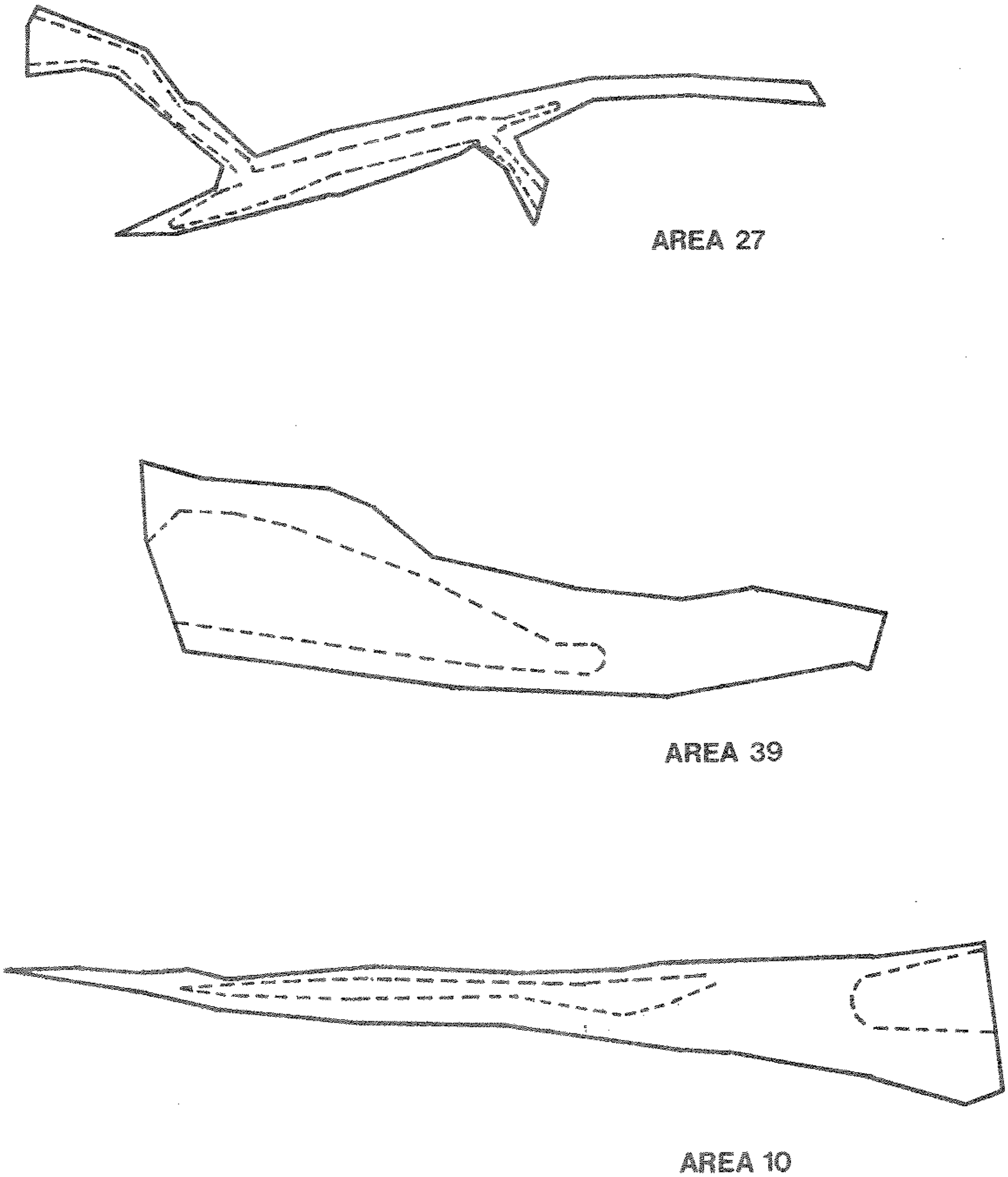

Figure 33. Outlines of wetted spawning gravel at 4000 cfs (solid line) and 2300 cfs (dotted line) in three spawning areas on the mainstem Flathead River.

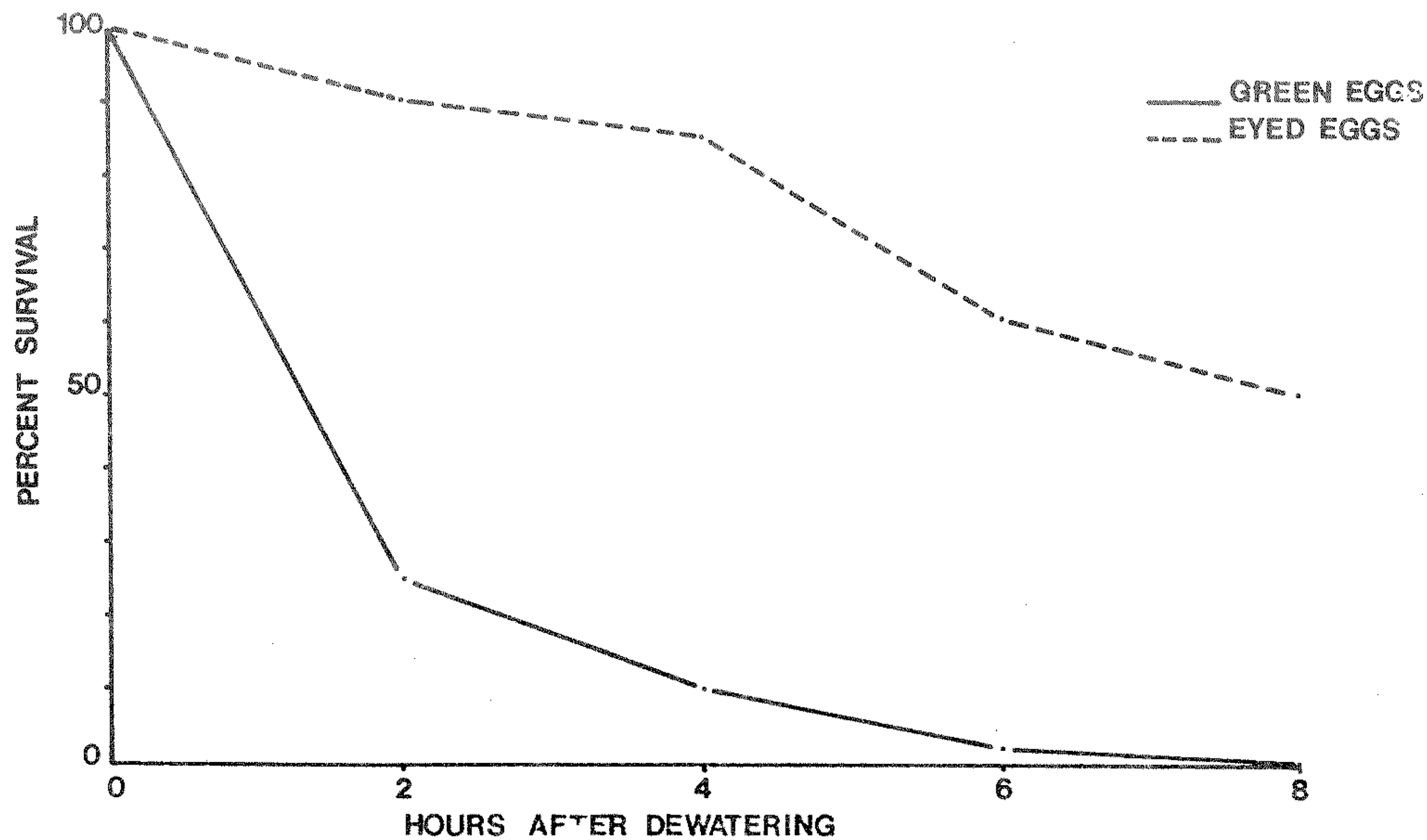

Figure 34. Percent survival (average survival in four sediment mixtures) of kokanee eggs in the green and eyed stages during dewatering experiments in 1981-82. The green egg experiment was conducted on 5, 6 January (air temperatures -13 to -23°C) and the eyed egg experiment was conducted on 20, 21 January air temperatures (-13 to -18°C).

Table 13. Provisional energy deliveries met from Hungry Horse Dam and associated flow conditions for kokanee reproduction from 1956 1982.

Fiscal (Water) Year	Provisional Energy Delivery (MW Hours)	Spawning-Incubation Gauge Height Difference	Spawn Year
1956	0	.94	1959
1957	351,327	.96	1960
1958	500,000	-3.22	1961
1959	0	.15	1962
1960	0	-1.06	1963
1961	0	-0.15	1964
1962	0	1.68	1965
1963	0	1.53	1966
1964	0	3.16	1967
1965	0	2.39	1968
1966	0	0.99	1969
1967	603,006	-1.54	1970
1968	198,348	-0.14	1971
1969	0	0.76	1972
1970	879,047	-1.35	1973
1971	893,337	1.78	1974
1972	868,165	-0.27	1975
1973	885,074	-0.04	1976
1974	0	0.52	1977
1975	1,103,152	-2.07	1978
1976	0	-0.97	1979
1977	0	0.46	1980
1978	?	-1.22	1981
1979	322,479	-1.97	1982
1980	209,040	-3.86	1983
1981	209,040	0.25	1984
1982	359,900	0.49	1985

benefit. The incubation flow should be adequate to provide the optimum number of fish.

If these flow requests are implemented, we would expect the kokanee population to return to previous levels similar to 1975, which was considered to be an average "good" year for the mainstem kokanee run and for which data is available. An estimated 150,000 river kokanee spawners averaging 12.8 inches in length were harvested in 1975 (Hanzel 1977). An estimate of the harvest rate would yield a reasonable estimate of the total number of spawners. A creel census conducted in 1981 (Fredenberg and Graham 1982) found a harvest rate of approximately 50% of the kokanee in the river system. This is probably higher than in 1975 for at least two reasons.

The fishermen have completely changed the focus of their fishery from 1975 to 1981. In 1975, fishermen concentrated almost their entire effort on the late run of fish (October-December) spawning in the regulated Flathead River. With the decline of this run, fishermen now focus almost entirely on the early run, destined for McDonald Creek. An estimated 152,000 kokanee were harvested in the river system in 1981; 135,000 from the early runs migrating to the Middle Fork drainage and 17,000 from the later run of mainstem spawners. This represents an overall harvest rate of 51% of the run with the great majority (80%) of the fish coming from the early run of fish mainly migrating to McDonald Creek.

The harvest rate in 1975 was certainly lower than 50% of the run, because virtually no harvest occurred in September or on the Lower Middle Fork which comprised 75% of the use in 1981. The tag return rate for the early run in 1981 was 23%. Because fisherman tag returns underestimate harvest rate (not all tags are returned), a 23% harvest rate is probably too low. In addition, there are a number of other factors which can bias the estimate up or down including length of season, fish distribution and rate of movement of fish. Based on the above, we estimated a 30% harvest rate for kokanee in 1975. Applying a 30% harvest rate to harvest data for 1975, would yield a total preharvest estimate of 500,000 kokanee spawners in the river system for that year. The managment goal for kokanee production is a late mainstem run similar to the base condition in 1975, approximately 330,000 preharvest spawners (with 170,000 spawners bound for other river system areas such as McDonald Creek).

We feel that implementation of the recommended flow request would provide this level of production and would greatly enhance recreational benefit to the anglers. Assuming a 50% harvest rate, we would expect 165,000 spawners taken by anglers from the late mainstem run, if it was built to the level estimated in 1975. This compares to an estimated 17,000 fish harvested from the late mainstem run in 1981 and would be a ten fold increase in numbers. After harvest, 165,000 fish would be present to spawn in the mainstem, a 12 fold increase over 1981 levels. This would result in a direct benefit to the lake population by approximately doubling recruitment.

If the flow recommendations were not adopted and the Hungry Horse Project was operated in a similar manner to the years of provisional energy deliveries (water years 1967-1980), we would expect the mainstem kokanee run to remain at the present level. This level is represented by the "best case" year of the study, or 35,000 preharvest spawners averaging nearly 15 inches in the mainstem. This represents only 11% of the management goal of 330,000 mainstem spawners averaging approximately 13 inches estimated in 1975.

If provisional draft is discontinued, but no recommended flow pattern is implemented, we would expect erratic levels of kokanee spawner abundance in the mainstem, similar to the pattern seen prior to 1966. This is difficult to assess, however, because kokanee populations may not have been stabilized prior to that time.

If a flow regime similar to the study flows of the 1981-82 spawning (4,000 cfs) and incubation (2,300 cfs) seasons is implemented, we would expect kokanee numbers to stabilize at approximately 40 to 50 percent of the management goal level of the 1975 base to mainstem run. This would mean approximately 130,000 to 160,000 preharvest kokanee spawners utilizing the mainstem.

A major emphasis is continuing to determine the potential usable spawning area in the Flathead River below the South Fork at various flows. This effort has been limited because of the small number of kokanee spawning during the study period. Potential spawning areas can be predicted based on spawning criteria. However, we do not know to what degree kokanee will use these areas at larger population levels.

Wetted area for kokanee production (Figure 35) was used to calculate kokanee production at various incubation flows, assuming a 4,500 cfs spawning flow, based on wetted area measurements in four major mainstem spawning areas (Areas 10, 27, 32 and 39) (Table 14).

Table 14. Estimated number and length of returning mainstem kokanee spawners at various minimum incubation flows, if flows during the spawning period are held at 4,500 cfs. Estimates are total number of spawners in the river system assuming a constant 170,000 spawners in river system spawning areas other than the mainstem.

	MINIMUM INCUBATION FLOW					
	4,500	4,000	3,500	3,000	2,500	2,000
Percent wetted spawning gravel	100	82	67	53	24	14
Number of kokanee	330,000	271,000	221,000	175,000	79,000	46,000
Spawner length (inches)	12.9	13.2	13.5	13.8	14.1	14.5

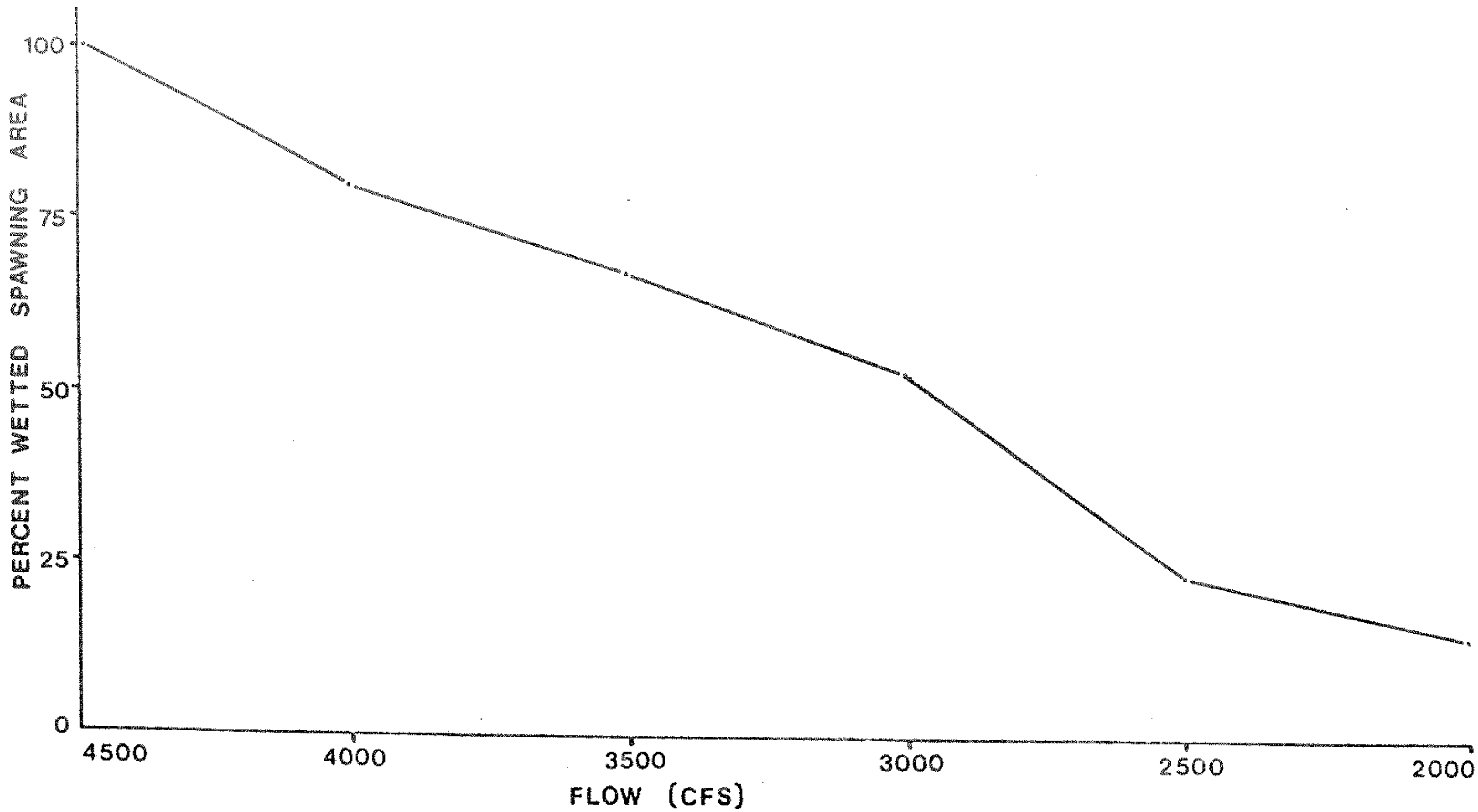

Figure 35. Percent wetted spawning area at various flows in the Flathead River based on measurements in spawning areas 10, 27, 32 and 39.

If we assume that the desired number of river kokanee spawners could be produced at the 4,500 cfs spawning flow, an incubation flow of 2,500 cfs would produce only 25% of those fish. This is a result of large decreases in wetted spawning area at incubation flows below 3,500 cfs which would result in decreases in egg survival and much lower kokanee production.

If studies show that spawning area is not limited below 4,500 cfs, a lower spawning and incubation flow might result in favorable production of kokanee in the mainstem. When more information on the potential spawning area survey is available, the estimate of kokanee production at various flows can be improved. This information will be presented in the 1983 annual report to the Bonneville Power Administration.

Wetted perimeter studies conducted in the mainstem lend support to the 3,500 cfs minimum flow request (Figure 36). Wetted area in selected riffle cross-sections dropped sharply at the 3,500 cfs inflection point, indicating a significant reduction in spawning area may occur at flows less than 3,500 cfs.

Work is continuing to evaluate and monitor kokanee reproductive success under the flow request. Day and night spawning habits of kokanee will be studied to determine if more flexibility (power peaking during the daylight hours) could be provided for the operation of the system without substantially affecting kokanee production. A reregulating dam could provide increased flexibility in daily power peaking throughout the spawning season by allowing daily peaking while keeping flows below 4,500 cfs, and could also help maintain minimum flows during the incubation period.

Studies will be conducted during the 1982-83 season to determine the effects of daytime power peaking on kokanee spawning success. If the spawning flow requests for kokanee cannot be met without substantial loss of power peaking capability, it may be feasible to mitigate some of the kokanee losses by other means, such as the construction of a kokanee spawning channel.

MINIMUM FLOW FOR OTHER FISH SPECIES

Westslope cutthroat, bull trout, mountain whitefish and rainbow trout are important sportfish in the mainstem Flathead River. Anglers harvested 8,557 cutthroat, 1,827 bull trout, 1,582 mountain whitefish and 477 mature bull trout in the mainstem during the 1981 fishing season (Fredenberg and Graham 1982b).

A minimum flow of 3,500 cfs at Columbia Falls throughout the year has been submitted as a recommendation to the Power and Planning Council under the Pacific Northwest Electric Power and Conservation Act for the protection of overwintering and rearing habitat for these species and invertebrate fish food production. Studies of wetted perimeter in the mainstem have indicated that wetted area decreases quickly at flows below 3,500 cfs (Figure 36).

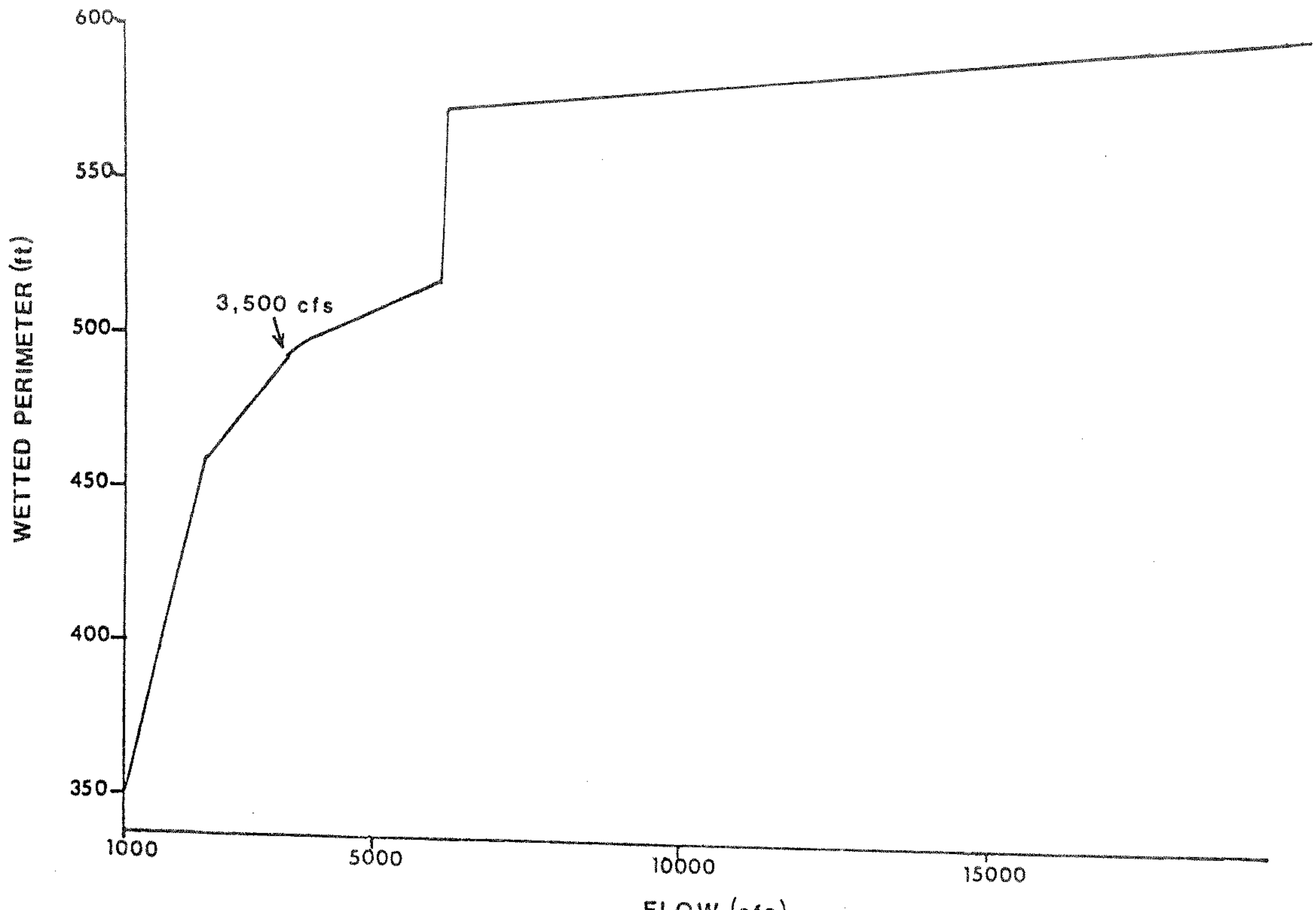

Figure 36. Relationship between wetted perimeter and flow for a riffle cross-section in the Flathead River.

The majority of juvenile cutthroat and bull trout enter the mainstem below the South Fork from August to October (McMullin and Graham 1981). This is a critical period when a stable minimum flow would be highly desirable.

McMullin and Graham (1981) reported that adult cutthroat utilize the Flathead River below the South Fork as a migration corridor to upstream spawning areas and as a holding area from November through April (Figure 37).

A stable minimum flow in the mainstem during the winter and early spring months would be greatly beneficial to migration and holding of adult cutthroat due to warmer water temperatures and greater wetted perimeter.

The minimum flow is met by natural (unregulated) flows in an average year from April through August and October through November (Table 15). Hungry Horse Reservoir would have to provide an additional release (above natural inflows) of 500-700 cfs during September, December and March and an additional 1,000 cfs during January and February. These releases may or may not be compatible with power demand. Flows provided by Hungry Horse would result in a four percent increase in wetted area in September, December and March, and a nine percent increase in wetted area during January and February above natural flows in an average year.

EVALUATION OF MULTILEVEL OUTLET WORKS

A multilevel outlet system was proposed for further study (Pacific Northwest River Basin's Commission, 1976) to improve the temperature regime of the South Fork and mainstem Flathead River for trout production. Simulated release temperatures from a multiple level outlet system at Hungry Horse Dam (Bureau of Reclamation, unpublished data), with outlets at elevations 3,200, 3,319, 3,440, 3,490, and 3,540 feet above mean sea level indicates that a substantial improvement in temperatures could be achieved from May - September (Figure 38). To increase temperatures during the summer months, the majority of releases would be withdrawn from near the surface of Hungry Horse Reservoir. Water drawn off from this level may result in losses of cutthroat through the intake structure from this portion of the water column. Losses of cutthroat from intake structures were reported for Libby Reservoir (Joe Huston, personal communication). The intake structure should be designed to minimize losses of cutthroat through intake structures from Hungry Horse Reservoir. A surface withdrawal system would provide the benefit of increased water temperatures and may be less costly than a multiple outlet structure.

Trout growth generally occurs in water temperatures ranging from 6 to 17 degrees centigrade (Vincent 1977). Trout growth units in the Flathead River below the South Fork were calculated as the number of degree days for each month with 6 degrees centigrade as the base temperature level (Table 16). For example, one day of water temperature of 7°C would constitute one degree day or one trout growth unit. With the present withdrawal system, only 56% of the growth units available before impoundment

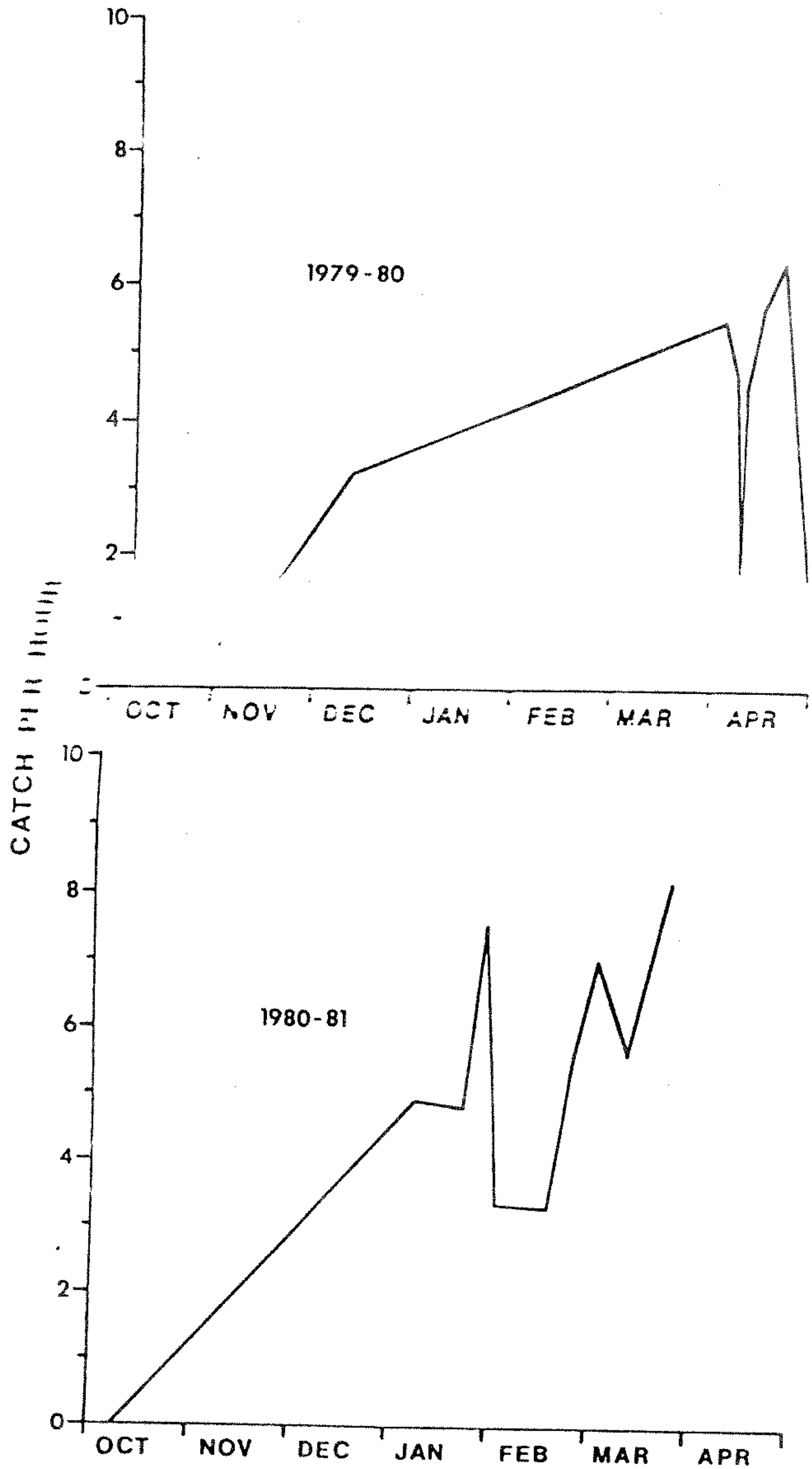

Figure 37. Adult westslope cutthroat trout catch per hour of electrofishing effort in the Kalispell section, 1979-81 (from McMullin and Graham 1981).

Table 15. Mean monthly flows of the North and Middle Fork Flathead River combined and the Flathead River at Columbia Falls (theoretically unregulated). Data from water years 1929 through 1980 provided by the Bureau of Reclamation, Boise District Office.

Month	Combined North and Middle Fork (cfs)	Flathead River(unregulated) (cfs)
October	2,312	3,422
November	2,241	3,496
December	1,875	3,071
January	1,523	2,531
February	1,509	2,530
March	1,659	2,841
April	6,873	11,511
May	21,165	33,882
June	21,190	33,894
July	8,156	12,016
August	3,038	4,153
September	2,122	2,985

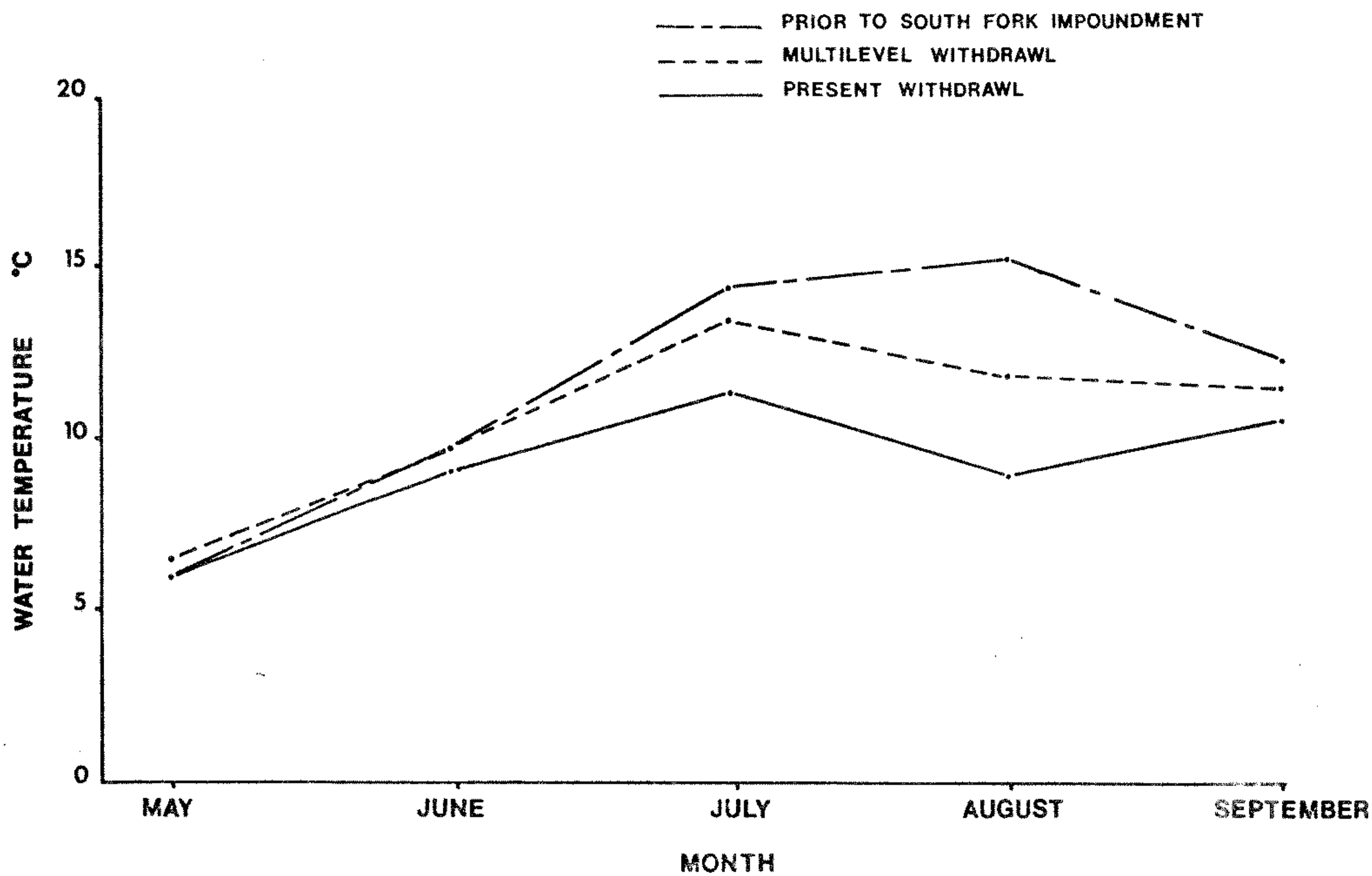

Figure 38. Mean water temperatures of the Flathead River at Columbia Falls during 1979 under various flow regimes. Multilevel outlet temperatures are based on a temperature simulation program by the Bureau of Reclamation and the relative flow contributions of the North, Middle and South forks from May-September 1979. Temperatures prior to impoundment were calculated, using average values in the North Fork and the South Fork above Hungry Horse Reservoir.

Table 16. Temperature growth units for trout from May through September 1979 in the Flathead River below Columbia Falls under the present withdrawal system, multiple outlet system and theoretically unregulated.

Flow withdrawal	Month					
	May	June	July	August	September	Total
Present withdrawal single outlet	5	90	171	93	135	494
Multiple outlet 1/	12	108	233	183	162	698
Prior to impoundment of the South Fork 2/	5	105	256	294	195	855

1/ Based on temperature simulation by Bureau of Reclamation personnel (Dave Smith, unpublished data) and the relative flow contribution of the Middle, North and South Forks, May through September, 1979.

2/ Based on temperatures in the North and Middle Forks and South Fork above Hungry Horse Reservoir.

are currently available. Under the selective withdrawal system, 82 percent of the growth units in the river before impoundment would be available. The result of the multilevel outlet system would be to increase trout growth in the Flathead River by about 40 percent.

Increased trout growth due to a multilevel outlet structure would greatly enhance the mainstem trout fishery for larger trout. Hanzel (1977) reported a higher percentage of larger trout than smaller trout were kept by anglers. Increased growth of juveniles would result in recruitment of larger sized fish to the lake population. It is probable that an overall benefit of 40 percent to the recreational trout fishery would be realized if a multilevel structure was built. It is possible that temperature increases in the Flathead River might favor rainbow trout over westslope cutthroat trout.

Trout growth in the 7 km of the South Fork below Hungry Horse Dam is virtually nonexistent under the present withdrawal system (Table 17). A multilevel withdrawal system would increase trout growth units to 43 percent of what was available in the South Fork before impoundment.

Table 17. Temperature growth units for trout from May through September 1979 in the South Fork of the Flathead River below Hungry Horse Dam under the present withdrawal system, multilevel withdrawal and prior to impoundment.

	Month					
	May	June	July	August	September	Total
Present withdrawal	0	10	6	5	6	27
Multi-level withdrawal	0	30	125	155	40	350
Prior to impoundment 1/	3	75	248	294	195	815

1/ Based on temperatures of the South Fork above Hungry Horse Reservoir.

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APPENDIX A

Summary of aerial counts of kokanee spawners made from 4 September to 8 November, 1981

Tables 1 and 2

Table 1. Means and range (in parentheses) of aerial counts of kokanee spawners made in September, 1981.

River section	9-4	9-6	9-7	9-8	9-15	9-17
Flathead River						
Stillwater to Pressentine	2650 (1800-3500)	4800 (4200-5400)	3050 (2600-3500)		300 (100-500)	300 (100-500)
Pressentine to Highway 40	200 (100-300)	1150 (800-1500)	---	---	0	0
Highway 40 to Blankenship	100 (50-150)	0	---	150 (100-200)	4000 (2000-6000)	200 (100-300)
Middle Fork						
Blankenship to West Glacier	0	0	---	1650 (1300-2000)	4300 (2100-6500)	1500 (900-2100)

Table 1. (Continued)

River section	9-22	9-23	9-26	9-30
Flathead River				
Stillwater to Pressentine	125 (50-200)	800 (400-1200)	650 (300-1000)	200 (100-300)
Pressentine to Highway 40	0	0	1200 (900-1500)	1200 (800-1600)
Highway 40 to Blankenship	450 (200-700)	200 (100-300)	5400 (3000-7800)	1900 (1100-2700)
Middle Fork				
Blankenship to West Glacier	3100 (1700-4500)	1400 (700-2100)	3050 (1700-4400)	4450 (2200-6700)

Table 2. Means and range (in parentheses) of aerial counts of kokanee spawners made in October and November, 1981.

	Dates			
	10-1	10-2	10-4	10-7
River Section				
Flathead River				
Stillwater to Pressentine	200 (100-300)	0	400 (200-600)	0
Pressentine to Highway 40	450 (200-700)	0	2,100 (1,400-2,800)	750 (500-1,000)
Highway 40 to Blankenship	850 (400-1,300)	0	1,300 (800-1,800)	62.5 (25-100)
Middle Fork				
Blankenship to West Glacier	14,050 (7,300-20,800)	8,050 (4,200-11,900)	4,850 (2,500-7,200)	4,050 (3,000-5,100)

Table 2. (Continued).

	Dates			
River Section	10-8	10-9	10-14	10-15
<u>Flathead River</u>				
Stillwater to Pressentine	0	0	450 (300-600)	0
Pressentine to Highway 40	1,200 (900-1,500)	400 (300-500)	600 (400-800)	62.5 (25-100)
Highway 40 to Blankenship	400 (300-500)	0	0	600 (400-800)
<u>Middle Fork</u>				
Blankenship to West Glacier	5,500 (3,000-8,000)	3,250 (2,500-4,000)	12,800 (6,600-19,000)	7,400 (4,000-10,800)

Table 2. (Continued).

	Dates					
	10-17	10-21	10-22	10-28	10-29	11-8
River Section						
Flathead River						
Stillwater to Pressentine	0	0	0	0	0	0
Pressentine to Highway 40	1,250 (800-1,700)	1,900 (1,100-2,700)	662.5 (325-1,000)	262.5 (125-400)	62.5 (25,100)	62.5 (25-100)
Highway 40 to Blankenship	0	262.5 (125-400)	725 (450-1,000)	200 (100-300)	262.5 (125-400)	800 (600-1,000)
Middle Fork						
Blankenship to West Glacier	4,650 (2,400-6,900)	3,600 (2,100-5,100)	4,600 (2,400-6,800)	0	0	262.5 (125-400)

APPENDIX B

Summary of tag return information
for kokanee salmon during 1981.

Tables 1 and 2

Table 1. Fisherman returns (date caught and river km) of adult kokanee tagged on 6 September, 1981 in the Flathead River near Kalispell (river km 42.0).

Date caught	River km	Distance moved(km)	Movement rate(km/day)
9/6	42	0	0
9/7	42	0	0
9/7	38	-4	-4.0
9/9	42	0	0
9/9	42	0	0
9/9	42	0	0
9/9	44	2	0.7
9/9	44	2	0.7
9/9	44	2	0.7
9/9	44	2	0.7
9/9	44	2	0.7
9/9	47	5	1.4
9/9	60	18	6.0
9/9	67	25	8.3
9/10	42	0	0
9/11	71	29	5.9
9/11	40	-2	-0.4
9/12	68	26	4.3
9/13	98 1/	56	8.0
9/14	46	4	0.5
9/14	38	-4	-0.5
9/15	98 1/	56	6.2
9/15	66	24	2.7
9/15	48	6	1.3
9/15	47	5	0.60
9/15	89 1/	47	5.2
9/16	61	19	1.9
9/16	61	19	1.9
9/19	74	32	2.5
9/22	79	37	2.3
9/23	97 1/	55	3.2
9/23	99 1/	57	3.4
10/3	98 1/	56	2.1
10/5	98 1/	56	1.9
10/13	111 1/	69	1.9
10/18	58	16	0.4
10/19	98 1/	56	1.3
11/11 2/	69	27	0.4
MEAN		21.1	2.1

1/ Middle Fork River
2/ Observed by study personnel at a spawning area.

Table 1. Legal descriptions of kokanee spawning areas in the mainstem Flathead River.

Area number	Description
1	Sec. 15 T28N R21W
2	Sec. 9-10 T28N R21W
3	Sec. 10 T28N R21W
4	Sec. 3 T28N R21W
5	Sec. 3 T28N R21W
6	Sec. 2-3 T28N R21W
7	Sec. 2 T28N R21W
8	Sec. 2 T28N R21W
9	Sec. 2 T28N R21W
10	Sec. 35 T28N R21W
11	Sec. 35 T29N R21W
12	Sec. 26 T29N R21W
13	Sec. 26 T29N R21W
14	Sec. 30 T29N R20W
15	Sec. 26 T29N R21W
16	Sec. 25-26 T29N R21W
17	Sec. 30 T29N R21W
18	Sec. 23 T29N R21W
19	Sec. 19 T29N R21W
20	Sec. 18 T29N R20W
21	Sec. 18 T29N R20W
22	Sec. 18 T29N R20W
23	Sec. 7 T29N R20W
24	Sec. 7 T29N R20W
25	Sec. 30-31 T30N R20W
26	Sec. 30 T30N R20W
27	Sec. 30 T30N R20W
28	Sec. 25 T30N R21W
	Sec. 30 T30N R20W
29	Sec. 30 T30N R20W
30	Sec. 30 T30N R20W
31	Sec. 30 T30N R20W
32	Sec. 17 T30N R20W
33	Sec. 16 T30N R20W
34	Sec. 16 T30N R20W
35	Sec. 9 T30N R20W
36	Sec. 10 T30N R20W
37	Sec. 3 T30N R20W
	Sec. 4 T30N R20W
38	Sec. 3 T30N R20W
39	Sec. 11 T30N R20W
40	Sec. 2 T30N R20W
41	Sec. 1 T30N R20W
42	Sec. 1 T30N R20W

Table 2. The numbers of kokanee redds counted in late November of 1979, 1980 and 1981 in areas of the Flathead River below the South Fork.

Area number	River km	Number of kokanee redds observed 1979	1980	1981
1 1/	37.0	425	136	341
2	41.42	5	0	12
3	42.0	7	1	0
4	42.2	0	25	67
5	42.5	0	0	14
6 1/	43.4	60	11	0
7	44.3	0	6	30
8	45.0	0	0	133
9	45.5	0	15	218
10	46.7	0	0	517
11	47.9	0	0	165
12	48.0	0	0	254
13	48.3	22	0	0
14 1/	48.8	0	0	151 4/
15	49.0	0	0	9
16 1/	49.4	119	12	106
17	50.0	359	0	118
18	50.5	10	0	0
19	52.0	0	3	174
20	52.2	55	0	604
21	52.4	0	13	226
22	54.4	100	0	179
23	55.3	100	7	31
24	55.5	200	1	13
25	59.8	290	5	363
26	60.2	0	0	3
27	60.3	150	0	494
28	60.7	0	1	51
29 2/	60.8	250	0	375
30	61.0	25	0	94
31	61.5	25	0	23
32	65.0	0	0	735 4/
33	66.0	0	0	11
34 1/	66.5	20	0	160
35	67.6	50	0	146
36 1/	68.5	330	231	0 3/
37	67.7	100	0	495
38 1/	68.5	100	0	288
39 2/	69.5	0	0	1083
40	70.6	0	0	76

Table 2. (Continued).

Area number	River km	Number of kokanee redds observed 1979	1980	1981
41	70.9	0	0	92
42	73.7	0	0	2
TOTAL		2,802	467	7,853

1/ Spring influenced
2/ Limited groundwater or spring influence
3/ Beaver dammed during 1981.
4/ Redds found after late November redd count.

1. *Brenneman's Slough* (RK37.0)

A spring slough area that enters the main river upstream of the mouth of the Stillwater River from the east side and extends approximately 3km north. The spawning area is in the upper end of the slough in the northeast corner of Sec. 15, T28N, R21W above the first culvert. A large area of good spawning gravel is located near the upper end of this section of the slough. Many springs are in the area. All of the gravel is covered with silt. The water level in this area is affected by the level of Flathead Lake. There is also a large area of fine loose gravel below the first culvert, but most of this is dewatered when the lake level drops.

2. *East and West Side Channels Below Steel Bridge* (RK41.8)

Side channels split off both sides of the river approximately 1km downstream from the Old Steel Bridge. The west channel connects to the Stillwater River at high flow. There are several areas of good spawning gravel in this channel. During low flow periods, this channel receives no surface water from the Flathead River, but there is some flow from the Stillwater River. Pockets of water remain over 70 to 80 percent of the good spawning gravel. The east channel also contains a number of pockets of spawning gravel, but only 10 percent of it remains wet during low flow.

3. *Kiwanis Lane* (RK42.0)

There is a gravel bar along the west bank below the Kiwanis Lane picnic area. The substrate was considered marginal.

4. *West Bank Above Old Steel Bridge* (RK42.2)

Approximately 200 m upstream from the Old Steel Bridge along the west bank is a backwater area. Good spawning gravel extends from halfway into this backwater downstream about 100 m along a steep eroding bank where it meets and runs along the edge of an adjacent riffle.

5. *East Bank Above Old Steel Bridge* (RK42.5)

Approximately 300 m above the bridge along the east bank is a side channel with good spawning gravel running along the east side of a gravel-cobble island.

6. *Highway 2 Backwater* (RK43.4)

Just downstream from the U.S. Highway 2 Bridge along the west shore is a side channel. There is some spawning gravel near the upstream end of this channel. Water flows through here only during higher flows. During low flow, some of the spawning gravel is wetted by ground water.

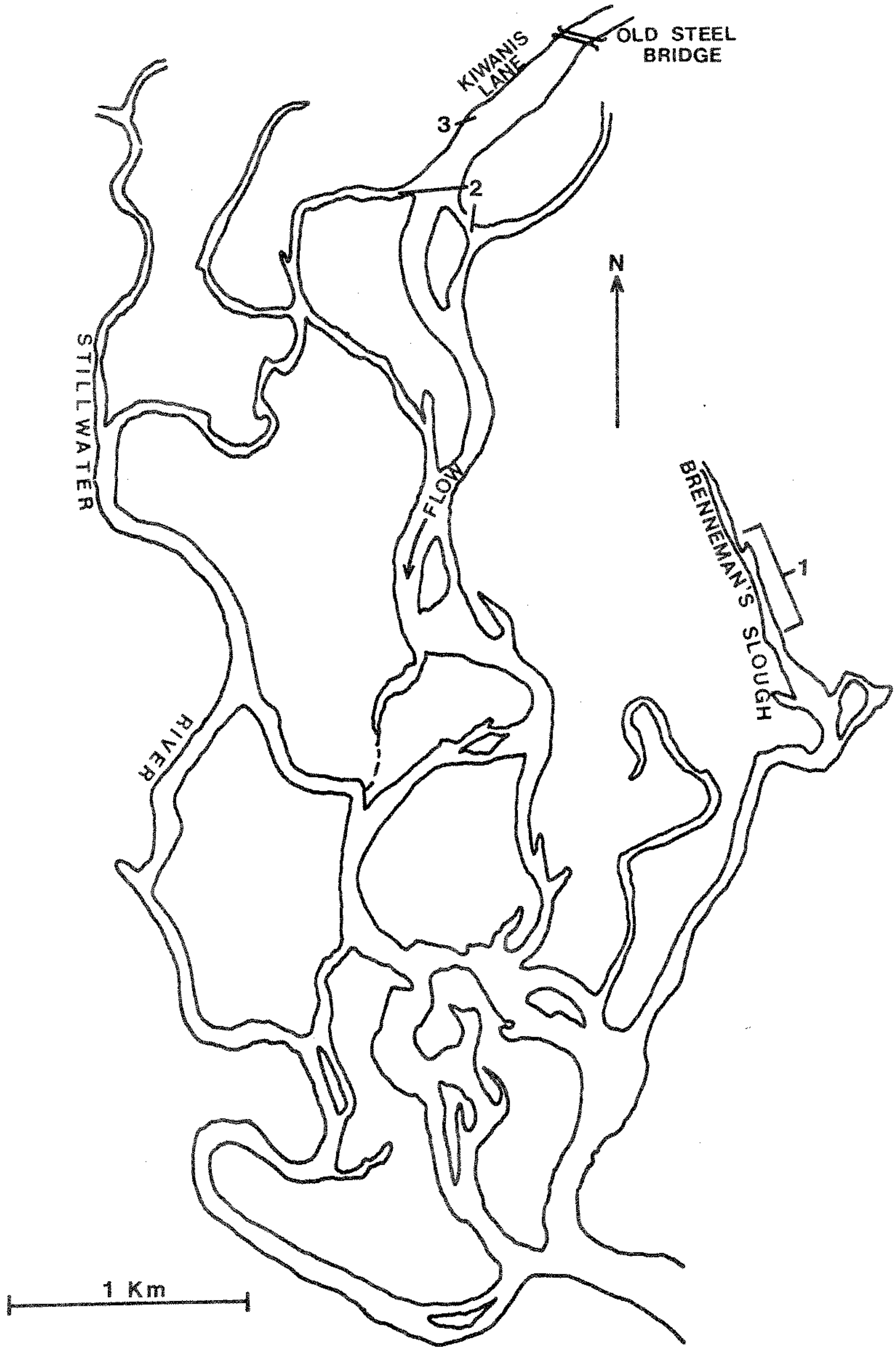

Figure 1. Map locations of spawning areas 1-3 in the mainstem Flathead River.

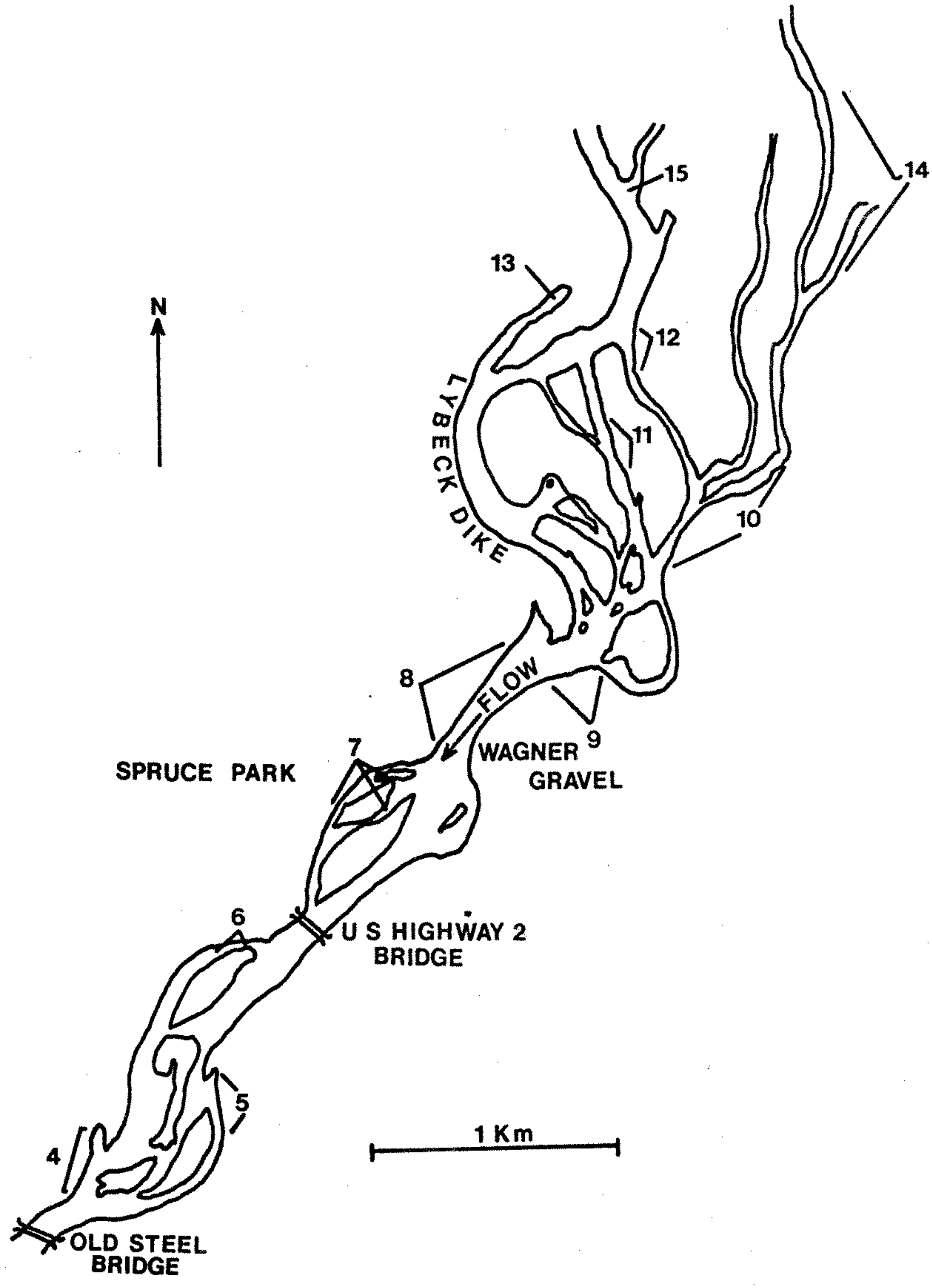

Figure 2. Map locations of spawning areas 4-15 in the mainstem Flathead River.

7. *Spruce Park* (RK44.3)

A small channel on the west side of the river near Spruce Park above the U.S. Highway 2 Bridge. Near the upstream end of this channel, where it converges with the main channel, there is a large gravel flat along the west bank. There are also some pockets of spawning gravel in the sandbars along both sides. Most of this gravel is dry during low flows, although some of the pockets trap and hold water.

8. *West Bank Above Wagner's Gravel* (RK45.5)

At the northern end of the Spruce Park Trailer Court across from Wagner's gravel is the entrance to a slough backwater area. Approximately 100 m to 150 m below the mouth of this backwater along a steep eroding bank is a small to medium sized but narrow gravel deposit. This deposit runs along the bank for about 100 m. The area was mostly dry at 4000 cfs S.F. except for isolated pockets (intergravel flow) of water.

9. *East Bank Above Wagner's Gravel* (RK45.5)

Above Wagner's gravel is a steep cut bank which extends from the mouth of the easternmost channel downstream approximately 75 meters. With the exception of the first 20 m of gravel, most of the good gravel is in water depths of one to three meters at 4000 cfs and should stay watered at low flow.

10. *East Channel below Lybeck Dike* (RK46.7)

At the big bend just downstream from Reserve Drive along the west side of Section 35, T 28N, R21W, a channel branches off the east side. Approximately 1 km up this channel are two small sloughs that extend back through the islands to the east. Each of these sloughs have some patches of spawning gravel in them. There is also some spawning gravel where these two sloughs enter the east channel. Most of this gravel is dry during low flows of 2300 cfs.

11. *Middle Channel Near Lybeck Dike*

At the mouth of the east channel mentioned in description area 10 is a large expanse of gravel suitable for spawning. Most of this area has slow velocities and suitable depths at 4000 cfs.

12. *Head of East Channel above Lybeck Dike*

At the head end of the easternmost channel split 0.5 km above Lybeck Dike is a medium to large spawning area. This area starts at the head end of the east channel split and extends downstream along a steep eroding bank (10 feet high) for about 75 m and is approximately 3-4 m wide.

13. *Reserve Drive Backwater* (RK48.3)

At the upstream end of Lybeck Dike is a backwater extending back from the west side of the river. There is some good gravel at the upstream end of this backwater with ground water seeps and large springs. Approximately 75 percent of this gravel is dry during low flows of 2300 cfs. Much of the gravel is silt covered.

14. *Easternmost Channels below Fairview (RK48.8)*

Below east Fairview spawning area (area 17) several kilometers east of the main river channel are several small side channels which split off and flow into the river at area 10. There is a relatively large amount of good spawning gravel in these channels and considerable influence from springs.

15. *Large Pool below Fairview (RK49.0)*

There is a large deep pool at the channel splits described in area 16. Good spawning gravel is distributed from the west bank of the pool out to about three meters in depth at 4000 cfs flow.

16. *Spring Area Above Reserve Drive (Fairview Area) (RK49.4)*

Approximately 1 km upstream from Reserve Drive, the river splits. The larger channel is to the west and a smaller channel to the east. Just upstream from this split, the east channel branches to the north. This branches into several channels and backwaters. The largest backwater extends 200 to 300 meters back into the island. Most of the upper half of this long slough contains good spawning gravel. Some ground water enters at the upstream end. There is also good spawning gravel in some of the other channels and backwaters in this area.

17. *East Fairview Area (near old shack) (RK50.0)*

One km up the above mentioned east channel is a medium size spawning area. This area is in the northwest corner of Section 30, T29N, R21W. Just downstream of where this channel makes a bend to the north, there is a large, deep hole containing spawning gravel with a log jam along the east bank. There is an old shack just upstream from this log jam above a cut bank on the east side.

18. *Mouth Gooderich Bayou (RK50.5)*

Gooderich Bayou enters the westernmost channel above Reserve Drive in the southeast corner of Section 23, T29N, R21W. Above the mouth of the bayou, one channel bends to the west while a small channel continues to the north and loops back to the west river channel. Approximately 100 meters up the north channel it narrows to a flowing, gravel-bottomed stream. This channel is approximately 200 meters in length, with several pockets of good gravel.

19. *East Bank below Mouth of Lower Pressentine Side Channel (RK52.0)*

Along the east bank below area 20 is an area of good spawning gravel which is in deep water just off the bank. Just below this there is a

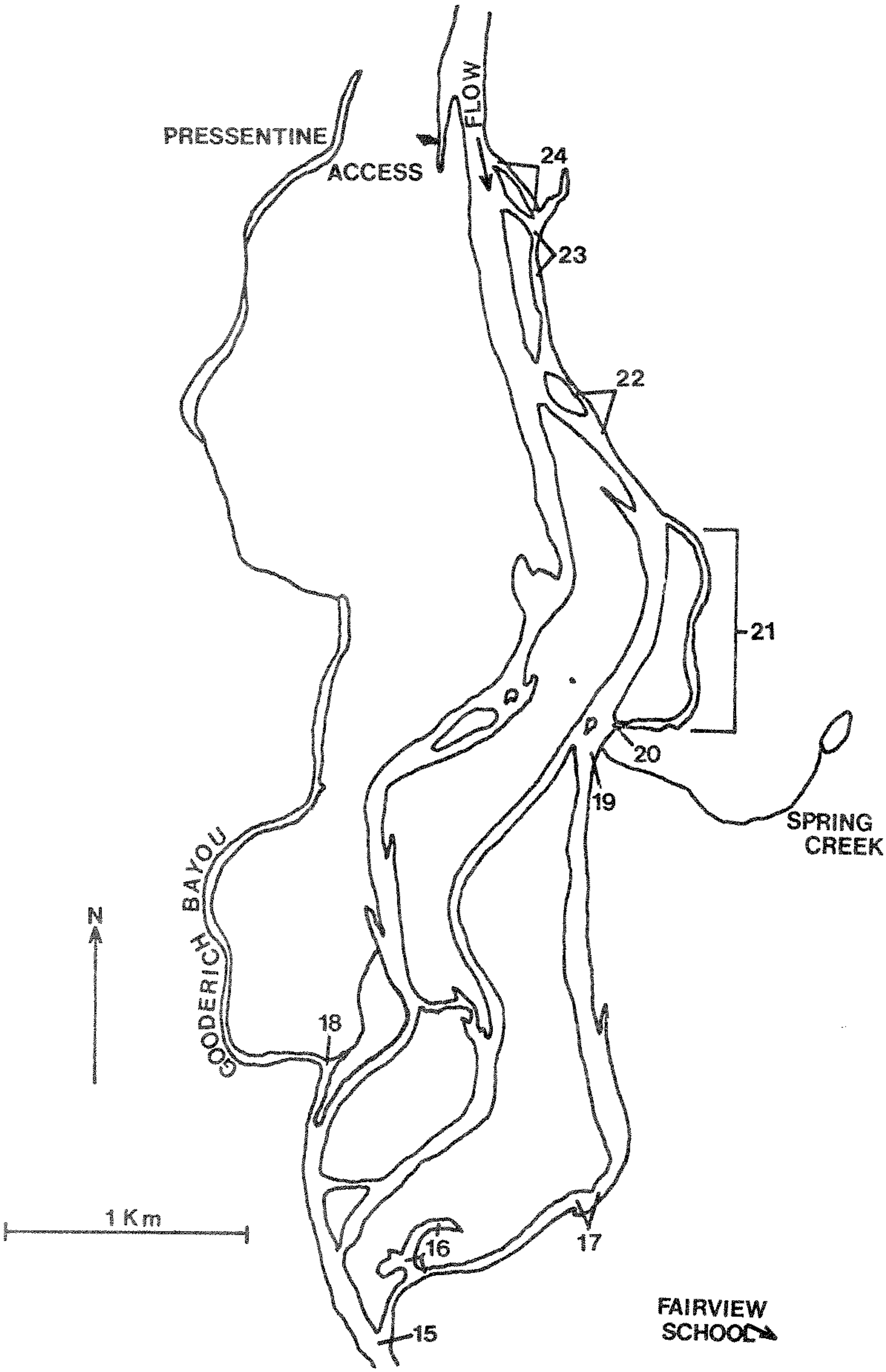

Figure 3. Map locations of spawning areas 15-24 in the mainstem Flathead River.

gravel bar which is 60 percent wetted at 2300 cfs.

20. *Mouth of Lower Pressentine Side Channel (RK52.2)*

Where the east and middle channels of the splits above Reserve Drive diverge south of center in Sec. 18, T29N, R20W, another small channel enters from the east lower Pressentine side channel. Near the mouth of this small channel along the east river bank, there is a large pool with a pumphouse on the south side. The pool contains good spawning gravel along the east bank.

21. *Lower Pressentine Side Channel (small east channel between Reserve and Pressentine (RK52.4)*

The small east channel mentioned above leaves the main channel approximately 2.4 km below Pressentine access on a bend with a high bank on the east side. There is a house visible on top of this high bank. The channel runs for approximately 1 km to the above mentioned pumphouse. There are stretches of spawning gravel along the center the full length of this channel. Most of the gravel remained wetted at 2300 cfs.

22. *Lower Pressentine Area (below the island) (RK54.4)*

At the first major channel split below Pressentine access in the northwest corner of Sec. 18, T29N, R20W, there is a small island along the east side. A large spawning area is located in the backwater east of this island and in the pool at the tip of the island. This area has good spawning gravel interspersed with some fines.

23. *Upper Pressentine Side Channel (RK55.3)*

At the head end of the island mentioned above, another channel converges from the east. This channel forms a second larger island approximately 0.8 km below Pressentine access. At the head end of this island is a small highwater channel on the east bank. A channel blocked by a large beaver dam enters the channel that runs behind the island. There is some good gravel in the area where these channels converge. This gravel extends out to the middle of the east channel.

24. *Highwater Channel Across from Pressentine (RK55.5)*

A small highwater channel is located on the east side of the main river channel approximately 200 m upstream from the large island mentioned above. It converges with the east channel that runs behind this island. Though the channel contains good spawning gravel, it is almost completely dry at 4000 cfs.

25. *Bucks Garden Area (RK59.7)*

Approximately one-third of the distance up the east channel behind the island below Buck's Gardens, two channels converge at a large gravel flat. This flat is composed of good spawning gravel. There are also pockets of gravel along both channels upstream from this flat. One-half

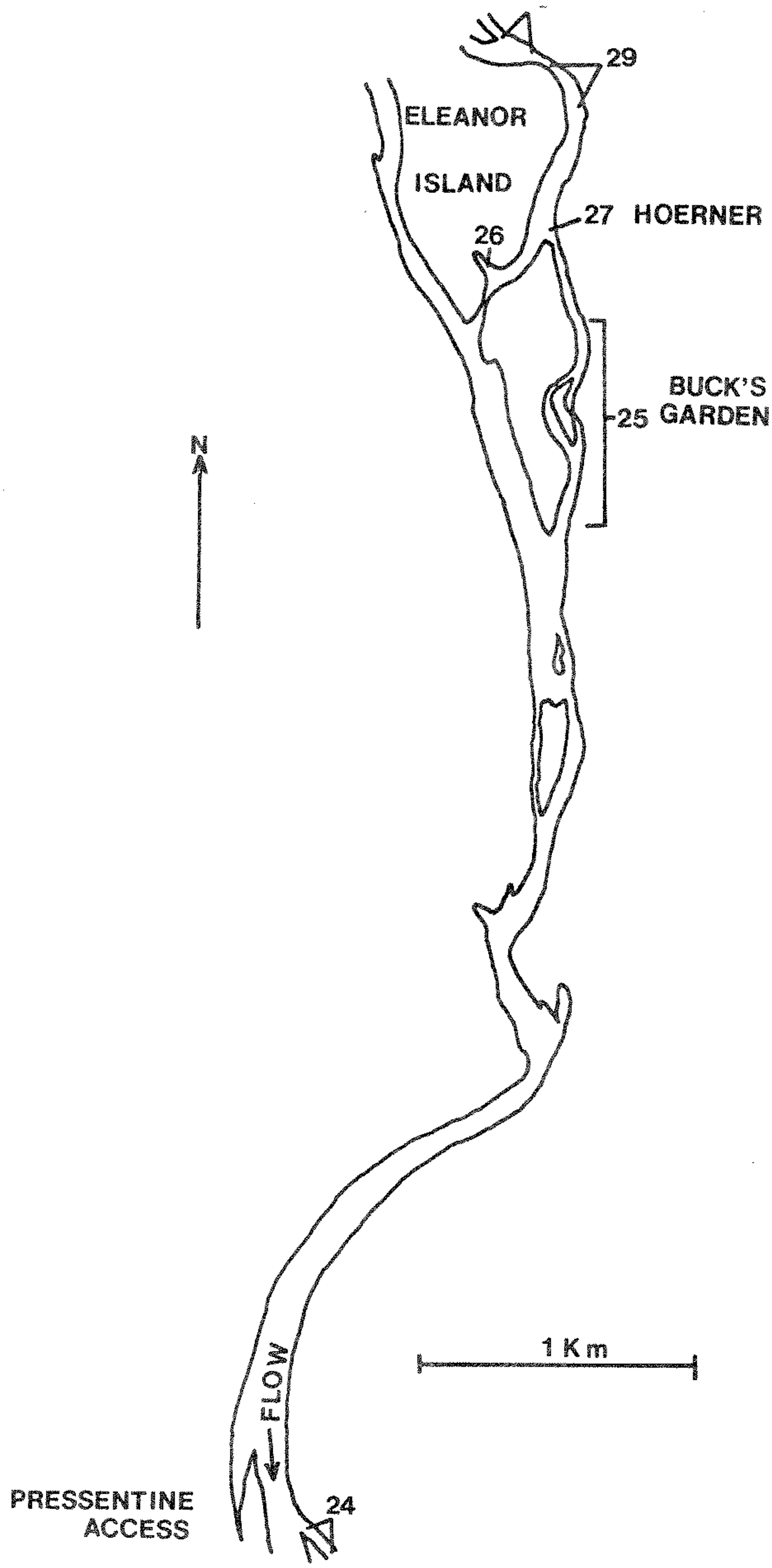

Figure 4. Map locations of spawning areas 24-30 in the main stem Flathead River.

the distance up the east channel behind Buck's Island, a large pumphouse is situated on the east bank immediately downstream of the channel divergence. Just upstream of the split channels along the east bank is an area of spawning gravel.

26. *Mouth of Slough at Southeast Side of Eleanor Island (RK60.2)*

Just west of and slightly downstream from Hoerner spawning area is a slough that extends back into Eleanor Island from the east side. A small gravel flat is at the mouth of this slough. This area has moderate current velocities at higher flow, but is mostly dry during flows of 4000 cfs.

27. *Hoerner Spawning Area -- Head End of Buck's (RK60.3)*

At the head of the channel along the east side of Buck's Island is a large area of spawning gravel along the east river bank. Some of the gravel is watered by the small channel cut. Areas of gravel extend into the main river channel.

28. *West Side of Eleanor Island (RK60.7)*

Approximately one-half the distance up the west channel around Eleanor Island along the east bank is a moderate size area of spawning gravel.

29. *Kokanee Bend -- Large Bend Below Access (RK60.8)*

Between Buck's Island and Kokanee Bend access, the east channel makes a big bend with a steep cut east bank. From the large rock field at the lower end of the bend up part way around the bend, there is marginal gravel along the east bank. This area is in the main river channel but the redds are along the bank where velocities are moderate at high flow. The area is mostly dewatered at low flow, but there is ground water coming in along the bank.

30. *Kokanee Bend Backwater at End of Road, Mouth of Side Channel (RK61.0)*

Approximately one-third of the way down the east channel is a second smaller island along the east side. The Kokanee Bend access road that extends the farthest downstream ends on a sandbar at the south end of this small island. This sandbar extends downstream to form a point with a small backwater behind it along the east bank. There is some ground water flow at this site.

31. *Kokanee Bend -- East Side Channel (RK61.5)*

Just upstream from where the river splits around the small island mentioned above, but downstream from the northernmost Kokanee Bend access, there is a small gravel area along the east shoreline. There is good gravel in the riffle at the head of this small channel and the full length of the channel.

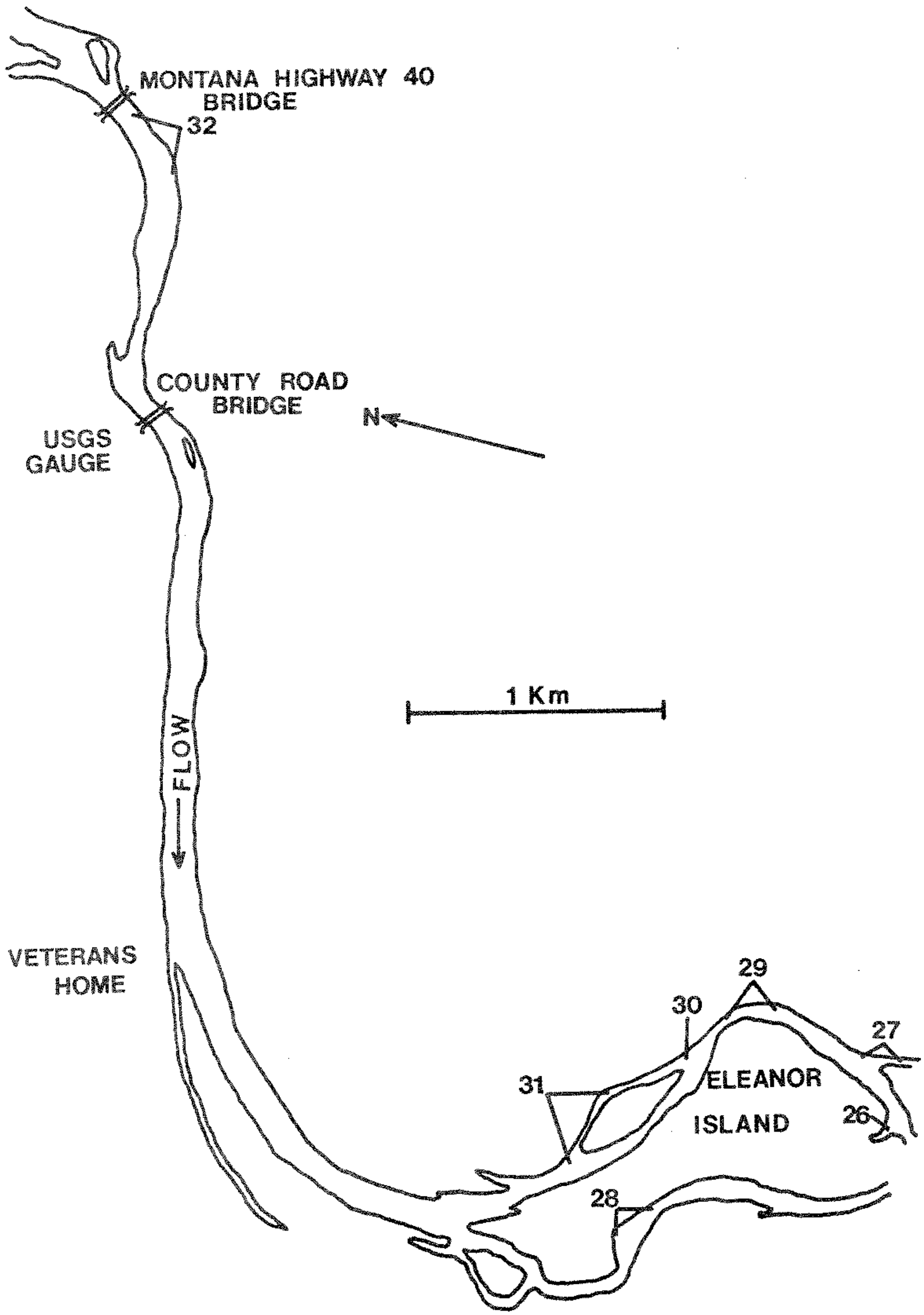

Figure 5. Map locations of spawning areas 26-32 in the mainstem Flathead River.

32. *Highway 40 Bridge* (RK65.8)

On the southeast side of the river, 200 m below the Highway 40 Bridge, is a large deposit of good spawning gravel which extends for 200 meters downstream along the bank and out in the channel around a small island.

33. *Gravel Area Near Taylor Outflow* (RK66.0)

Approximately 200 meters upstream from the Highway 40 Bridge is a gravel area along the east bank at Taylor's outflow.

34. *Large Gravel Bar Above Highway 40 Bridge* (RK66.5)

Approximately 0.8 km above the Montana Highway 40 Bridge at Columbia Falls is a large gravel bar along the east side of the river. During high flow, water runs behind it creating an island. There is some good gravel along the outside of the point at the downstream end of this bar just above the steep cut east bank. This area has some spring influence.

35. *Mouth Columbia Falls Slough* (RK67.6)

A spring slough converges with the main river on the east side approximately 200 m upstream from the above mentioned gravel bar. The mouth of this slough is in the northeast corner of Section 9, T30N, R20W. There is some good gravel at the mouth of this slough along the south shoreline. During high flows the main river cuts across the point but most of the current is broken by the fallen trees. There is also some flow coming from the slough itself.

36. *Columbia Falls Slough* (RK68.5)

The slough mentioned above extends approximately 1 km to the east. Approximately one-half way up this slough, just below where a road crosses it, the bottom changes from silt to gravel and cobble. From the road to the end of the slough there is a large quantity of good spawning gravel. The gravel is interspersed with fines, but there are many springs in the area. There were 50 redds in this area on November 9, 1979 and approximately 330 redds on November 30, 1979. This slough is fed mostly by springs and is affected little by fluctuating river levels. Few of these redds are dewatered at low flow.

37. *East Bank Above Columbia Falls Slough* (RK67.7)

Just upstream from the mouth of the above mentioned slough, the river splits around a large gravel bar. At the downstream end of the south channel, just before the convergence is a hole by a boulder along the south bank. There are gravel areas along the steep bank extending all the way up from the mouth of the slough.

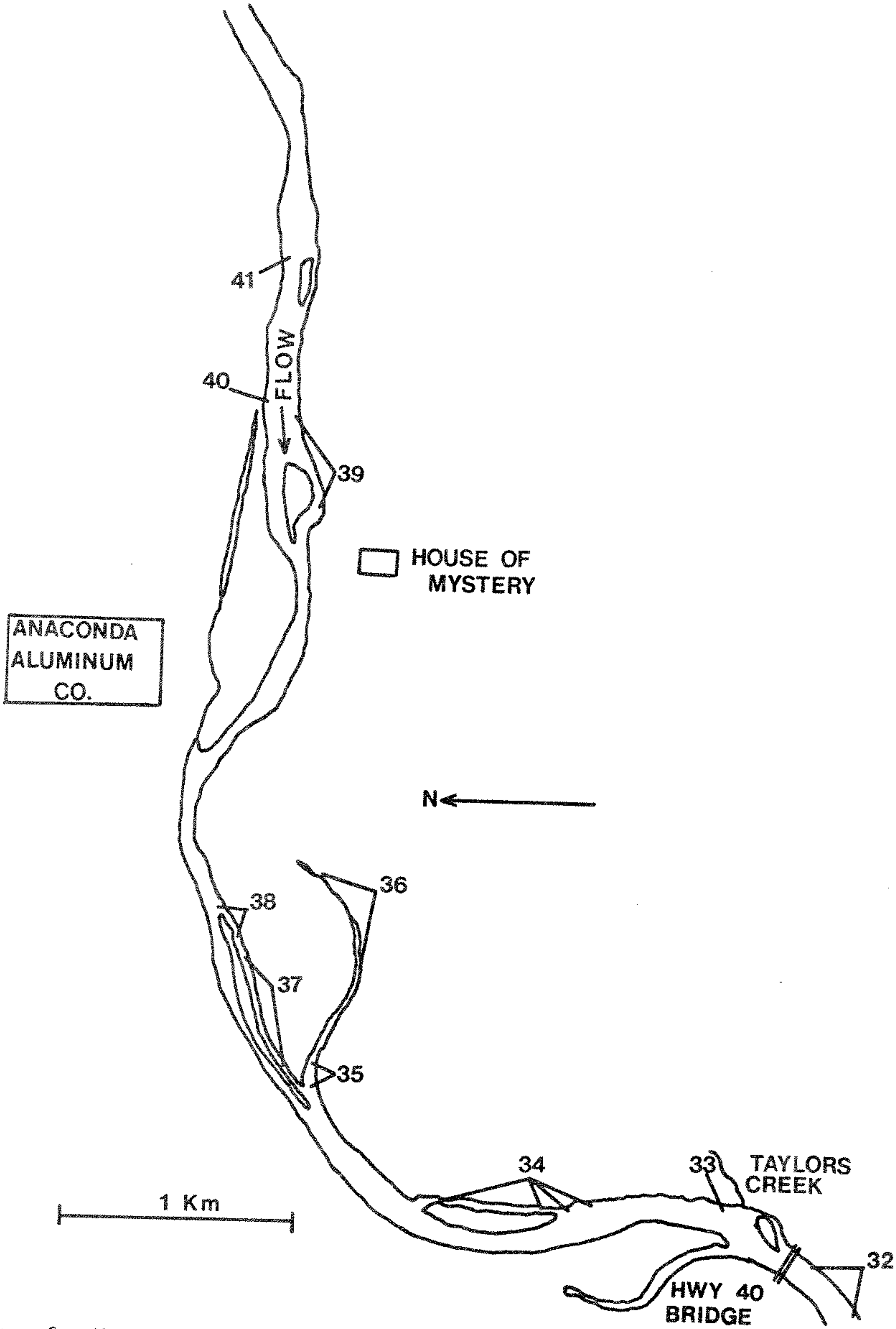

Figure 6. Map locations of spawning areas 32-41 in the mainstem Flathead River.

38. *Lower Anaconda Bar (RK68.5)*

At the head end of the south channel mentioned above there is an area of good gravel along the south bank. It is across from a large slide area on the north river bank. Most of the current flows along the north bank so the velocity over these redds is slow. During low flow nearly all of the water flows along the north bank leaving most of this area dewatered. This area is spring influenced.

39. *House of Mystery (RK69.5)*

There is an island in the river channel directly below the House of Mystery tourist stop. On the southeast side of the island in the channel along the south bank is a large amount of good spawning gravel extending for approximately 300 meters. This area contained the largest number of redds of any area in 1981. There is some ground water influence in the area.

40. *Large Flat at Upstream End of Anaconda Bar (RK70.6)*

At the upstream end of the gravel bar below the Anaconda Aluminum Company is a large gravel flat along the north bank. This area is in a large back eddy with little current over it.

41. *Deposit Behind Large Boulder near Outflow of Cedar Creek Overflow (RK70.9)*

A large boulder lies near the north bank approximately 200 m upstream of the Anaconda Bar and just below the Cedar Creek overflow outlet. A pocket of good gravel has collected behind this rock.

42. *Mouth of the South Fork - towards the Flathead River Ranch boat ramp along the south river bank. (RK73.7)*

Some good gravel is present along the center of this channel. There is some spawning gravel on the north and south banks of the river just below the confluence with the South Fork.

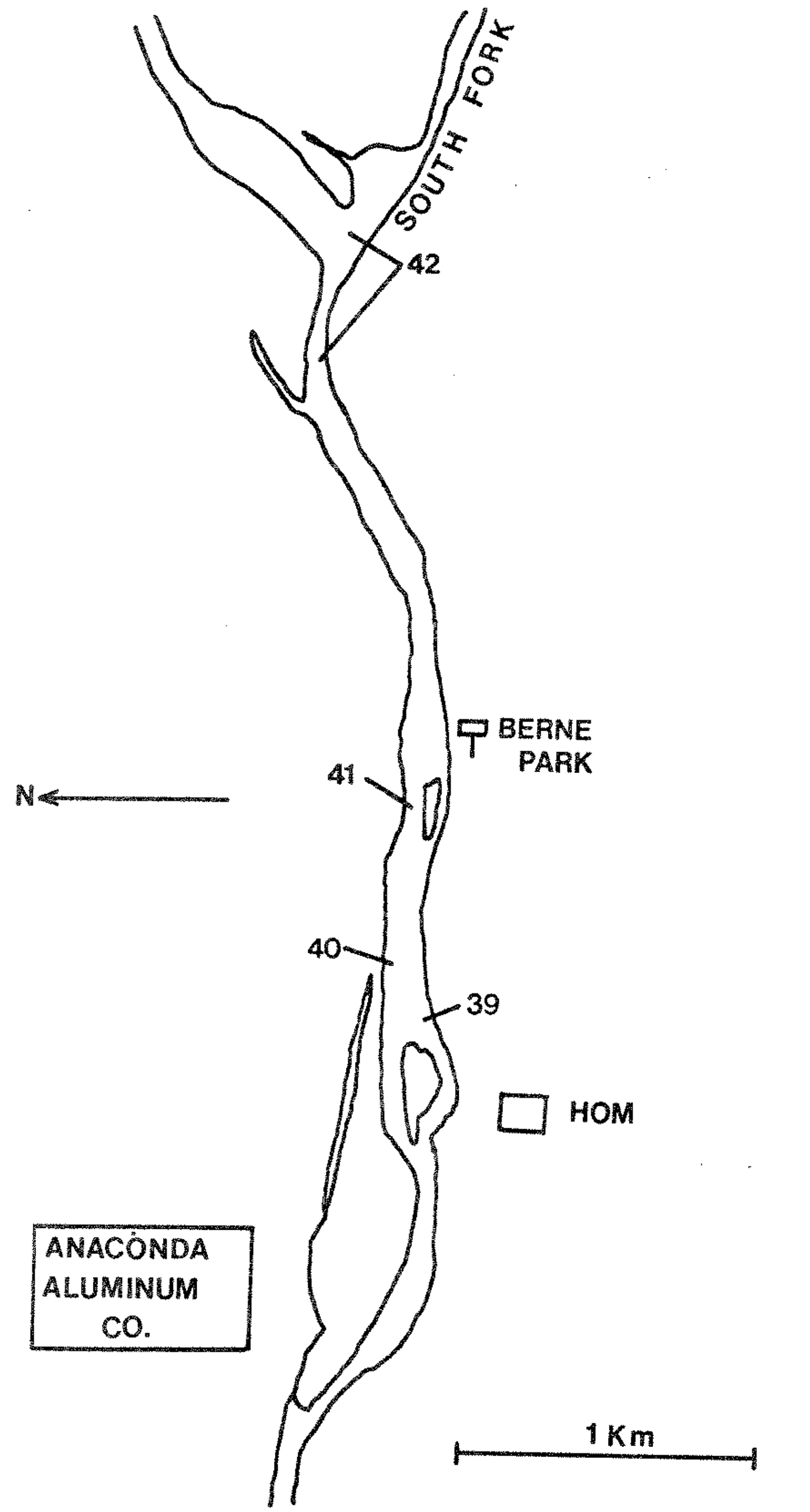

Figure 7. Map locations of spawning areas 39-42 in the mainstem Flathead River.

Table 3. Number of kokanee redds counted in the South Fork of the Flathead River on October 29, 1981.

Spawning area description	Area #	River km	Number of redds
Left bank 300-400 m above Hwy. 2 bridge	1	2.2	45
Side channel left side of island below gauge	2	5.4	5
Along rockwall directly across from USGS gauge	3	5.5	9
Gravel bar left bank 200 m below Devils elbow	4	5.9	90
2nd run-pool left bank 100 m below bend in gravel pocket between boulders	5	6.2	21
Devils elbow-left bank of big bend, gravel bar	6	6.3	125-150
3rd run-pool by small creeks on left bank	7	6.4	4
		TOTAL	310

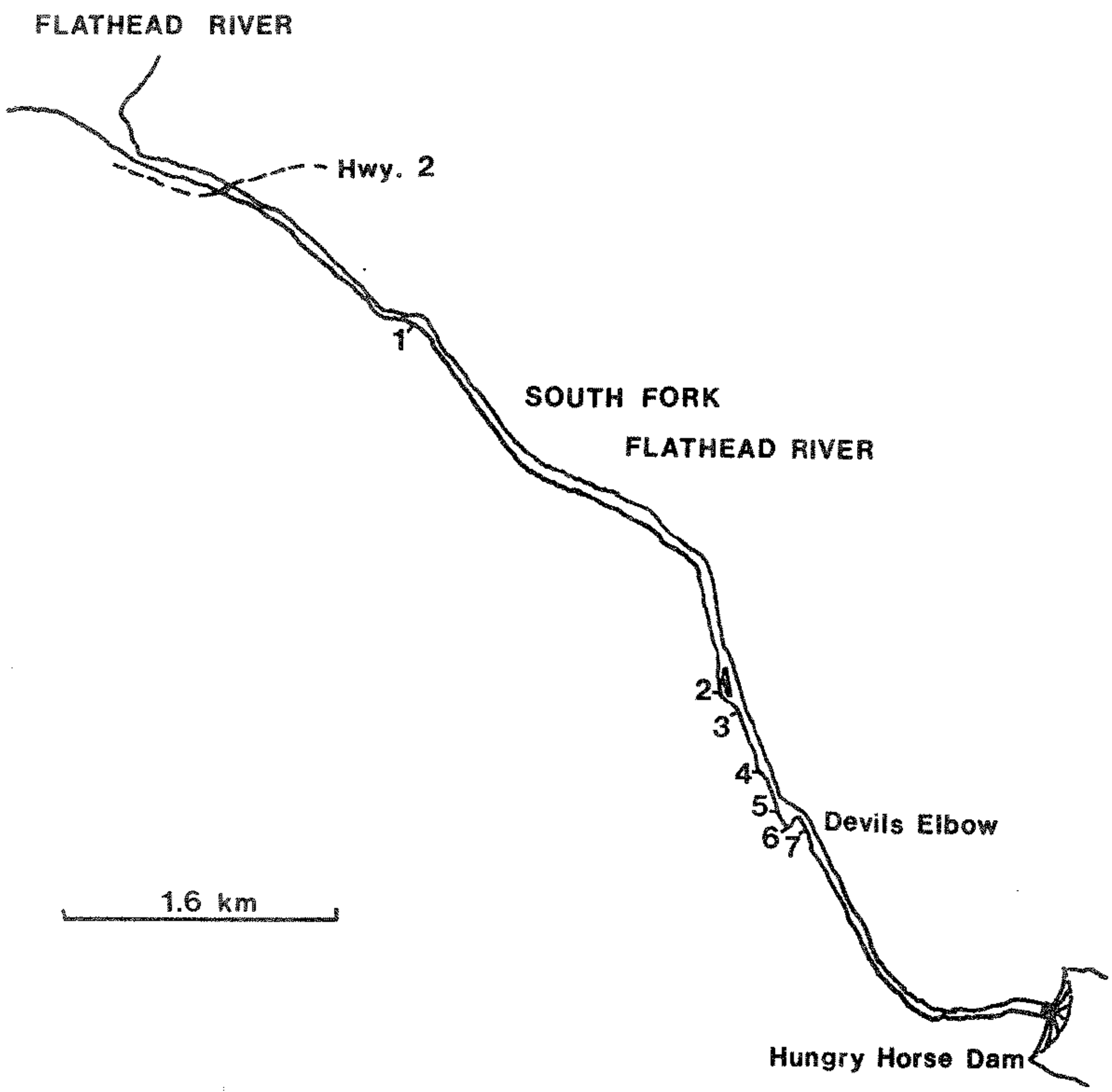

Figure 8. Kokanee spawning area locations on the South Fork of the Flathead River below Hungry Horse Reservoir.

Table 4. Number of kokanee redds counted in the Middle Fork of the Flathead River between October 20 and 22, 1981.

Spawning area description	Area #	River km	Number of redds
First run and pool of canyon	1	2.2	140
Second run/pool	2	2.6	230
Third run	3	2.9	246
Fourth run	4	3.2	170
Fifth run	5	3.5	62
First hole in canyon	6	3.8	62
Sixth run	7	4.5	23
Second hole of canyon	8	4.8	250
Third hole of canyon	9	5.1	14
Hole at tail of USGS cable	10	5.9	40
Below first house on hill	11	6.9	119
Below McDonald Creek	12	7.4	4
Run above golf course	13	8.6	25
Run below new W. Glacier bridge	14	9.1	35
New W. Glacier bridge	15	9.6	51
Run below Old W. Glacier bridge	16	10.7	307
First run below canoe dump rapids	17	12.0	360
Last tunnel	18	12.8	95
Second hole below Lincoln Cr.	19	16.0	10
Between Deerlick and Harrison Cr.	20	21.9	7
Mouth Deerlick Creek	21	22.4	66
		TOTAL	2316

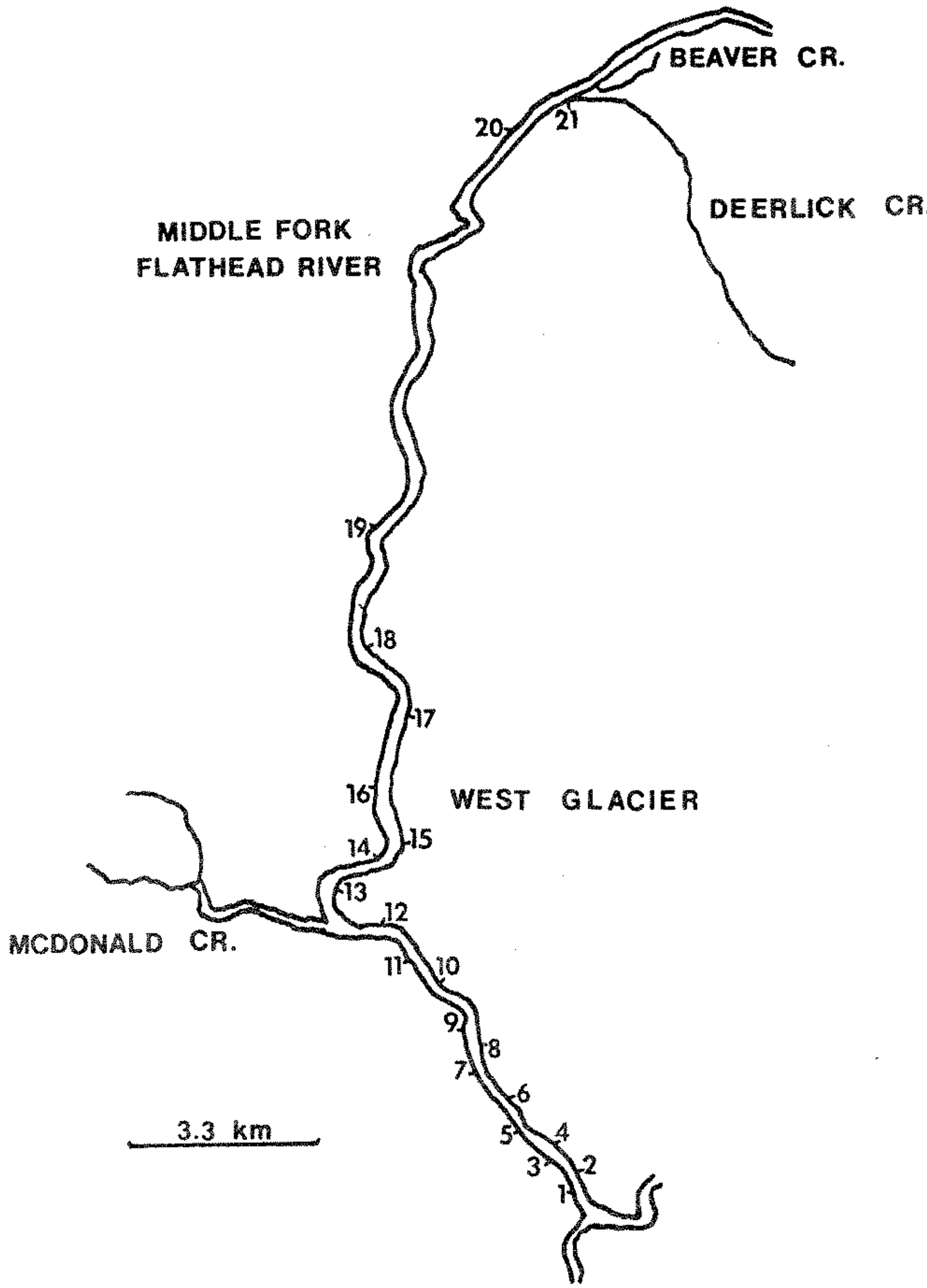

Figure 9. Kokanee spawning area locations on the Middle Fork of the Flathead River.

Table 5. Number of redds counted in Beaver and Deerlick Creeks on December 4, 1981.

Spawning area description	Area #	Creek km	Number of redds
Deerlick Creek			
Mouth of Deerlick Creek to Moccasin Creek river access	1	0-.5	48
Hwy. 2 bridge to Dalimata bridge	2	1.0-1.5	11
Gas line crossing to Hwy. Dept. shed	3	2.0-3.0	143
Beaver Creek			
Run below ford crossing to beginning of creek (including side channel by ford)	1	3.0-4.0	516
			TOTAL 718

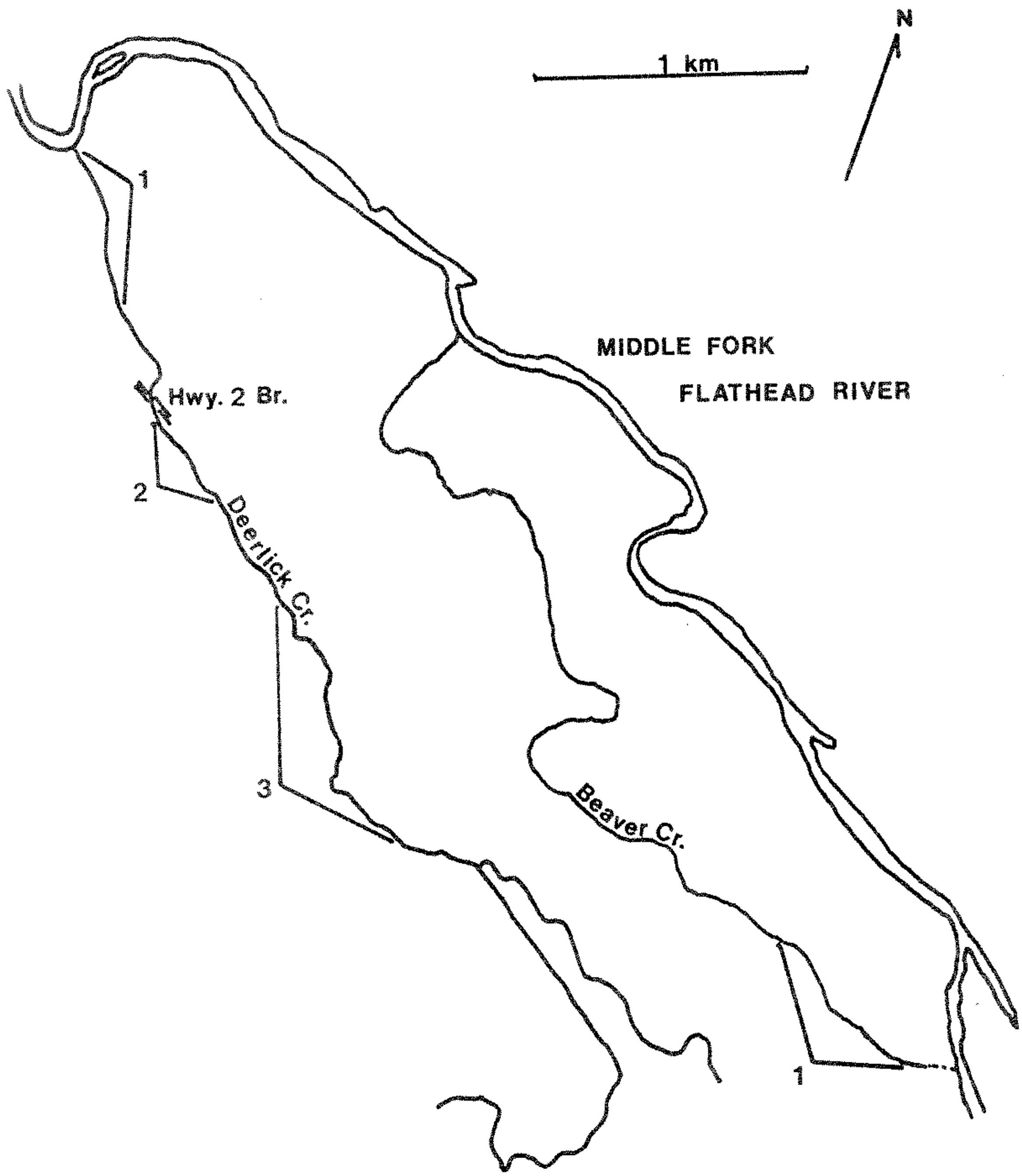

Figure 10. Kokanee spawning area locations on Beaver and Deerlick creeks.

Table 6. Number of kokanee redds counted in the Whitefish River on October 19, 1981.

Spawning area description	Area #	River km	Number of redds
0.5 km above Rose crossing	1	6.4	73
Just below Birch Grove bridge	2	9.4	192
0.6 km above Birch Grove bridge	3	10.9	44
Above side channels below bridge	4	11.8	1
Just below Tetrault bridge	5	12.9	3
Pumphouse below junk cars	6	14.6	41
0.5 km above Hodgson crossing	7	15.4	59
		TOTAL	413

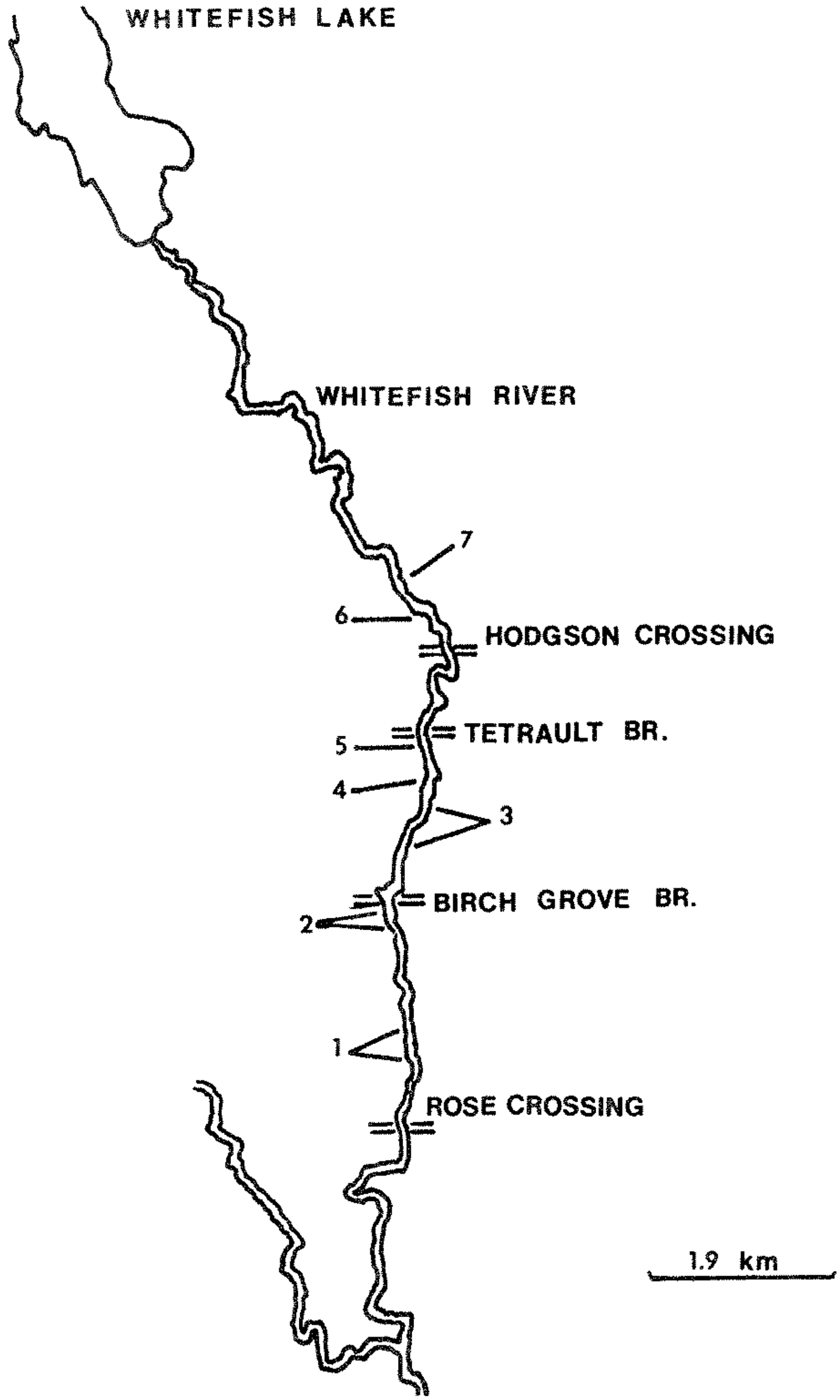

Figure 11. Kokanee spawning area locations on the Whitefish River.

APPENDIX D

Water elevation surveys of kokanee spawning areas in the Flathead River below the South Fork. Water depth contour maps of spawning areas 10, 27 and 39 in the mainstem Flathead River.

Table 1, Figures 1-3

Table 1. Difference in water surface elevation (feet) between 4,000 cfs and 2,300 cfs in some spawning areas of the Flathead River below the South Fork.

Spawning area[1/]	River km	Drop in elevation (ft) between 4000 and 2300 cfs
7	44.3	.65
10	46.7	.83
15	49.0	.77
18	50.5	.49
20	52.2	.68
21	52.4	.66
22	54.4	.82
27	60.3	.77
28	60.7	.81
31	61.5	.68
---[2/]	62.0	.93
---[2/]	64.8	1.22[3/]
37	68.5	1.27

1/ See Appendix C for location and description of spawning area.
2/ Not utilized by kokanee spawners.
3/ Gauge site near Columbia Falls.

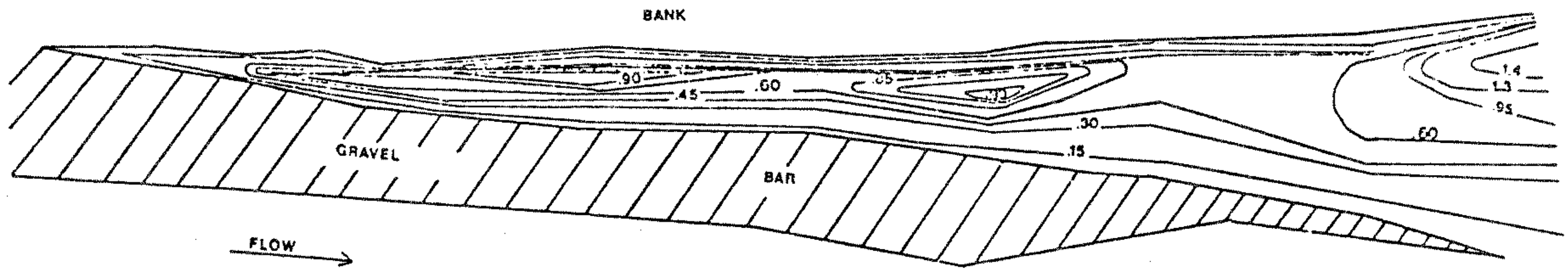

Figure 1. Map of water depths in kokanee spawning area number 10 in the Flathead River at the 4,000 cfs spawning flow.

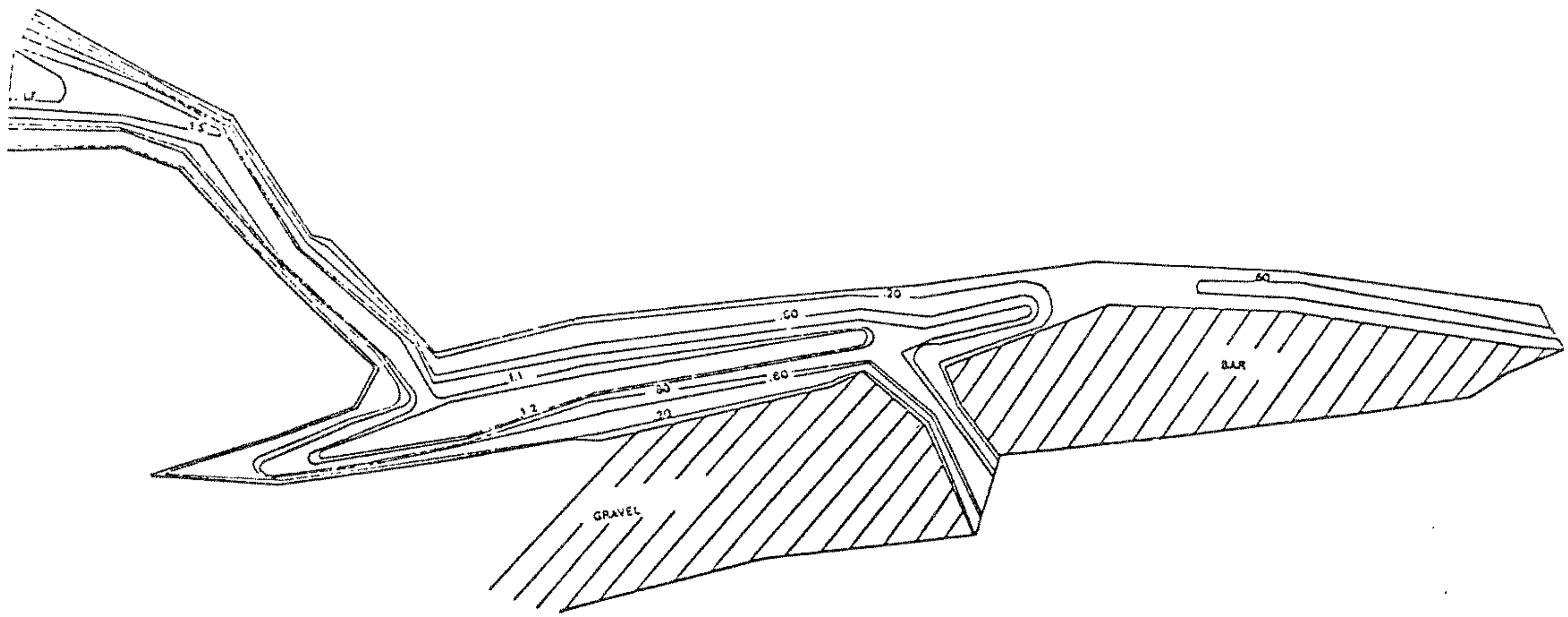

Figure 2. Map of water depths in spawning area number 27 in the Flathead River at the 4,000 cfs spawning flow.

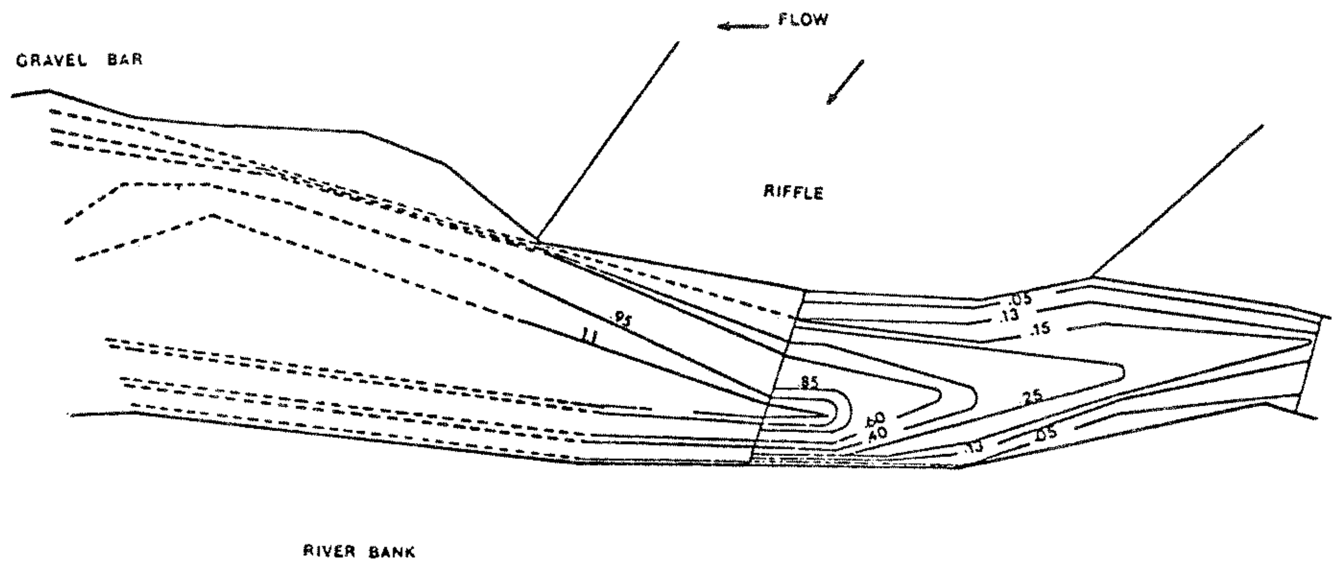

Figure 3. Map of water depths in spawning area number 39 on the Flathead River at the 4,000 cfs spawning flow. Dotted intervals are estimates based on limited data.

APPENDIX E

Microhabitat measurements of kokanee redds in the Flathead River system.

Table 1, Figures 1 and 2

Table 1. Measurements of kokanee redds in areas of the Flathead River below the South Fork and the Middle Fork River during December, 1981 and January, 1982.

	Measurements of redds				
	Main Flathead River Area 1/			Middle Fork River Area	
	10	12	27	16	12
Date	1/25/82	1/27/82	1/18/82	12/17/81	12/17/81
Number redds measured	26	24	20	16	9
Mean length of redd	1.7	1.5	1.5	.7	.8
Mean width of redd	.8	1.3	1.0	.4	.4
Standard deviation length	.4	.4	.3	.4	.5
Standard deviation width	.2	.2	.2	.2	.2

1/ See Appendix C for description and location of spawning areas.

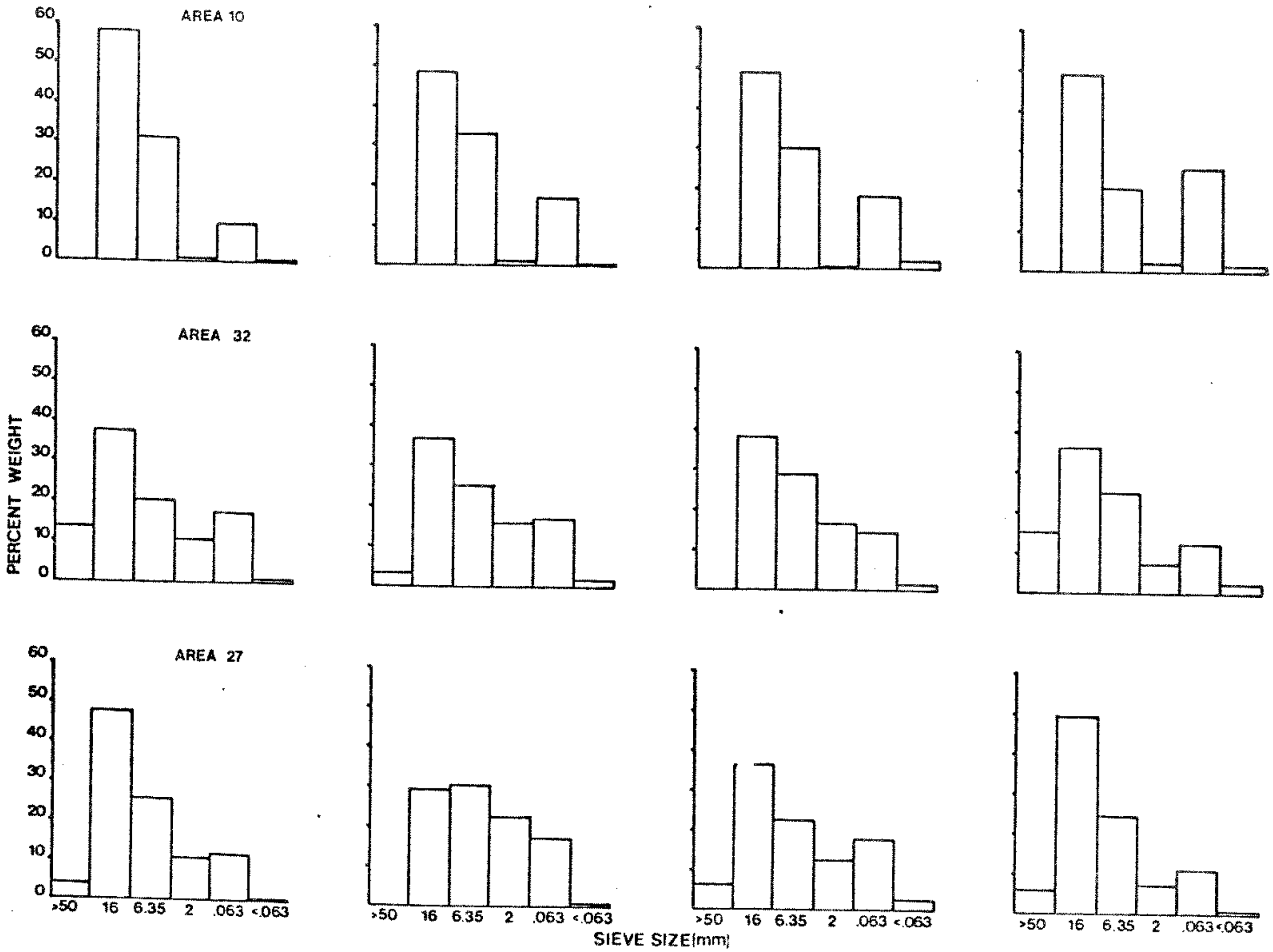

Figure 1. Substrate size compositions (percent by weight) in kokanee redds at spawning areas in the Flathead River.

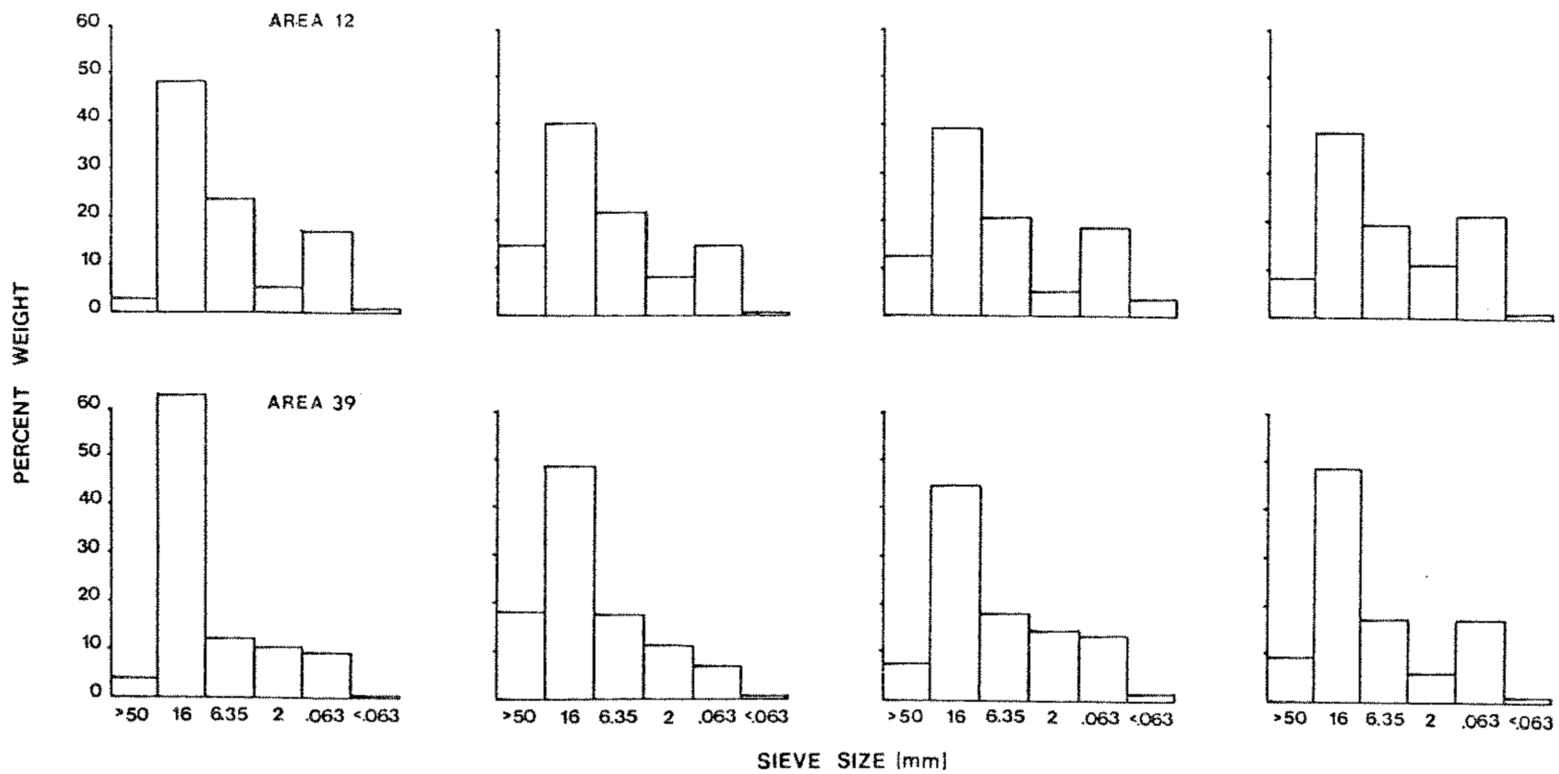

Figure 2. Substrate size composition (percent by weight) in kokanee redds at spawning areas in the Flathead River.

Table 2. Survival and development of kokanee eggs planted in fiberglass screen bags in four large gravel areas of the Flathead River below the South Fork (River km of each area in parentheses).

Area	Date	Number of bags harvested	Number of live eggs	Number of dead eggs	Percent of live eyed eggs	Number of live sac fry	Number of dead sac fry	Percent survival of eggs and sac fry
Old Red Bridge[1/] (RK 65.0)	12/22/81	1	91	8	0	0	0	92
	1/14/82	2	79	118	51	0	0	20
	3/01/82	5	2	498	0	0	0	0-4
Main channel[2/] above kokanee bend (RK 63.0)	1/14/82	2	199	1	98	0	0	98
	3/01/82	2	182	22	100	0	0	89
	4/09/82	3	71	105	100	74	6	57
West channel[3/], Eleanor Island (RK 61.0)	1/14/82	8	794	8	98	0	0	97
	3/26/82	13	1,227	73	100	6	0	94
	4/09/82	1	0	10	0	81	5	84
Below Old[4/] Steel Bridge (RK 40.0)	12/31/81	1	98	2	0	0	0	98
	3/26/82	2	181	19	100	0	0	90

1/ Eggs were planted on 11/11/81.
2/ Eggs were planted on 11/12/81.
3/ Eggs were planted on 11/12/81.
4/ Eggs were planted on 11/17/81.

Table 3. Survival and development of kokanee eggs planted in fiberglass screen bags in the Flathead River at various water levels in relation to the 2300 cfs incubation study flow (IF). See Appendix C for description of spawning areas.

Area	Date	Eggs	Percent survival: 0.2 feet above IF	0.0 feet at IF	0.2 feet below IF	0.4 feet below IF	Percent of live eggs eyed	Percent sac fry
Area 27	12/15/81	800	.5	1.5	98	97.5	----	---
	1/14/82	800	0	10	97.5	99	0.5	0
	3/01/82	770	0	6.5	97.7	92	98.9	0
	4/10/82	405	0	0	46	84.0	100	0.7
Area 31	12/15/81	900	0	44	98.5	99	----	---
	1/14/82	813	0	78.7	99	99.5	4	0
	3/01/82	784	0	0	77.2	97.9	98.5	0
	4/10/82	405	0	0	94.2	88.2	100	1.6
Area 38	12/15/82	450	85	97	96	99	----	---
	1/14/82	445	82.6	82.4	76.7	93.2	91.1	0
	2/26/82	198	45	58.2	----	----	100	61.8
	3/01/82	246	----	----	91.6	86.1	97.6	3.7
	4/09/82	449	0[1]	51	3[1]	53.6	0	100

1/ Egg bags were covered and filled with sand.