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IMPACTS OF HUNGRY HORSE DAM ON AQUATIC LIFE IN THE FLATHEAD RIVER

ANNUAL REPORT 1980

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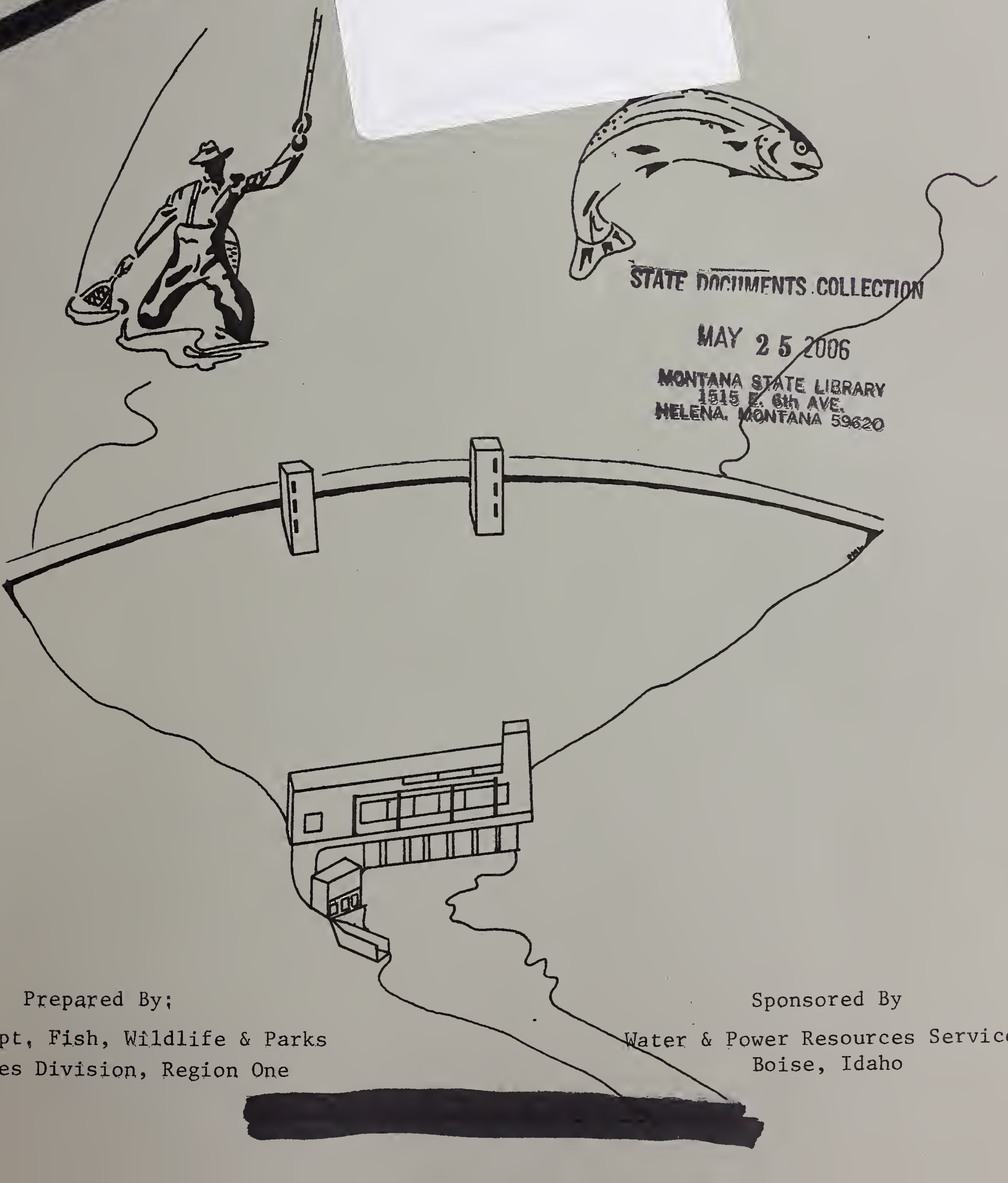

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Sponsored By
Water & Power Resources Service
Boise, Idaho

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LOWER FLATHEAD RIVER AQUATIC RESOURCES STUDY - 1980

MONTANA DEPT. OF FISH, WILDLIFE AND PARKS
FISHERIES DIVISION

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May, 1980

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PERSPECTIVES

Hungry Horse Dam was completed in 1953. At that time it was the fourth largest and highest concrete dam in the world. The dam, 6km upstream from the mouth of the South Fork of the Flathead River, created a reservoir approximately 66km long with a storage capacity of 4,267.9 x $10^6 m^3$ (3.47 x 10^6 acre-feet). It is operated both for flood control and power production. The crest of the dam is 1087m above sea level. Four penstocks are located 75m below the crest. With four generators operating, the powerplant has a nameplate capacity of 285mw.

Operation of the dam has altered normal discharge and temperature regimes from the South Fork and modified conditions in the main Flathead River. The present minimum flow from Hungry Horse is $4.2 m^3/sec$ (150 cfs) and peak discharge is approximately $323.1 m^3/sec$, (11,417 cfs). The influence of discharge from Hungry Horse on the main Flathead River is modified by the combined natural flows from the North and Middle Forks. Aquatic biota which are significantly affected by Hungry Horse discharge include kokanee salmon (*Onchorhynchus nerka*), westslope cutthroat trout (*Salmo clarki bouvieri*), mountain whitefish (*Prosopium williamsoni*) and aquatic invertebrates.

The Hungry Horse project is part of the Bonneville Power Administration power grid. Operation of the project is determined in concert with the complex network of power producing systems and power needs throughout the northwest. Water leaving Hungry Horse passes through 19 dams before reaching the Pacific Ocean.

To meet the anticipated need for more peak power in the northwest, many existing baseload or existing peak power projects are being reviewed for increasing power production. Several alternatives are presently being assessed for the Hungry Horse Dam project. These include:

	Alternative	Peaking power (mw)	Discharge ($m^3/sec.$)
1.	existing	328	323.1 (11,417cfs)
2.	rewind existing generators	385	341 (12,060cfs)
3.	powerhouse addition	55	383 (13,367cfs)
4.	combine 2 and 3	440	390.1 (13,783cfs)

These options are being assessed both with and without a reregulating dam. The dam would be located on the South Fork and be approximately 12m high with a storage capacity of 2.40 x $10^6 m^3$ - (1950 acre feet). These alternatives would increase peaking capacity of the project and could increase total annual power production by ten percent.

This study was undertaken to assess impacts of the various power alternatives and operating regimes on the aquatic biota in the Flathead River. Preliminary comments on the impacts of the project will appear in an Appraisal Level Study.

These comments and recommendations are also contained in Appendix A of this report.

To more completely evaluate the influence of the project alternatives on the aquatic biota, this study was begun in April,1979. Objectives of the study include:

A. Fishery Study

1. To provide the Water and Power Resources Service with the Department of Fish, Wildlife and Park's best estimate of minimum flows 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 dischrge fluctuations on survival of incubating whitefish and kokanee salmon eggs in the Flathead River below the South Fork junction.

3. To quantify the suitable kokanee habitat at staged flows in Flathead River Basin on additions of flow increments with one to four turbine generators; that is, natural flows from above the South Fork plus increments of approximately 2,500 cfs per generator.

4. 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.

B. Aquatic Invertebrate Study

1. To estimate biomass and species diversity and to compare life history characteristics of major macroinvertebrates in the Flathead River above and below the confluence of the South Fork and in the South Fork of the Flathead River below Hungry Horse Dam.

2. To make estimates of macroinvertebrate habitat loss as related to extended periods of minimum discharges from Hungry Horse Dam. To compare the biomass, composition and life histories of the macroinvertebrate communities altered by reservoir discharges. Cooperation and coordination with the Flathead Basin Study under the Environmental Protection Agency's (EPA) guidance will be necessary to ineterpret altered and non-altered riverine relationships.

C. Temperature Study

1. To estimate desirable seasonal water temperatures to release if it is determined that a multiple outlet discharge structure is significantly beneficial to game fish and macroinvertebrate production.

This report contains results from the first year of study and anticipated research for next year. Some of these preliminary data were used in our most recent comments on the various project alternatives (Appendix A-2 & 3) although it must be remembered that these are preliminary recommendations.

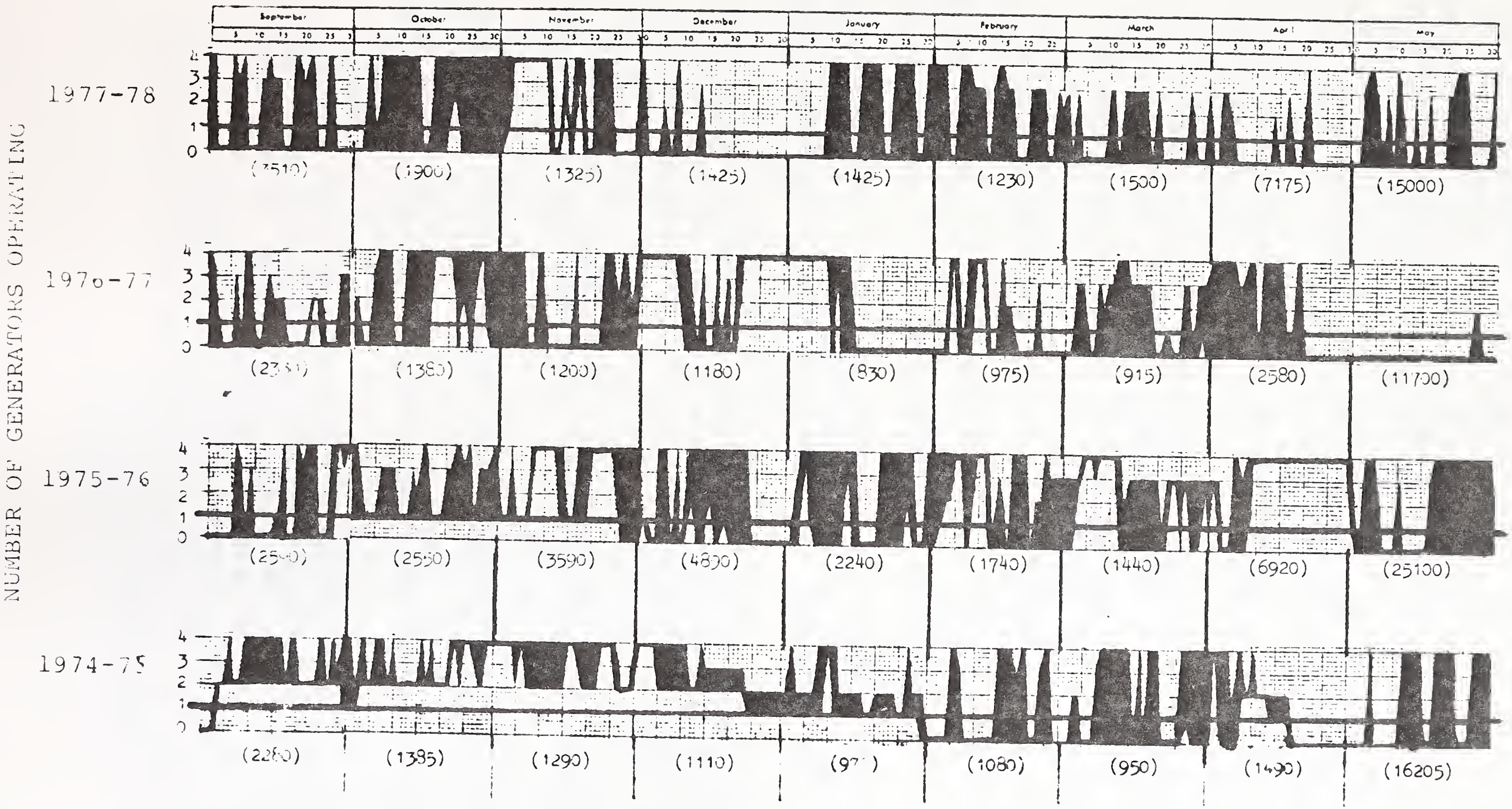


Figure 1. Daily maximum and minimum flow fluctuations in the Flathead River below Columbia Falls as influenced by operational discharges from Hungry Horse Dam during the kokanee spawning and incubation period (September-May 1974-1978). Discharges are expressed in the number of generators operating (0-4) with operation occurring at or above the one generator reference line. One generator is equivalent to approximately 2500 cfs discharge. The numbers in parentheses are the average monthly flows of the Flathead River below Columbia Falls excluding the South Fork. Compiled by D. A. Hanzel and S. Rumsey, Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

To compare the relative benefits derived from the various alternatives, a common unit of measure was established to be Fisherman Satisfaction Units (FSU). These units are a value judgement as to the relative worth an angler places on capturing various size groups of the different sport fish on a scale of 1 to 10 (Appendix A-1). For example, an adult bull trout larger than 610mm (24 inches) was assigned a value of 10 while cutthroat trout less than 229mm (9 inches) was given a value of only 2. In general, impacts of each alternative on the recruitment of fish into the fishery were used to determine changes in Fisherman Satisfaction Units.

Certain assumptiosn about the operation of the project were made before the alternatives could be evaluated. These included modeling mean monthly flows for Hungry Horse based on historical flow data, existing operation constraints in the BPA system and projected power needs. It was assumed that peak flows would occur on a regular weekly and daily schedule.

These predictable release patterns are the essence of any benefits that would be derived from the reregulating dam.

Various operational discharges considered in Appendix A-2 and A-3 include:

Peak	5 days per week	8 hours per day	52 weeks per year
Peak	5 days per week	8 hours per day	48 weeks per year
Peak	5 days per week	6 hours per day	48 weeks per year
Peak	4 days per week	8 hours per day	48 weeks per year

It was determined that negative impacts would result from all power alternatives without the reregulating dam. Approximately a 25 percent increase over present good years in FSU's would result for all power alternatives during average or above average water years with the reregulating dam and a normal peaking operation schedule. Although it was not an alternative it should be pointed out that a constant baseload operation would be the most satisfactory for maintaining the aquatic biota in the main Flathead River. Natural high spring flows from the North and Middle Forks provide the mechanism for channel maintenance.

Balancing the needs of the aquatic biota with the unnatural flow regime from Hungry Horse is complex even with a predictable flow regime. However, the benefits of the expansion project may be negligible or negative compared to existing conditions if a predictable peaking operation for Hungry Horse is not adopted.

Presently, year-to-year variation in mean monthly discharge is quite variable. This is also true of weekly and daily discharge patterns (Figure 1). From this figure it can be seen that on many occasions peak discharges occurred non-stop for weeks at a time and were often followed by days or weeks of no generation at all. The small storage capacity of the reregulating dam could not significantly ameliorate this type of operation. An example of the effect of these flow variations is contained in the stream flow-fish length section which is part of the kokanee salmon studies.

Description of Study Area

The Flathead River drains 21,876km^2 of southeast British Columbia and northwest Montana (Figure 2). The Flathead is the northeastern most drainage in the Columbia River Basin. Three forks of approximately equal size drain the west slope of the continental divide.

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

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

The upper South Fork is also a wild river, flowing out of the Bob Marshall Wilderness to Hungry Horse Reservoir. A short stretch of the South Fork, from the headwaters of Hungry Horse Reservoir upstream to Spotted Bear, is classified recreational. The lower South Fork is regulated by flows from Hungry Horse powerhouse. Vertical water level fluctuations in the lower South Fork can be as much as 2.5m due to peak hydroelectric energy production.

The main stem Flathead River is classified a recreational river from the confluence of the North and Middle Forks to the confluence of the South Fork. Downstream of the South Fork, flows in the main stem are largely regulated by operation of Hungry Horse powerhouse.

Peak flows in the main stem normally occur in late May or early June, coinciding with peak runoff in the North and Middle Fork drainages (Figure 3). Except for peak runoff periods, the hydrograph of the main stem mirrors that of the South Fork.

Water temperatures in the main stem are also partially regulated by Hungry Horse powerhouse. Hypolimnial water released from Hungry Horse Dam lowers summer water temperatures and elevates winter water temperatures in the main stem (Figure 4). Flow and temperature fluctuations caused by Hungry Horse operations can have profound effects upon the biota of the South Fork and main stem Flathead Rivers.

The substrate material in the Flathead River consists of large cobble interspersed with smaller gravels and sand. In the South Fork, the smaller materials have been removed from the surface layer of rocks by the clearwater discharges from Hungry Horse Dam. The reservoir acts as a settling basin for inorganic materials so there is no redeposition of the finer gravels and sand in the tailwater area.

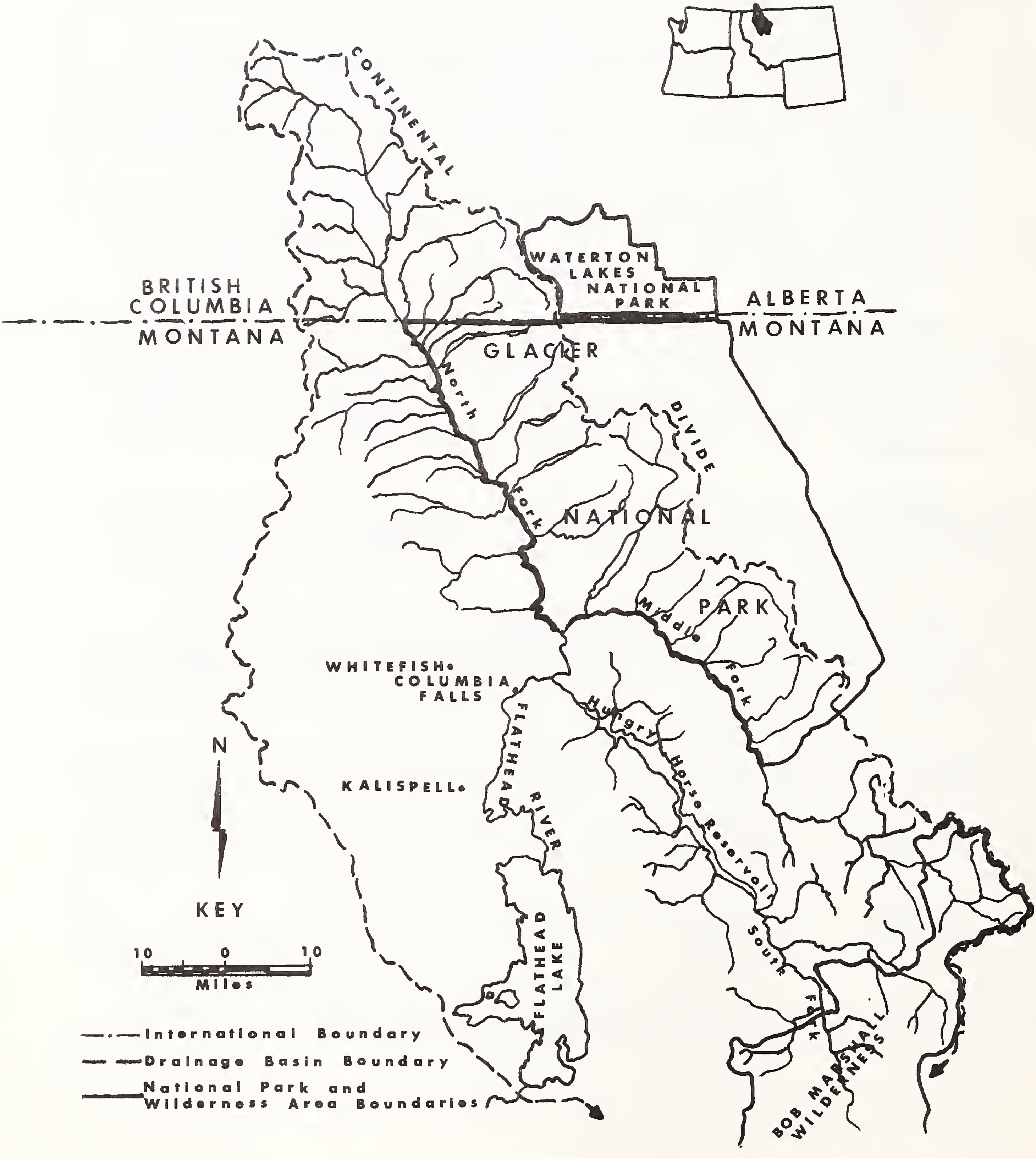


Figure 2. The Upper Flathead River Drainage

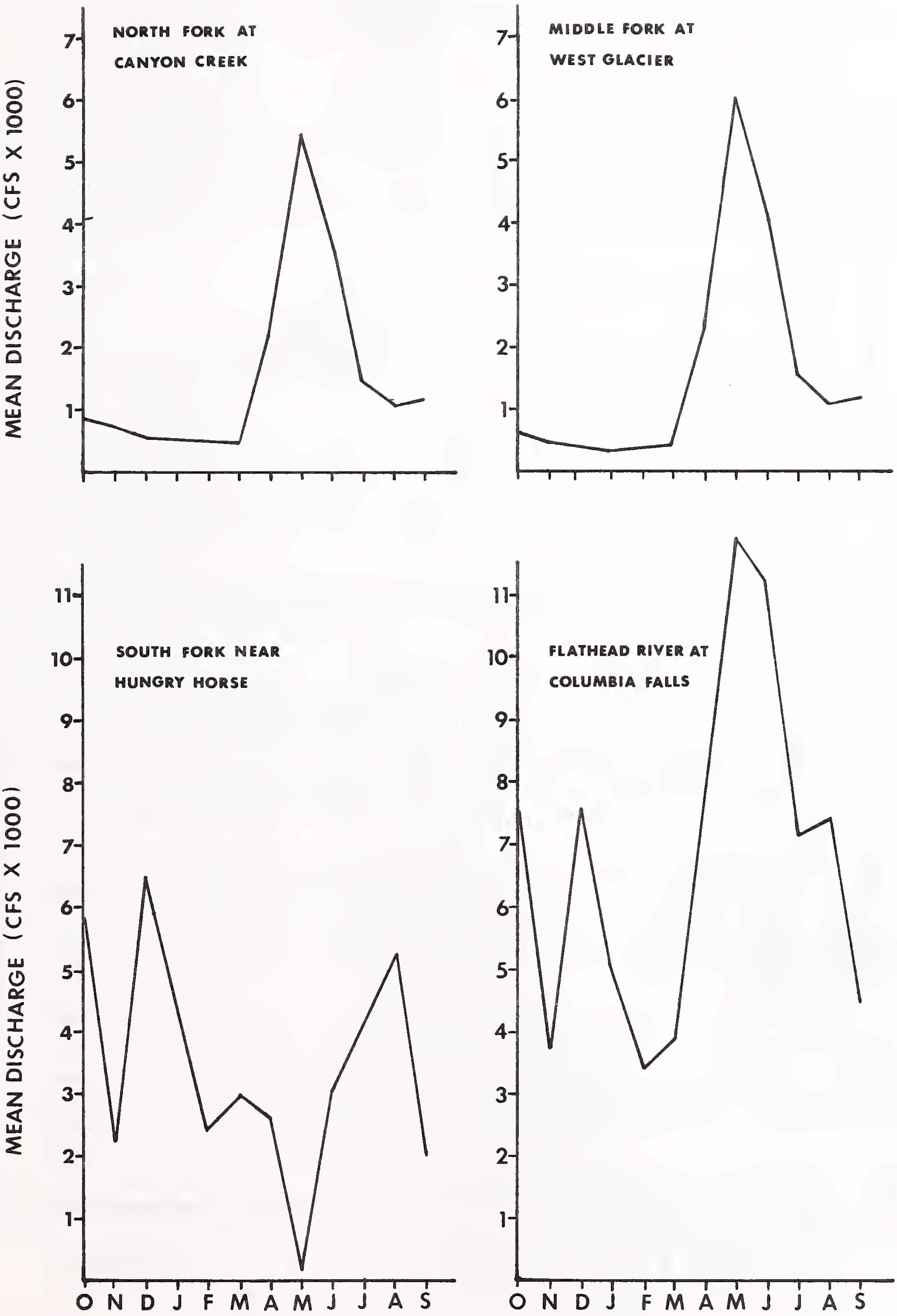


Figure 3. Mean monthly flows of the North, Middle and South Forks of the Flathead River and the main stem Flathead River. Water Year 77

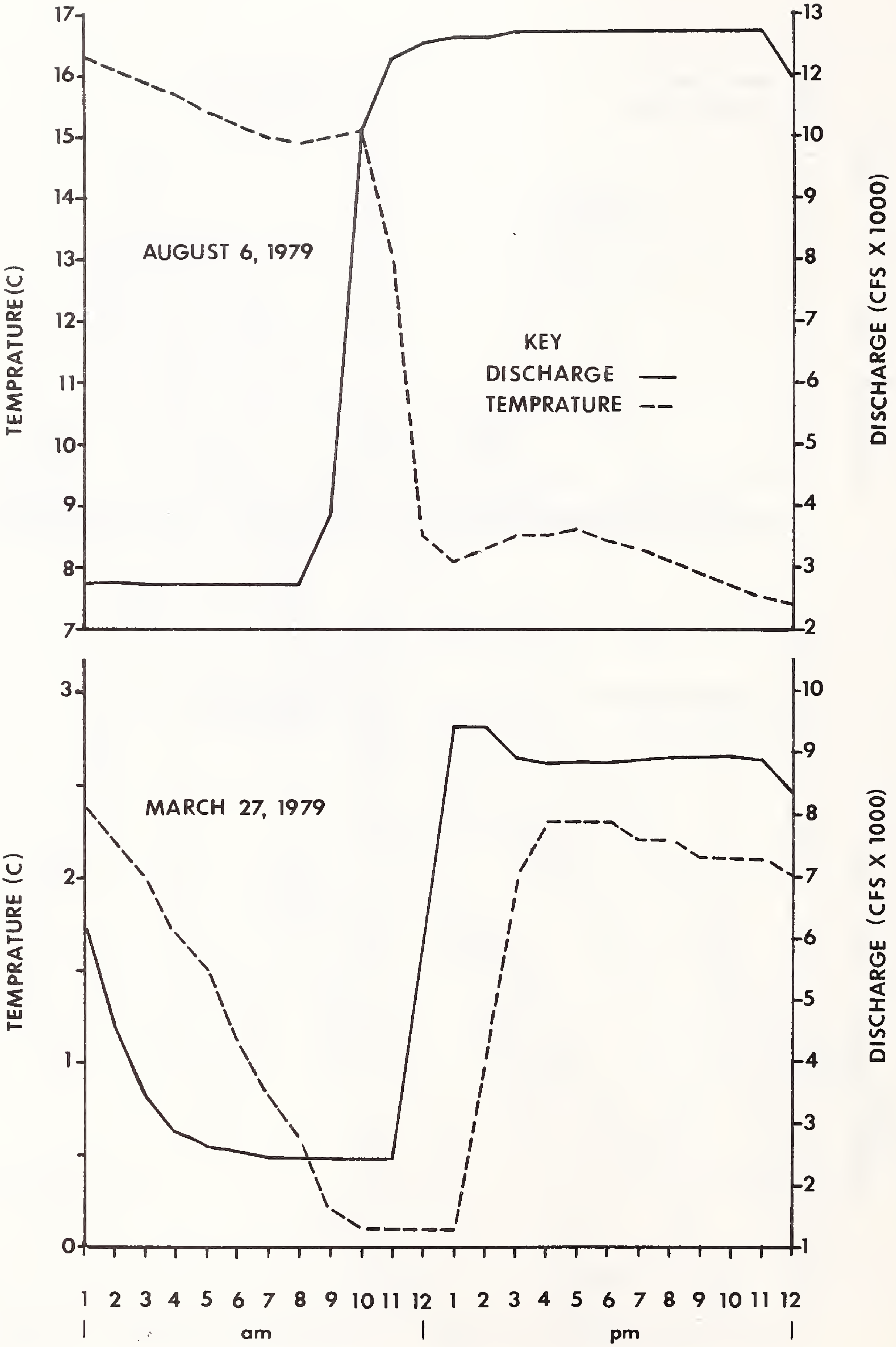


Figure 4. Diel fluctuations in temperature of the Flathead River at Columbia Falls due to release of peaking discharge at Hungry Horse powerhouse.

The large rocks in the South Fork are covered with dense growths of periphytic algae. The partially regulated areas of the Flathead River also appear to have more periphyton.

A description of the water chemistry of the Flathead River has been done by the Flathead Research Group (Stanford et al. 1979). Water samples have been taken during the duration of this project. Samples are collected monthly at the same time the invertebrate work is done and are being analyzed at the University of Montana Biological Station. Chemical data will be included with our next report.

Fisheries

Native westslope cutthroat trout (*Salmo clarki lewisi*) and introduced kokanee salmon (*Oncorhynchus nerka*) both migrate out of Flathead Lake and up the main stem river to spawn. Cutthroat begin their migration in late winter and early spring. The exact timing of migration may be affected by operation of Hungry Horse powerhouse (Huston and Schumacher 1978). Cutthroat spawning success is little affected by river fluctuations because most spawning occurs in tributaries of the North and Middle Forks.

Three distinct life history patterns of westslope cutthroat trout commonly occur throughout their range (Behnke 1979). Adfluvial cutthroat trout 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 adfluvial fish in glacial Lake Missoula (Wallace 1979). Fluvial westslope cutthroat follow a life history pattern similar to adfluvials except maturation occurs in a large river. Spawning typically occurs in smaller tributaries. Resident westslope cutthroat trout spend their entire lives in small headwater streams.

Adfluvial and resident westslope cutthroat are known to be present in the Flathead River drainage. The presence of fluvial fish has not been proven. Fluvial cutthroat may be present in the upper South and Middle Fork drainages where anglers frequently catch large cutthroat. The North Fork has apparently never supported a fishable population of fluvial cutthroat trout (Morton 1968).

Many kokanee spawn in the main stem river during late fall. Incubation of kokanee eggs can be directly affected by fluctuating water levels. Kokanee also spawn in springs and a lake outlet creek upstream from the mouth of the South Fork. The extent of kokanee spawning in Flathead Lake is unknown at this time, but it is believed to be limited by lake drawdown.

Other fish species in the main stem river are probably affected by Hungry Horse operations during at least a portion of their life history. Other species commonly found in the Flathead include bull trout (*Salvelinus confluentus*), rainbow trout (*Salmo gairdneri*), mountain whitefish (*Prosopium williamsoni*), and largescale sucker (*Catostomus macrocheilus*). Several other species are encountered less frequently including brook trout (*Salvelinus fontinalis*), longnose sucker (*Catostomus catostomus*), northern squawfish (*Ptychocheilus oregonensis*), peamouth (*Mylocheilus caurinus*), slimy sculpin (*Cottus cognatus*), and mottled sculpin (*Cottus bairdi*). Several more species are known to be present in the drainage but are rarely encountered in the Flathead River.

Bull trout are widely distributed in the Flathead drainage and are important trophy sport fish. Recent research by Cavender (1978) distinguished bull trout from coastal Dolly Varden (*Salvelinus malma*). Separation of bull trout and Dolly Varden into the two species (*S. Confluentus* and *S. malma*) is proposed by the American Fisheries Society (Reeve Bailey, University of Michigan, personal communication, 1979).

Specific sites where we conducted fisheries research included three survey reaches and three electrofishing sites. Invertebrate collections were made in the regulated, partially regulated and unregulated reaches of the river.

Survey Reaches

Two known kokanee spawning areas in the main stem river and one in McDonald Creek were selected for intensive surveys. The McDonald Creek site served as a control (non-regulated) area. It was located just downstream of Apgar Bridge. Depth and velocity measurements were made along five transect lines (Figure 5). The Kokanee Bend survey site was located at RK62 in the east channel near the north end of Eleanor Island (Figure 6). Due to the large size of the river channel and the small liklihood that kokanee would utilize the entire channel for spawning, depth and velocity measurements on five transect lines were made out from the east bank as far as we could wade at low flow (Figure 6). The Reserve Drive survey site was located at RK50, just north of Lybeck Dike, in a backwater area containing many springs. Water velocities were negligible, but depths were measured along eight transect lines. In addition, we mapped water surface area at Reserve Drive at flows of $38.2m^3/s$ (1,350 cfs, Figure 7) and $300.2m^3/s$ (10,600 cfs, Figure 8). Flows were recorded at the U.S.G.S. gauge at Columbia Falls, Montana.

Electrofishing Sites

The upper river electrofishing section was located just upstream of the confluence of the South Fork and main stem at RK76 (Figure 9). Hungry Horse operations did not affect flows in this section. The section began in a long, deep run just below the entrance to a narrow canyon. A riffle separated the upper run from the shorter lower run. A boat ramp at Flathead River Ranch bounded the lower end of the section.

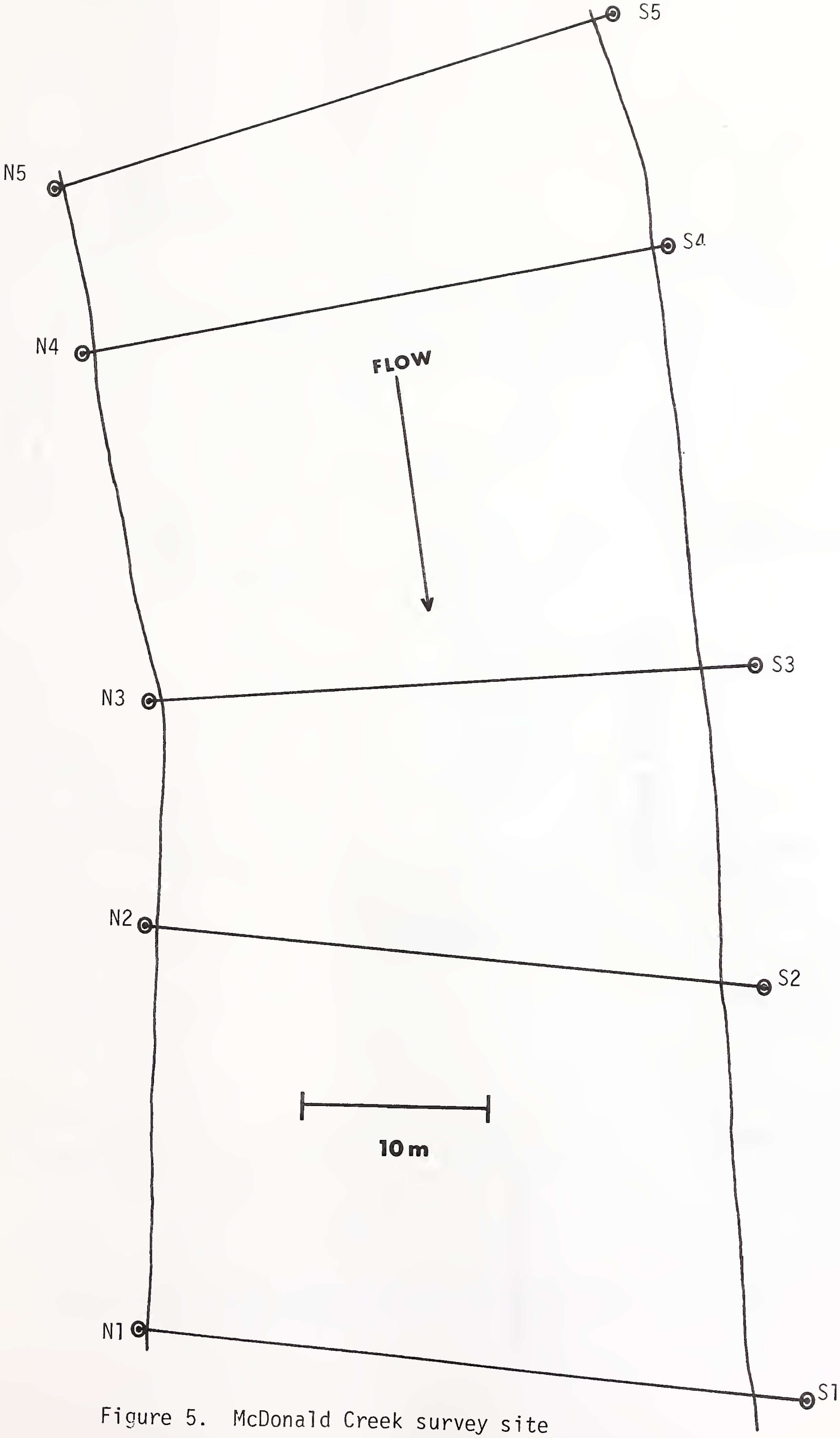


Figure 5. McDonald Creek survey site

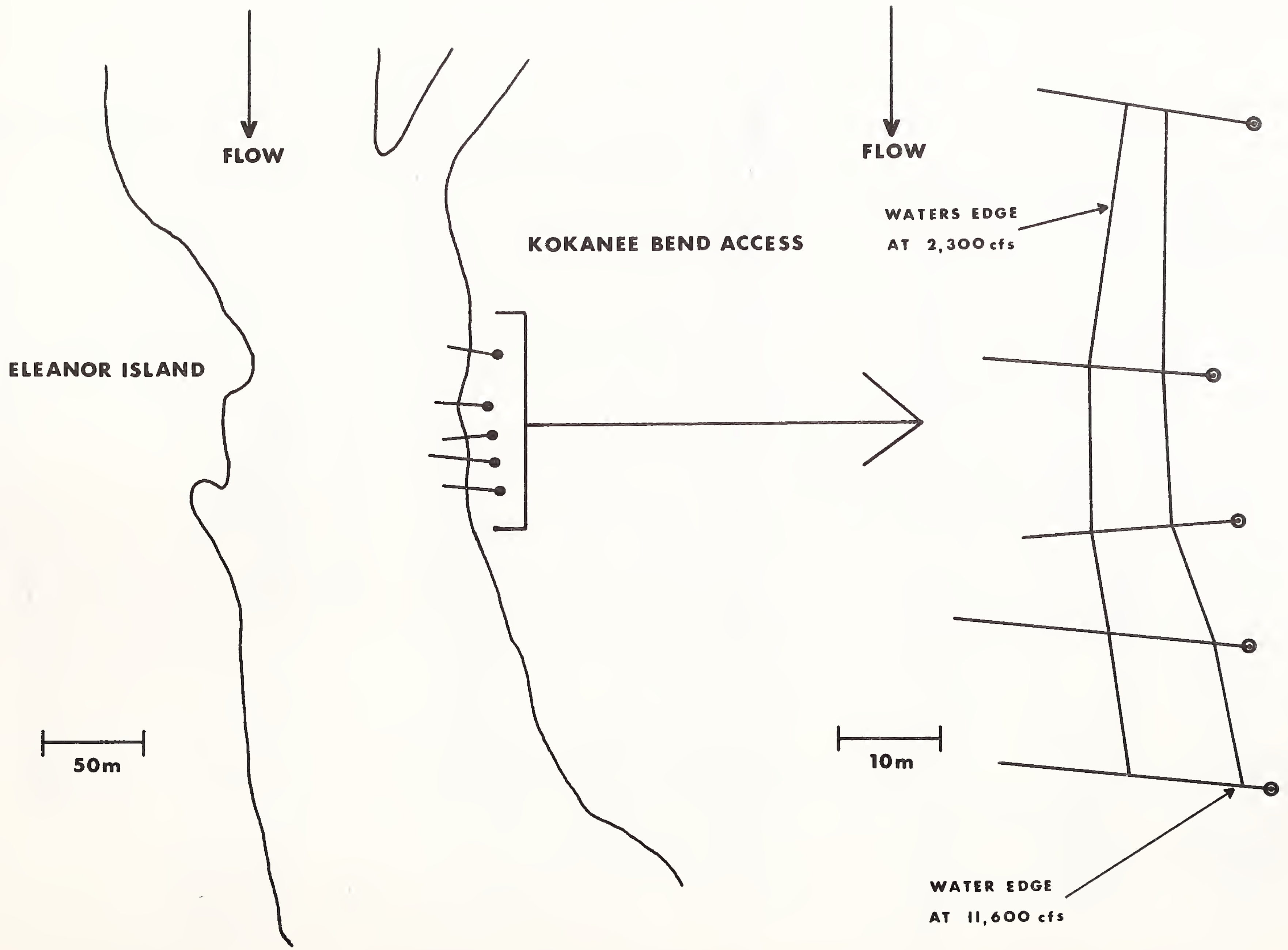


Figure 6. Main stem river survey site at Kokanee Bend

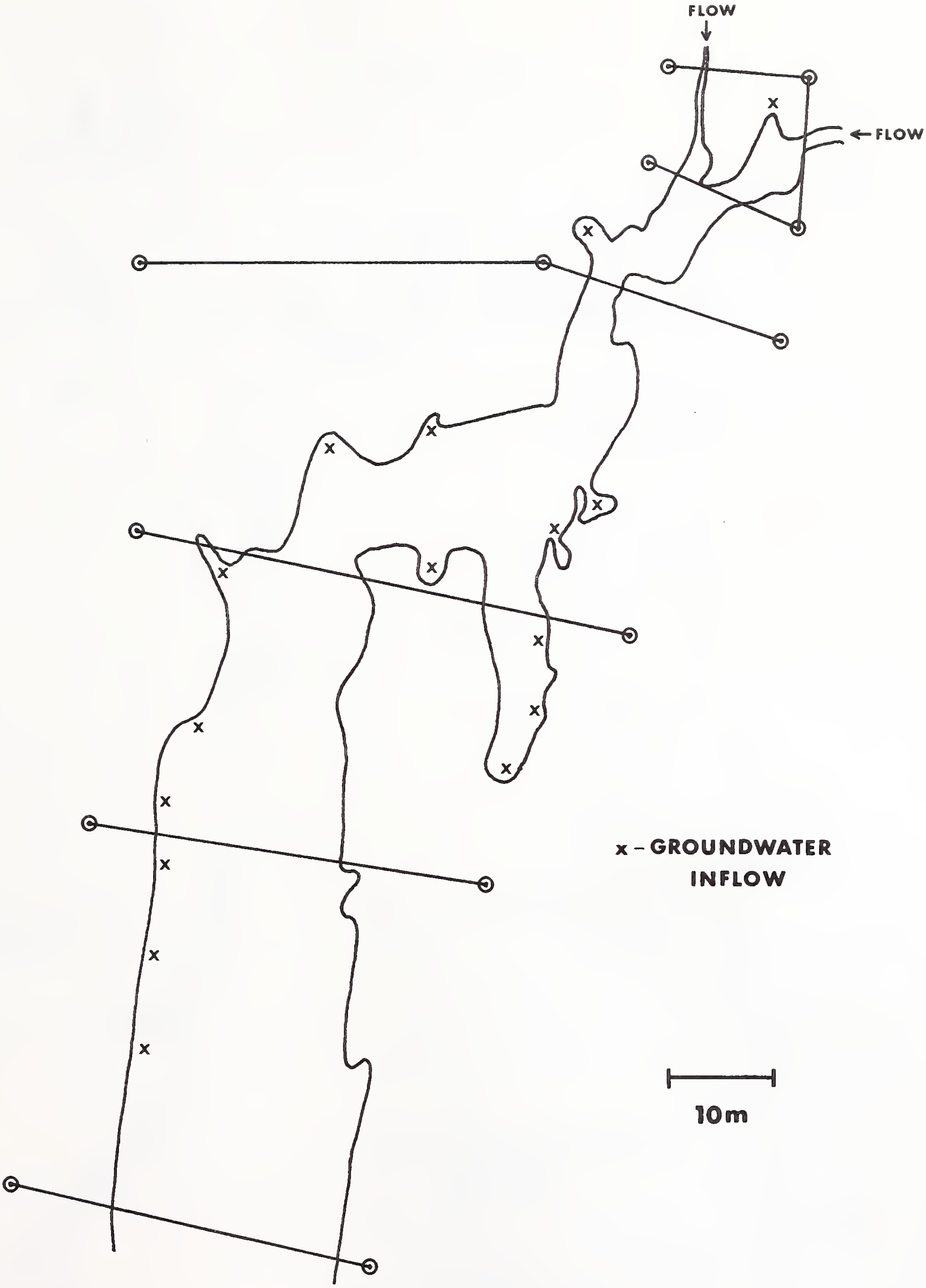


Figure 7. Reserve Drive survey site at a flow of 38.2 M^3/S (1,350 cfs).

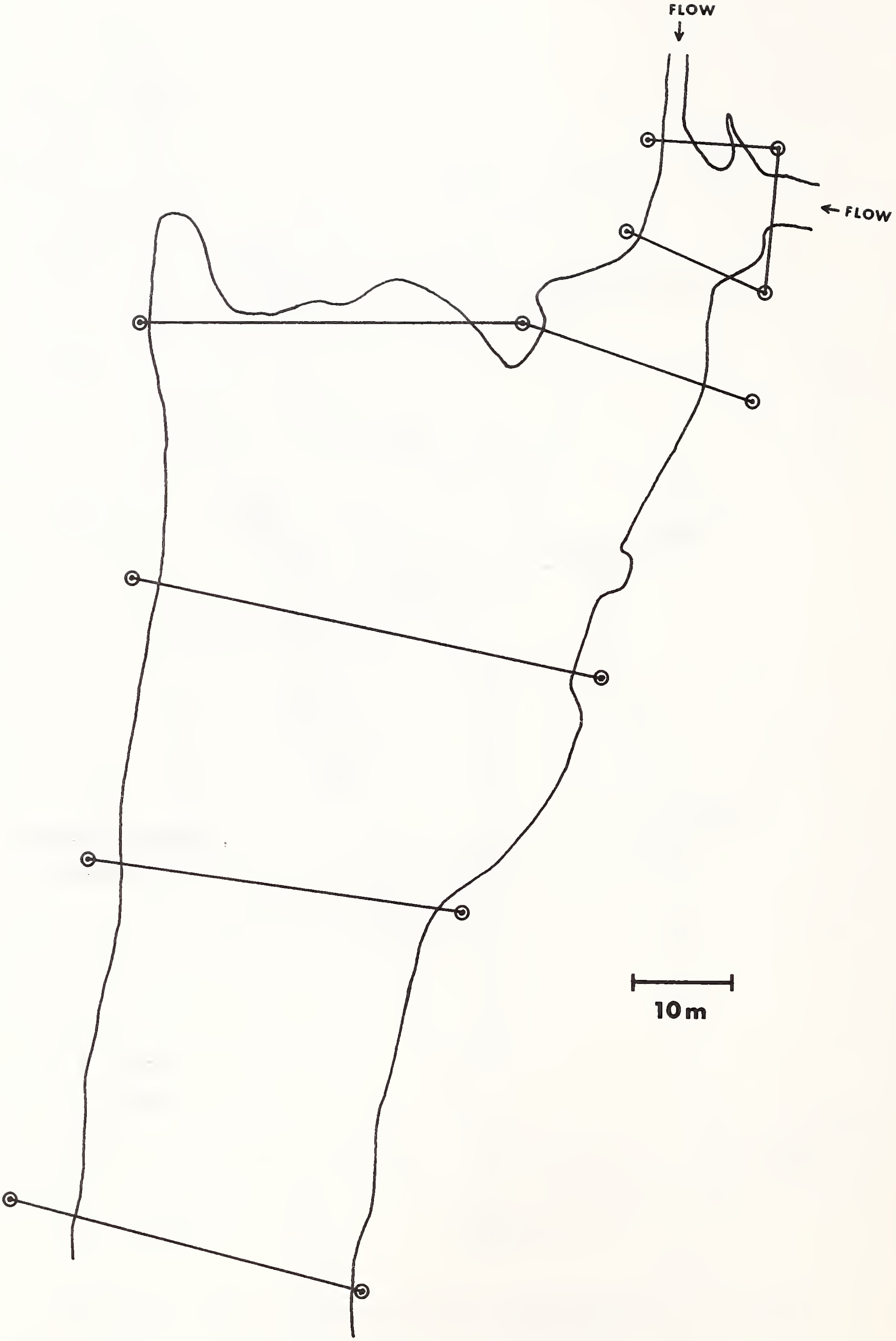


Figure 8. Reserve Drive survey site at a flow of 300.2 M^3/s. (10,600 cfs).

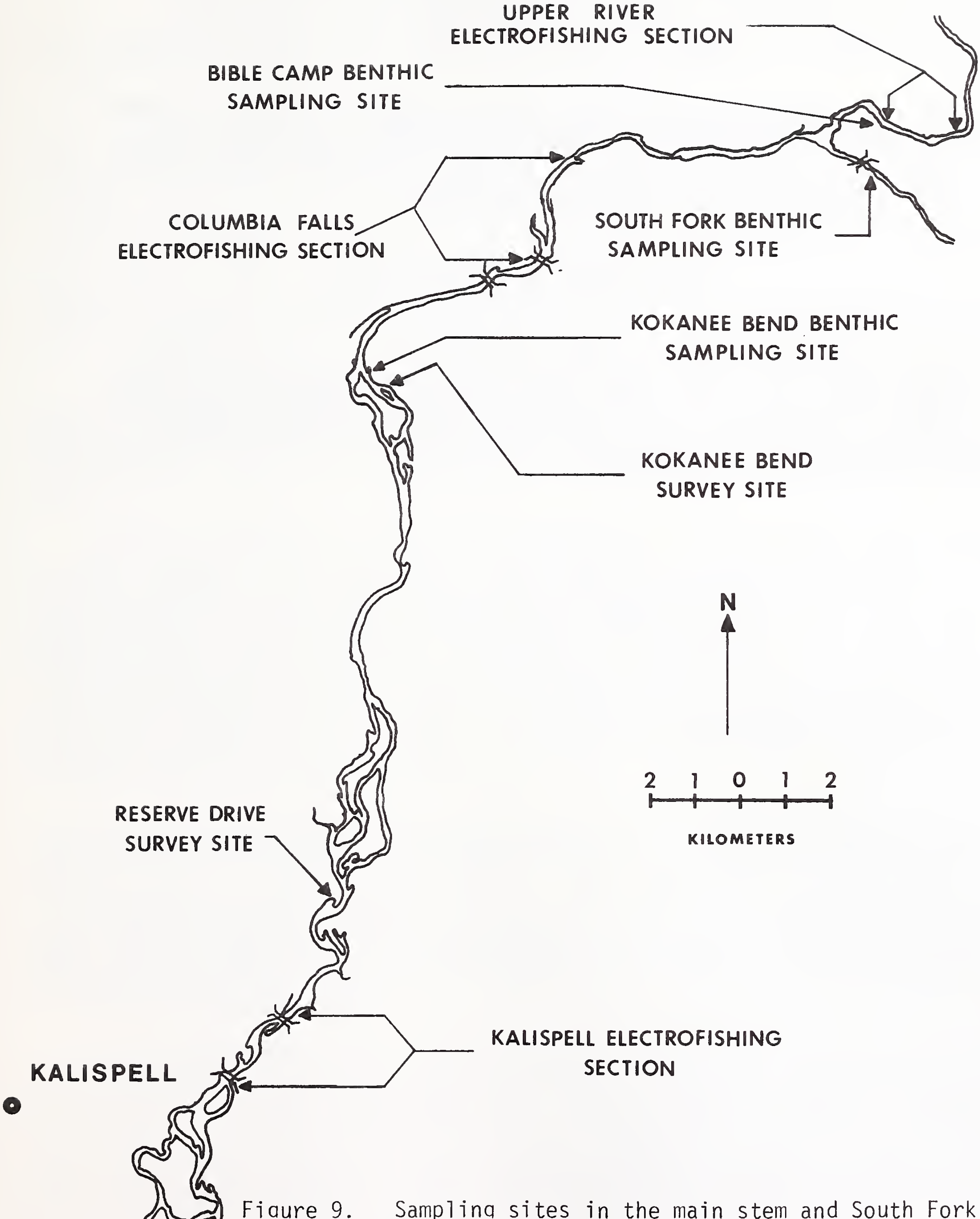


Figure 9. Sampling sites in the main stem and South Fork Flathead Rivers, 1979.

The Columbia Falls section, located at RK66 began approximately 1km below the Anaconda Aluminum Plant and extended downstream to the Montana Highway 40 Bridge (Figure 9). The section contained three long runs separated by riffles. It ended in a deep pool under the Highway 40 Bridge.

The Kalispell section, at RK43 began just upstream of the U.S. Highway 2 Bridge and extended below the Old Steel Bridge (Figure 9). Most of the section consists of a long, deep run broken by one riffle and a pool under the Old Steel Bridge, Between the bridges, the river splits into three channels. We sampled only the westernmost channel.

Invertebrate Collection Sites

The macroinvertebrate work has been concentrated in riffle areas at three study sites: 1) South Fork of the Flathead River - 7.4km from Hungry Horse Dam near the mouth of the South Fork, 2) Glacier Bible Camp (Control Site) - 1.2km north of the mouth of the South Fork and 3) Kokanee Bend - 11.3km south of the mouth of the South Fork in the partially regulated main stem Flathead River (Figure 9).

KOKANEE MIGRATION, SPAWNING AND INCUBATION

Introduction

"Red fish," probably kokanee salmon, were introduced to Flathead Lake in 1916. In the intervening years, the kokanee has become one of, if not the most important game fish in the Flathead drainage. In addition to the troll fishery in Flathead Lake, kokanee support a popular snagging fishery in the Flathead River and its tributaries. Kokanee made up over 80 percent of the harvest of game fish in the main stem Flathead River between May and October of 1975 (Hanzel, 1977). Anglers from the Flathead Valley, the rest of Montana and nearby states frequently catch kokanee at rates in excess of two per hour during the snagging season. Liberal bag and possession limits have helped make the fishery popular.

Kokanee benefit other fish as well as anglers. Bull trout and lake trout, both popular game fish, utilize kokanee for food in Flathead Lake. Kokanee have proven to be excellent forage for large predacious salmonids in several lakes, including Pend Oreille Lake and Kootenay Lake, as well as Flathead Lake (Behnke, 1979).

Kokanee are probably more directly affected by operations at Hungry Horse Dam than any other fish species in the drainage. A significant portion of the system's kokanee spawn in the main stem Flathead River below its confluence with the South Fork Flathead River. Other major kokanee spawning areas include McDonald Creek and Beaver Creek, tributaries of the Middle Fork Flathead River, the Middle Fork below McDonald Creek, the South Fork below Hungry Horse Dam, the Whitefish River and shoreline areas of Flathead Lake. A few kokanee spawn in the North Fork Flathead River drainage. It has been suggested that kokanee from Flathead Lake found their way into Kintla Lake. Allen (1964) reported kokanee were never planted in Kintla Lake.

Prior to impoundment of the South Fork by Hungry Horse Dam, most kokanee spawning took place along the Flathead lakeshore, in McDonald Creek and the Whitefish River (Stefanich,1953, 1954). After impoundment, a shift toward river spawners was noted (Hanzel, 1964). The reason for increased river spawning and decreased lakeshore spawning is not known but is probably related to warmer winter water temperatures in the main stem river (Figure 4) due to discharges from Hungry Horse. Winter drawdown of Flathead Lake is thought to have reduced survival of shoreline spawning kokanee.

Kokanee spawning in the South Fork and main stem are affected by fluctuating flows from Hungry Horse Dam. Maximum vertical fluctuations ranged from 2.3m in the South Fork to 1.5m in the main stem. Kokanee prefer to spawn in shallow areas with moderate velocities and small gravel. Consequently, redds were usually found along the margins of the river and in slough and spring areas. If flows were high during the spawning period, a large proportion of the kokanee redds would be left above the water's edge when Hungry Horse powerplant ceased discharging. During the cold winter months when kokanee eggs were incubating, mortality due to freezing or desiccation could occur rapidly after the water level dropped.

McNeil (1968) felt year-class strength of pink salmon (*Oncorhynchus gorbuscha*) in Alaskan streams was determined primarily by mortality during the incubation period. Stober et al. (1978) obtained similar results with Cedar River, Washington sockeye salmon. Life histories of kokanee, sea-run sockeye salmon and pink salmon are similar except pink salmon migrate to the ocean soon after emergence while kokanee are landlocked. Sockeye salmon normally spend one to two years in a lake before smolting.

Incubation mortality is probably one of the most important factors governing year class strength of kokanee. Thus, fluctuations in river level that increase incubation mortality, reduce year-class strength and could subsequently reduce angler satisfaction when a weak year-class recruits to the fishery. This could be offset to some degree by the larger size of the fish.

The goal of this phase of our study is to evaluate the impacts of Hungry Horse Dam operations on kokanee populations in the Flathead drainage. We established the following specific objectives in order to meet this goal:

1. Identify the various runs of kokanee spawners in the Flathead River with respect to timing and destination.
2. Locate and quantify real and potential kokanee spawning areas in the main stem Flathead River and its tributaries.
3. Determine kokanee spawning habitat preferences.
4. Assess incubation mortality of kokanee eggs in fluctuating and stable environments.

In addition, we studied historical records to determine if a correlation existed between Flathead River flows during the kokanee spawning and incubation period and the length of spawning kokanee produced under those flows. The stream flow:fish length correlation investigation was undertaken with the assumption that population density and kokanee length are inversely related. This assumption is supported by the studies of Foerster (1944), Bjornn (1957) and Johnson (1965).

Methods

Migration

Migration of kokanee spawners was monitored by direct underwater observation (snorkeling), mark and recapture and creel census. We snorkeled throughout the drainage in an effort to determine which areas were being utilized and to assess relative abundance in those areas. Tag return information was used to estimate rate of upstream migration and angler exploitation. Catch/effort data were collected at several sites to aid in documenting kokanee movement.

We spot-checked the North and Middle Forks in mid-September by snorkeling in and around the mouths of several tributaries. North Fork tributaries of particular interest were; Kintla, Bowman, Logging and Quartz Creeks, all of which drain large lakes in Glacier National Park. We also snorkeled the North Fork near Coal, Camas and Canyon Creeks where kokanee had been seen in previous years. The Middle Fork was checked at Ole, Paola, Coal and Harrison Creeks. We snorkeled McDonald Creek from the outlet of Lake McDonald to its mouth on September 21 and October 17. Pools in the Middle Fork from the mouth of McDonald Creek to its mouth were snorkeled on the same two dates. The main stem Flathead River was spot checked from the mouth of the South Fork to Pressentine Bar.

We tagged 247 kokanee with blank colored anchor tags on four different dates. Blue tags were used on 104 fish caught at the Old Steel Bridge near Kalispell on September 4. Twelve black tags were used on September 6 at Columbia Falls. Fifty-nine kokanee were tagged with green tags on October 4 and 72 fish were tagged with red tags on October 31 at the Old Steel Bridge. All fish were caught by electrofishing at night. Information on returns of tagged fish was volunteered by anglers.

Spawning

Redd counts in the main stem between the mouths of the Stillwater and South Fork Flathead Rivers were made during 7-to 10-day periods in early and late November. We used an inboard jet boat to locate areas that appeared to be suitable for kokanee spawning. Whenever possible, each area was carefully inspected on foot. We did not attempt to count redds in the North and Middle Forks, McDonald Creek or the Whitefish River.

Incubation

Egg and alevin mortality was assessed by two methods. Natural redds in several areas were excavated to determine percentage mortality. We also planted eggs in Whitlock-Vibert boxes and bags made of fiberglass screen. Boxes and bags were periodically excavated.

Natural redds were sampled in areas exposed to three distinct conditions, including permanently wetted areas, areas sometimes subjected to dewatering but influenced by ground water, and sometimes dewatered areas not influenced by ground water. Permanently wetted redds were excavated with a hydraulic sampling device (Figures 10 and 11) similar to that used by McNeil (1964). Dry redds and redds wetted only by ground water were excavated with a shovel. Live and dead eggs were sorted in the field, preserved in 10 percent formalin and counted in the lab.

Due to the high density of spawners in McDonald Creek, we were able to sample random points within a previously surveyed area instead of pre-selecting individual redds. This allowed us to estimate numbers of eggs per square meter for that section of stream as well as proportions of live and dead eggs. All McDonald Creek samples were taken with the hydraulic sampler. McDonald Creek temperatures were monitored with a Foxboro thermograph installed just below the outlet of McDonald Lake.

Experimental egg plants were made in three areas. Eggs were planted in fiberglass screen bags at Reserve Drive, a ground water influenced slough in the main stem Flathead River (Figure 9) and in the main river channel at Kokanee Bend. Both areas had been surveyed previously. Bags and Whitlock-Vibert boxes were buried side-by-side (Figure 12) in Beaver Creek, a large, spring creek tributary of the Middle Fork at Nyack Flats.

Figure 10. Centrifugal pump and sampler used to collect hydraulic samples of kokanee eggs

Figure 11. Close-up view of sampler with collecting net attached

Two groups of eggs were buried at Reserve Drive and Kokanee Bend. At each site, eggs were buried above and below the low water mark. Only one group of eggs was buried in Beaver Creek. Eggs were excavated periodically throughout the incubation period to assess mortality and development under the various conditions.

Mr.Gordon Pouliot, a local resident, monitored temperatures in Beaver Creek. No site specific temperature data were collected at Reserve Drive or Kokanee Bend. The U.S. Geological Survey maintains a thermograph at Columbia Falls, approximately 4km. upstream of Kokanee Bend.

Stream Flow: Fish Length Correlation

We studied historical records of discharge in the Flathead River at Columbia Falls and total length of male kokanee spawners in Flathead Lake in an effort to determine the correlation between them. Several researchers have suggested that growth of juvenile sockeye salmon (anadromous or landlocked) is inversely proportional to population density (Foerster 1944, Bjornn 1957, Johnson 1965 and Rogers 1978). Whether or not intraspecific competition is the mechanism, the inverse relationship has been demonstrated. It is clear that strong year-classes produce smaller fish. It appears that interactions between year-classes can also depress or enhance growth (Delano Hanzel, Mt. Dept. Fish, Wildlife and Parks 1979, personal communication). Intraspecific interactions may be affected by kokanee behavior. Kokanee are usually found in schools. Close association of fish in schools probably accentuates the interactions more than would occur if the fish were evenly dispersed.

We feel the most important interactions are those between adjacent year-classes. Thus, when kokanee fry (age 0+) enter Flathead Lake, they would interact primarily with members of their own year-class and the previous year-class (age I+). At Age I+ they would interact primarily with members of their own year-class, the previous year-class (now age II+) and the year-class entering Flathead Lake that year (0+). In subsequent years, II+ fish would interact primarily with I+ and III+ fish and III+ fish interact primarily with II+ fish. Most adult kokanee mature and spawn in the fall of their fourth year (age III+). The result of four growing seasons spent in Flathead Lake by a particular year-class, is three years of interaction with the previous year-class and three years of interaction with the following year-class.

We attempted to account for these interactions in calculating correlations between stream flow and total length of kokanee by using a weighted three-year moving average of flow conditions as the independent variable. Two correlations were calculated. In the first case, mean November flow of the main stem Flathead River at Columbia Falls was the independent variable. The independent variable in the second case was a ratio of mean December through March (incubation period) flows to mean November (spawning period) flows. Conditions for egg incubation improved as the flow ratio increased. The dependent variable in each case was mean length of male kokanee spawners.

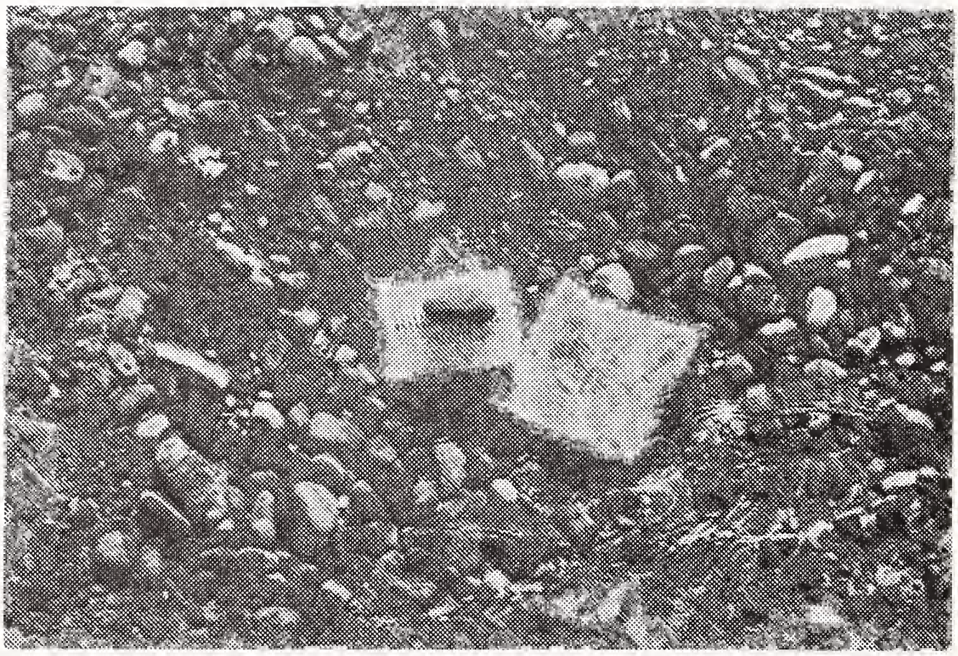


Figure 12. Whitlock - Vibert box and fiberglass screen bag used in experimental egg plant in Beaver Creek.

An example of the procedure followed is presented here using data from Table 1. Eggs spawned in the river in November, 1975 (water year 1976) hatched in spring 1976. Fry entered Flathead Lake in late spring or early summer. During their residence in Flathead Lake, the 1976 year class interacted three years each with the 1975 and 1977 year-classes. Most of the 1976 year-class returned to spawn in November 1979.

Flows during water year 1976 were poor for survival of eggs. Mean daily November flow was 271.2 m^3s (9,576 cfs), the second highest mean daily November flow during the period investigated. Mean daily December to March flow was 128.7 m^3s (7,396 cfs), yielding a flow ratio of 0.77. This means many redds were dewatered during at least part of the incubation period.

Water year 1975 was the worst water year during the study period with a mean daily November flow of 266.9 m^3s (9,423 cfs) and a flow ratio of 0.48. Water year 1977 was much more favorable with a mean daily November flow of 99.7 m^3s (3,522 cfs) and a flow ratio of 1.42. Thus, the weak 1976 year class interacted three years with an even weaker 1975 year-class and three years with a stronger 1977 year-class in addition to four years of interaction between members of the 1976 year-class. Weighted three-year moving average November flow is calculated:

$$\{ (3)\,(266.9) + (4)\,(271.2) + 3\,(99.7) \} \;/10 = 218.5\ m^3/s$$

Weighted three-year moving average flow ratio was calculated in the same manner giving a value of 0.88. These values were correlated with mean length of 1979 male kokanee spawners (361mm).

Results and Discussion

Migration

Although a few kokanee migrated up the Flathead River in mid-summer, the first large concentration of fish appeared in the Kalispell area approximately September 1. The first wave of fish moved upstream quickly. Two schools of kokanee were observed in McDonald Creek, 56km upstream of Kalispell, on September 10.

We received 14 returns (13.5%) from the 104 kokanee tagged near Kalispell on September 4. Seven tagged fish were caught in the area where they were released, all within a few days after being tagged. Two caught at Columbia Falls, 24km upstream, on September 10 and 13 had moved 4.0 and 2.7km per day, respectively. One was caught at Blankenship Bridge (47km upstream) on September 13 (5.2km per day). The rest were caught more than a month after being tagged, including one at the mouth of McDonald Creek and two that were caught downstream of the tagging site.

We believe most of the early run kokanee were bound for upper river spawning areas such as McDonald Creek and the Middle Fork. Angler success at various locations along the river indicate a wave of fish passed through the lower river during the month of September. Kokanee were abundant in the Old Steel Bridge area during the period September 4 to 13. During that period we received half of our tag returns.

Table 1. Water conditions during the kokanee spawning (November) and incubation period (December - March) for Water Years 1962-78. Mean length of male kokanee spawners and weighted three-year moving average water conditions are also given. All water data from USGS gauge on Flathead River at Columbia Falls, Montana

Water Year	Mean November flow (m^3/s)	Mean December-To March flow (m^3/s)	Mean December-March to November	Spawn Year	Male kokanee Length (mm)	Water years producing Interacting year classes	Weighted 3-year Moving average November flow (m^3/s)	Weighted 3-year Moving average flow ratio
1962	62.4	197.3	3.16					
1963	123.7	180.7	1.46	1966	290	1962-64	81.4	2.89
1964	44.1	200.1	4.54	1967	277	1963-65	91.6	3.02
1965	122.9	314.1	2.56	1968	291	1964-66	98.5	2.88
1966	120.3	195.7	1.63	1969	315	1965-67	166.4	1.60
1967	271.5	162.7	0.60	1970	328	1966-68	196.0	1.02
1968	171.1	168.2	0.98	1971	340	1967-69	199.7	0.98
1969	165.9	227.0	1.37	1972	345	1968-70	161.2	1.03
1970	144.9	92.1	0.64	1973	312	1969-71	131.7	1.39
1971	80.0	193.4	2.42	1974	328	1970-72	150.4	1.45
1972	249.8	241.6	0.97	1975	330	1971-73	170.8	1.43
1973	156.1	164.6	1.05	1976	321	1972-74	188.1	1.12
1974	169.2	228.9	1.35	1977	333	1973-75	194.6	1.00
1975	266.9	128.7	0.48	1978	348	1974-76	238.9	0.83
1976	271.2	209.5	0.77	1979	361	1975-77	218.5	0.88
1977	99.7	141.8	1.42					
1978	180.5	114.8	0.64					

After September 13, angler success dropped in the Old Steel Bridge area and we concentrated our creel census in the upper river. Angler success (catch/hour) increased from less than 1.0 on September 13 to over 3.0 on September 14 at Columbia Falls, 24km upstream of the Old Steel Bridge (Figure 13) and remained high through September 19. Angler success peaked on September 18 at the mouth of the South Fork, 8km upstream of Columbia Falls. At Blankenship Bridge, catch/hour increased during the period September 26 - October 1. Some fish may have moved upstream at a faster rate, as indicated by the down-swing of a peak in the catch/hour curve at Blankenship Bridge in mid-September (Figure 13).

During late September the majority of kokanee in the river system were observed upstream from the confluence of the Middle and North Forks. We observed small schools of kokanee in the North Fork on September 19 and 20 in the vicinities of Bowman, Quartz and Logging Creeks (Figure 14). On September 21, an estimated 1,200 - 1,500 kokanee were in McDonald Creek and 7,000 - 12,000 were observed in the Middle Fork below McDonald Creek (Figure 14). A large school was holding at the mouth of McDonald Creek but we could not snorkle the area due to a large concentration of anglers. Another large school of kokanee at the mouth of Deerlick Creek could not be counted due to anglers. During the same time period, only 800 - 1,000 kokanee were counted downstream in the main stem Flathead River between the South Fork and Pressentine Bar (RK 55).

A second and larger run of kokanee moved through the system in early October. The second run appeared to be composed largely of upper drainage spawners and moved upstream more quickly than did the first run. Although kokanee were more abundant at the Old Steel Bridge on October 4 than they were on September 4 (Figure 15), we tagged only 59 fish. Six (10.2%) of these tags were returned by anglers.

Angler success increased from less than two fish/hour on October 6 to 4.5 fish/hour at Columbia Falls on October 11 and from 1.7 fish/hour on October 11 to 5.0 fish/hour on October 12 (Figure 13) at the mouth of the South Fork. A similar, although smaller, peak in angler success occurred at Blankenship Bridge on October 16 and 17.

We snorkeled McDonald Creek and the lower Middle Fork on October 17. There were an estimated 40,000 to 64,000 kokanee in McDonald Creek at that time, and 6,500 to 9,500 kokanee in the lower Middle Fork (Figure 16). Kokanee were so abundant in McDonald Creek on October 17 that the estimate reported may not be accurate.

The majority of kokanee that spawned in the main stem Flathead and South Fork Flathead Rivers did not enter the snagging fishery until late October and early November. Anglers enjoyed continued success at Columbia Falls from October 21 through termination of the census on November 9 (FIgure 13). Catch rate peaked from November 3 through 7 at the mouth of the South Fork. No kokanee were checked at Blankenship Bridge after October 17, although anglers were interviewed on five separate dates after that.

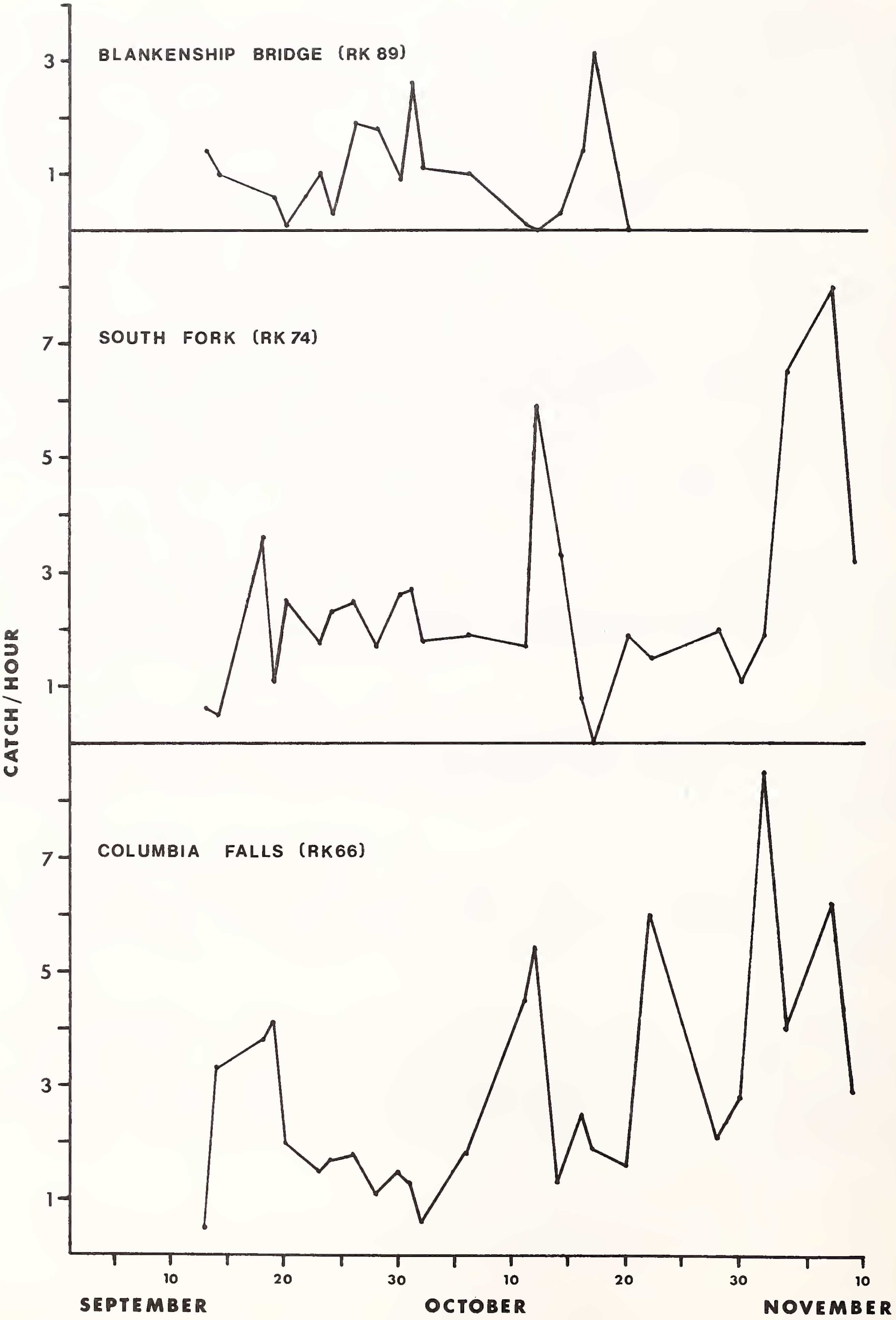


Figure 13. Catch of kokanee per hour of angling effort by snag fishermen at three sites in the main stem Flathead River, 1979

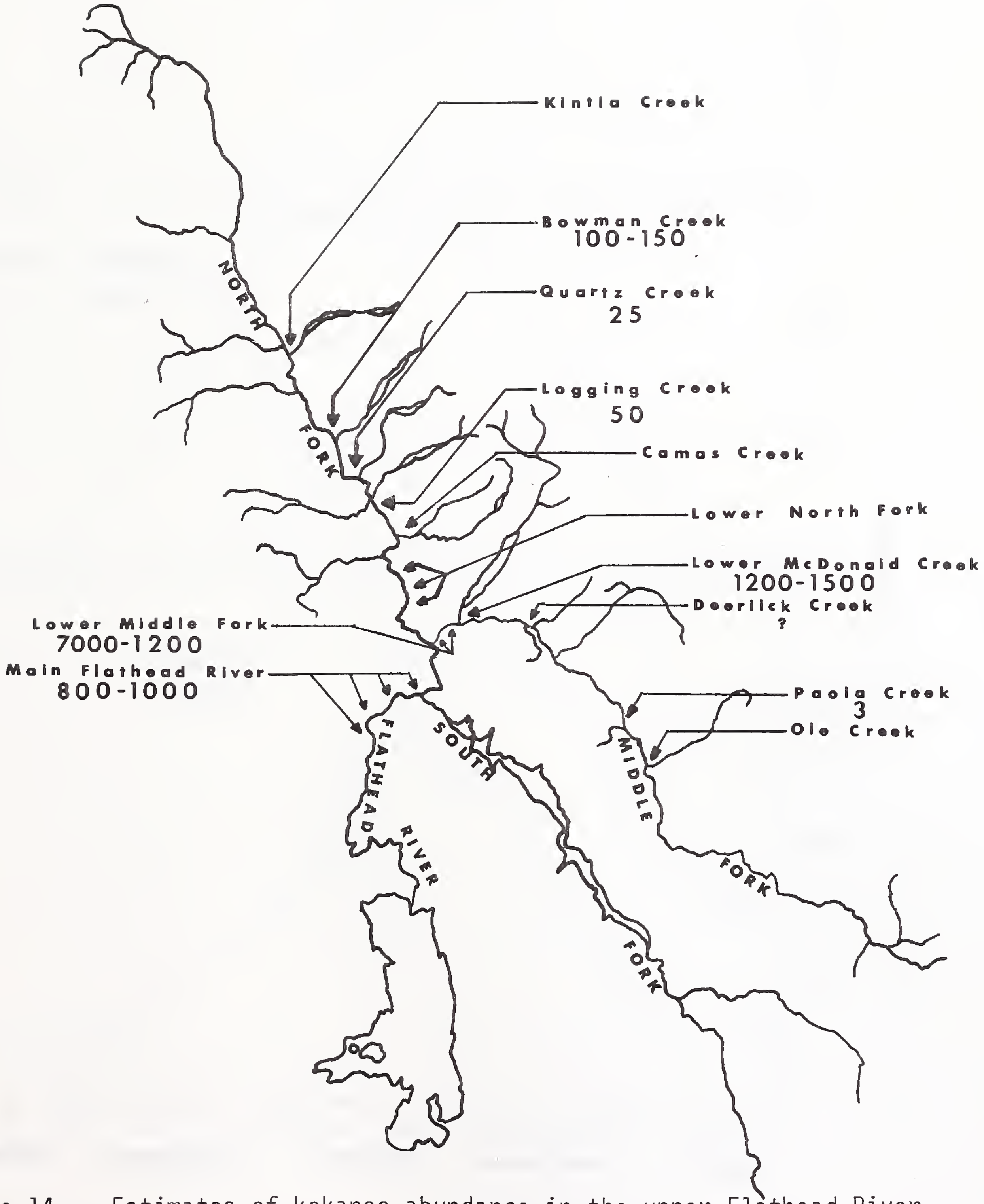


Figure 14. Estimates of kokanee abundance in the upper Flathead River during the period September 19-28, 1979.

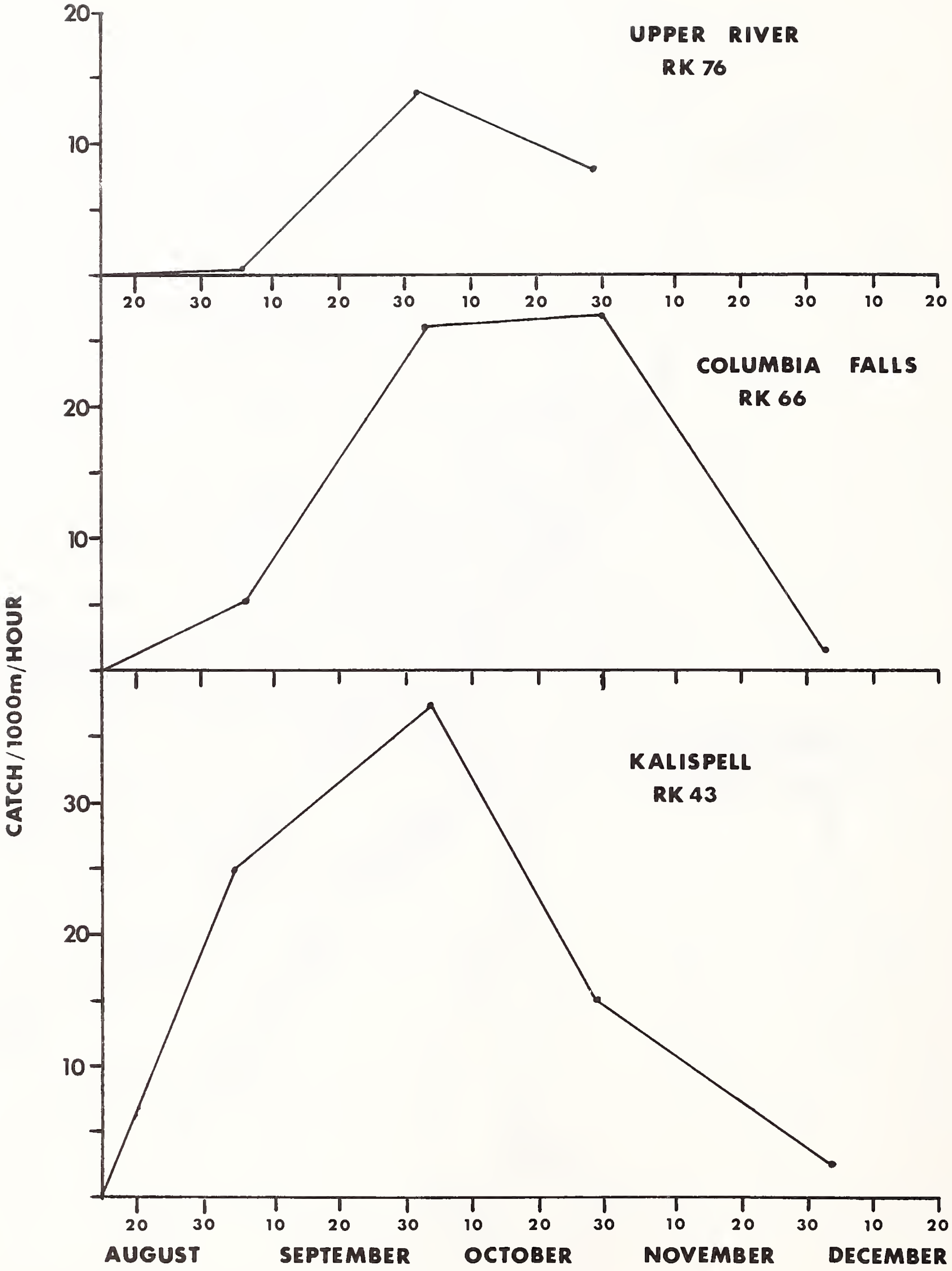


Figure 15. Catch of kokanee per 1000m per hour of electrofishing effort at night in three sections of the Flathead River, 1979.

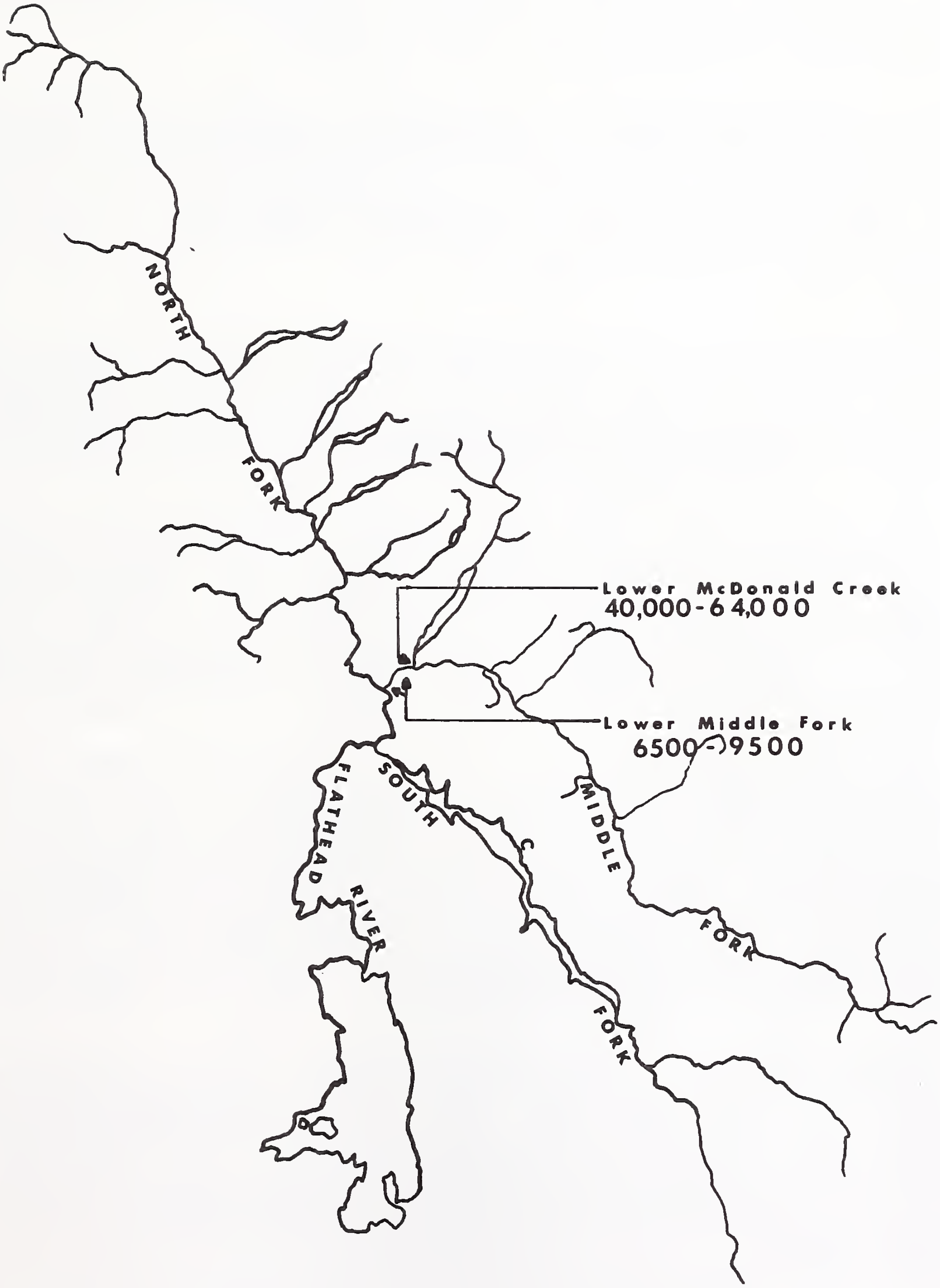


Figure 16. Estimates of kokanee abundance in McDonald Creek and the lower Middle Fork, October 17, 1979.

Spawning

During our early November redd survey, we counted approximately 755-880 redds in the main stem Flathead River (Table 2). Most of the redds were found in four areas -- Kokanee Bend, Buck's Gardens, Pressentine Bar and Brenneman's Slough. We later discovered a spawning area in the eastern-most channel between Pressentine Bar and Reserve Drive that was not checked during the early November survey. We estimated a minimum of 50 percent of the redds in the main stem were accounted for during this survey. The expanded count would total 1,500 to 1,760 redds in the main stem in early November.

A more thorough survey in late November resulted in a count of approximately 2,300 to 2,800 redds (Table 2). Spawning was concentrated in the same areas as before but redds were more numerous. Large concentrations of spawners were discovered near Columbia Falls and in the area between Pressentine Bar and Reserve Drive. We estimated a minimum of 70 percent of the redds in the main stem were accounted for during the late November survey. An expanded count would total 3,360 to 4,080 redds in the main stem.

A late group of spawners entered Brenneman's Slough after our late November survey. We estimated an additional 200 to 300 redds were constructed during December, bringing the total redd count to 3,650 to 4,510 in the main stem. Appendix B contains a complete list of observed and potential kokanee spawning areas we encountered in the main stem Flathead River.

With the exception of McDonald Creek, few kokanee spawned in the area we surveyed during summer 1979. Approximately 20 to 25 redds were counted at both the Reserve Drive and Kokanee Bend survey sites. Because of the large number, no attempt was made to count redds in McDonald Creek. Kokanee appeared to be utilizing all available spawning gravel in McDonald Creek when we snorkeled it on October 17. Spawning in McDonald Creek began in mid-October and continued until early December. Egg loss from redd superimposition was probably significant.

No kokanee spawned in Beaver Creek, a large spring creek in Nyack Flats (Middle Fork) in 1979. Historically, a large run of kokanee entered Beaver Creek in mid-October (Gordon Pouliot, West Glacier, Mt. 1979, personal communication). Beaver activity in the creek could have created migration barriers to kokanee; however, we never observed kokanee concentrated below the beaver dams. A change in the channel may have caused Beaver Creek kokanee to miss their homing cues. Whereas, Beaver Creek formerly emptied into the Middle Fork, it now empties into Deerlick Creek approximately one-quarter mile above its mouth. The channel change occurred during the spring 1979 flood.

Kokanee generally picked shallow areas with little or no water velocity as spawning sites. Mean depth of 189 redds in areas with measurable water velocity was 29cm (Figure 17). Mean water velocity over those redds where velocity was measurable was 11.7cm/s at a flow of approximately 285 m^3/s (10,000 cfs. Figure 18). Sixty-one percent were located in areas of velocity less than 10cm/s. These values are less than the spawning velocity criteria recommended for kokanee by Smith (1973) and Hunter (1973).

Table 2. Areas utilized for spawning by kokanee in the Flathead River between the mouths of the South Fork Flathead and Stillwater Rivers, 1979.

Landmark	RK	Early November redd count	Late November redd count
Slough - east bank	69.5	50	330
Main channel - east bank	69.2	*	100
Main channel - east bank	69.0	*	100
Mouth slough - east bank	68.9	*	50
Main channel - east bank	66.8	10	25
Kokanee Bend - end of road	61.6	20	25
Kokanee Bend	62.3	0	20- 25
Kokanee Bend - rockfield	61.2	75-100	2- 300
Hoerner spawning area	60.7	35- 45	150
Side channel - Buck's Gardens	60.2	40- 50	50
Side channel - Buck's Gardens	59.9	150-200	200- 280
Pressentine Bar - side channel east bank	56.2	50	200
Pressentine Bar - easternmost channel	56.1	100	100
Easternmost channel	55.4	40- 50	100
Easternmost channel	53.9	*	50- 60
Mouth Gooderich Bayou	52.3	3	10
Easternmost channel	51.8	*	8- 10
Easternmost channel	51.7	*	2- 500
Spring slough - east channel	51.5	*	110
Mouth of above slough	51.5	*	8- 10
Spring slough - Reserve Dr.	50.4	3	20- 25
West channel - Highway 2 Bridge	43.8	0	60
Kiwanis Lane - west bank	41.8	0	7
East channel	41.0	0	1
East channel	40.9	0	2
East channel	40.7	0	2
Brenneman's Slough	38.6	200	225**
Total		776-881	2353-2857

* Area not checked

** 200-300 more redds found after surveys completed

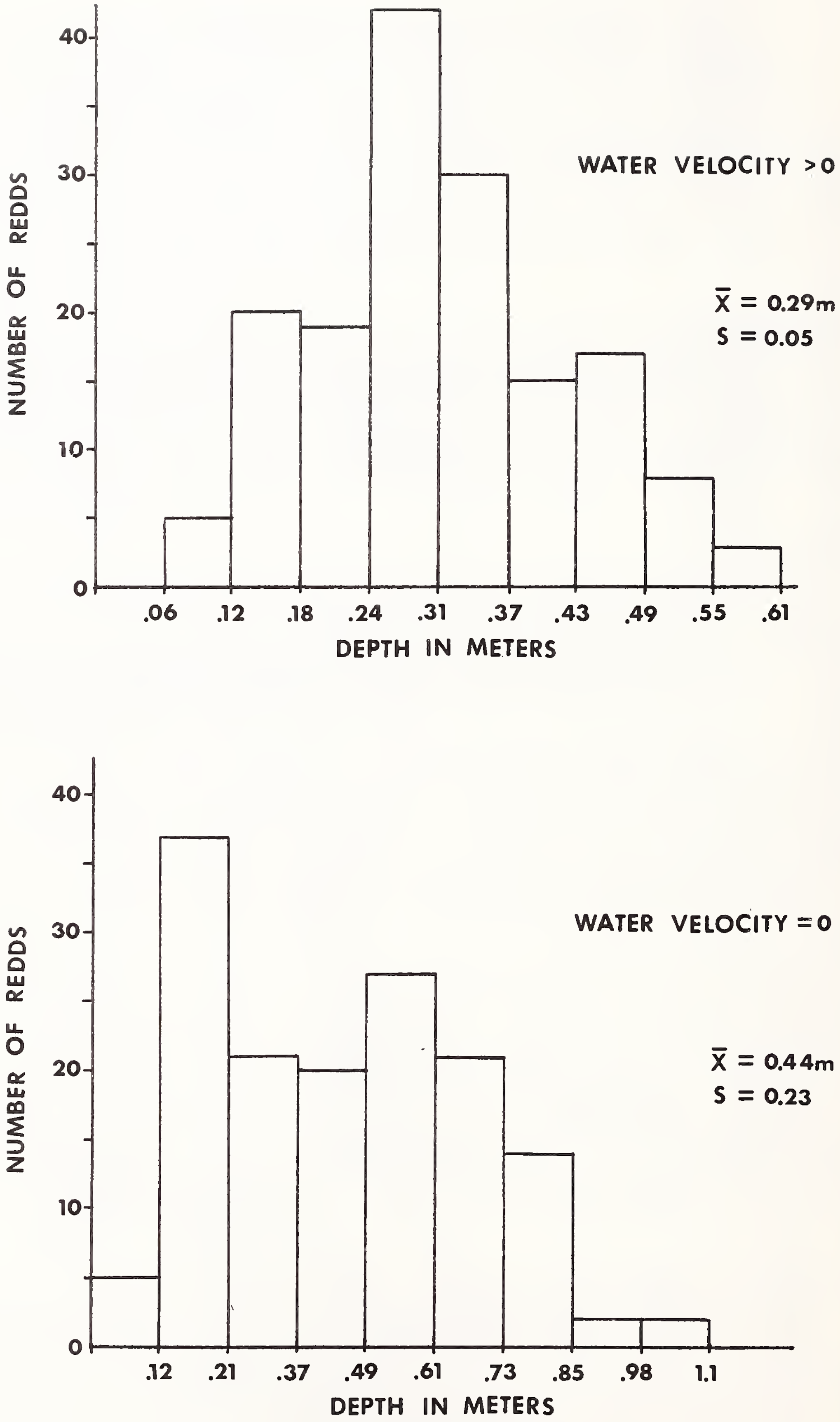


Figure 17. Frequency distributions of water depths over kokanee redds in areas of measurable water velocity (top) and areas with no measurable water velocity.

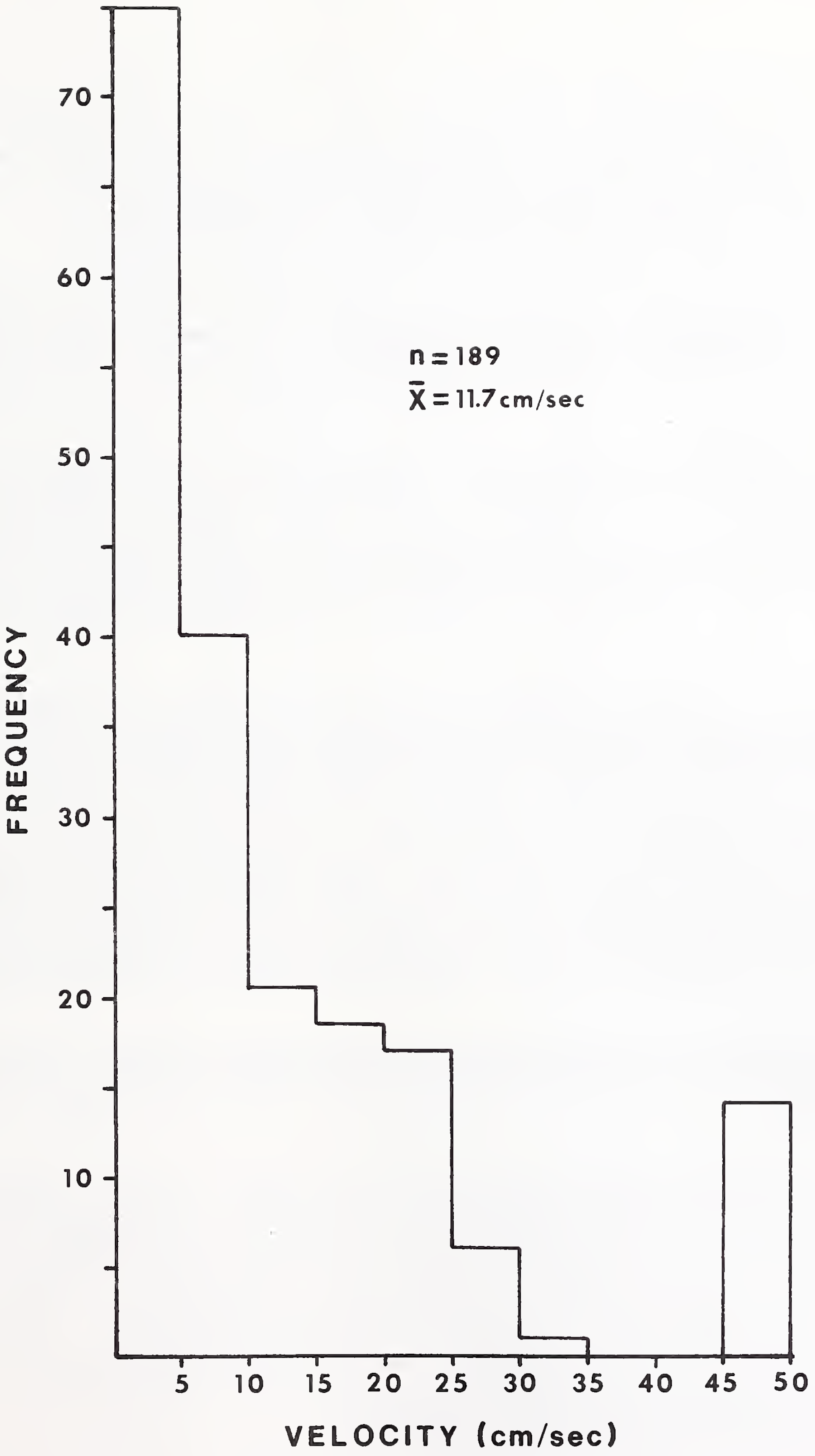


Figure 18. Frequency distribution of water velocities measured over kokanee redds in several areas of the main stem Flathead River. River discharge when measurements were taken was approximately 11,000 cfs.

Incubation

Natural Redds

Survival of kokanee eggs in the main stem Flathead River downstream from the South Fork during the winter of 1979-80 was poor. Excessive mortality was caused by high November flows followed by extended periods of low flow in December, January and February. Extremely cold weather in January contributed to mortality when redds located in some ground water influenced areas froze.

Every redd we sampled that was located above the low water mark and not influenced by ground water exhibited 100 percent mortality by early January (Table 3). Approximately 60 percent of the redds we counted in November were above the low water mark because kokanee utilized shallow areas during the high spawning season flows.

Hungry Horse powerplant operated at peak capacity for at least a part of all but five days in the month of November. Between 1700 hours on November 11 and 2400 hours on the morning of November 22, the plant operated constantly at peak capacity. Consequently, most kokanee spawning took place above the low water mark. Normal peaking operations were maintained until December 21 after which the plant shut down except for a few hours at a time until the time of this writing (March 26).

Egg survival in redds constructed in areas influenced by ground water was much better (Table 4). Survival averaged approximately 80 percent in early January. Some redds that received a flow of ground water nevertheless suffered 100 percent mortality. Mortality was probably caused by freezing during a period of extremely cold weather in mid-January. Two redds at Kokanee Bend sampled on February 5 suffered 98 percent and 100 percent mortality. They were located in an area that received a small amount of subsurface flow. One nearby redd still contained 40 percent live eggs. It was located in an isolated pool created by upwelling ground water. Domrose (1968,1975) found few live eggs or fry in dewatered areas of the Flathead River and Flathead Lake but found good survival in areas influenced by ground water.

Redds in permanently wetted areas experienced good survival. Survival in spring influenced areas was better than survival in main stem areas without springs (Table 5).

Survival in McDonald Creek was comparable to that of eggs in permanently wetted areas of the main stem Flathead River (Table 5). It is apparent from subsequent samples that we either underestimated survival on December 21 or overestimated survival on one or both subsequent sampling dates. Overestimation could be caused by loss of dead eggs due to predation or decay (McNeil 1968). However, our estimate of the density of live eggs was higher on February 1 ($1441/m^2$) than on December 21 ($1267/m^2$). Total egg densities were similar for the two dates ($1622/m^2$ on December 21 versus $1698/m^2$ on February 1). Reliability of the estimates could be improved by taking more samples.

Table 3. Survival of kokanee eggs in natural redds sometimes dewatered due to fluctuating flows and not influenced by groundwater. Samples were collected in the mainstem Flathead River during the 1979-80 incubation period.

Site	Date	Number samples	Number eggs	Percent survival	Percent mortality
Pressentine Bar	Dec. 31	2	731	0.0	100.0
Columbia Falls	Jan. 2	3	835	0.0	100.0
Kokanee Bend	Jan. 4	1	130	0.0	100.0
Hoerner Area	Jan. 4	2	406	0.0	100.0
Bucks Garden	Jan. 4	2	1,043	0.0	100.0

Table 4. Survival of kokanee eggs in natural redds sometimes dewatered due to fluctuating flows but influenced by ground water. Samples were collected in the main stem Flathead River during the 1979-80 incubation period.

Site	Date	Number samples	Number eggs	Percent survival	Percent mortality
Pressentine Bar	Dec. 31	1	263	83.7	16.3
Columbia Falls	Jan. 2	1	501	77.8	22.2
Fairview	Jan. 3	2	480	77.7	22.3
Kokanee Bend	Jan. 4	1	144	87.5	12.5
	Feb. 5	3	1,220	9.1	90.9
Highway 2 Bridge	Dec. 28	1	205	87.8	12.2
	Feb. 4	3	469	69.7	30.3

Table 5. Survival of kokanee eggs in natural redds in permanently wetted areas of the Flathead River drainage. Samples from control (nonfluctuating), fluctuating and fluctuating but influenced by spring areas are grouped. Samples were collected during the 1979-80 incubation period.

Type Area	Site	Date	Number samples	Number eggs	Percent survival	Percent mortality
Control	McDonald Creek	Dec. 21	5	1,330	79.2	20.8
		Jan. 14	5	725	89.2	10.8
		Feb. 1	5	1,393	84.8	15.1
Fluctuating	Pressentine Bar	Dec. 31	2	610	74.8	25.2
Fluctuating - Spring influenced	Columbia Falls	Jan. 2	2	532	88.9	11.1
	Fairview	Jan. 3	2	306	89.2	10.8

Experimental Egg Plants

Eggs buried above the low water mark in fiberglass screen bags suffered 100 percent mortality by December 29 at both Reserve Drive and Kokanee Bend (FIgure 19). These eggs had been dewatered for seven consecutive days prior to excavation. Although we buried the eggs at Reserve Drive in a spring area, we did not place them deep enough to keep them wetted by ground water.

Survival of eggs buried below the low water mark was slightly lower than that of eggs in natural redds. Dropping water levels, caused by freeze-up resulted in 100 percent mortality of eggs buried below the previous low water mark at Kokanee Bend. On December 28, the eggs were at water's edge and mortality amounted to 24 percent. By January 24, they were frozen solid in the substrate above the low water mark.

Eggs buried in fiberglass screen bags at Beaver Creek had better survival than eggs sampled anywhere else in the drainage. Mortality was less than five percent on February 2(Figure 20). Survival in Whitlock-Vibert boxes was lower, dropping from 99 percent on December 21 to 69 percent on February 2. Much of the mortality in Whitlock-Vibert boxes appeared to be a result of infiltration of silt into the boxes. Dead eggs were frequently found in tightly cemented clusters. Fungi and bacteria attacked the clusters and spread to adjacent live eggs. Harshbarger and Porter (1979) found sediment accumulation and fungus development were significant causes of mortality in brown trout eggs planted in Whitlock-Vibert boxes.

Rate of Development

Eggs buried in Beaver Creek on November 20 had accumulated 392 Centigrade temperature units (TU) as of February 1 at temperatures ranging from 6.7 - 4.4C (Figure 21). Essentially, all eggs were eyed (99.6%) but hatching had not yet begun (0.1% sac fry). Over 97 percent of the eggs were eyed on December 21 (180 TU). Backwards extrapolation would set the date of 50 percent eye-up at December 6 (100 TU). Based on Hunter's (1973) guidelines for temperature requirements of kokanee eggs to hatch, we expect hatching in the first week of March.

Spawning in McDonald Creek took place over a six-to seven-week period from mid-October to early December. Consequently, a single date is not representative of all eggs deposited in the creek. We chose November 1 as a median date of spawning. Eggs deposited in McDonald Creek on November 1 would have accumulated 487.5 TU as of February 1 at temperatures ranging from 10.6 - 1.1 C (Figure 22). on December 21 (350 TU) our samples yielded 54 persent eyed eggs. Backwards extrapolation results in an estimate of 50 percent eye-up on December 18 (335 TU). The disparity between TU required for 50 percent eye-up in McDonald and Beaver Creek is probably a result of two factors. More temperature units are required to attain eye-up at higher temperatures than lower temperatures (Hunter 1973, Stober et al. 1978). It is also possible that our arbitrarily selected date of November 1 is too early. Although much spawning had taken place in McDonald Creek prior to November 1, the high density of spawners may have resulted in displacement of a large portion of the eggs deposited by early spawners. Thus,

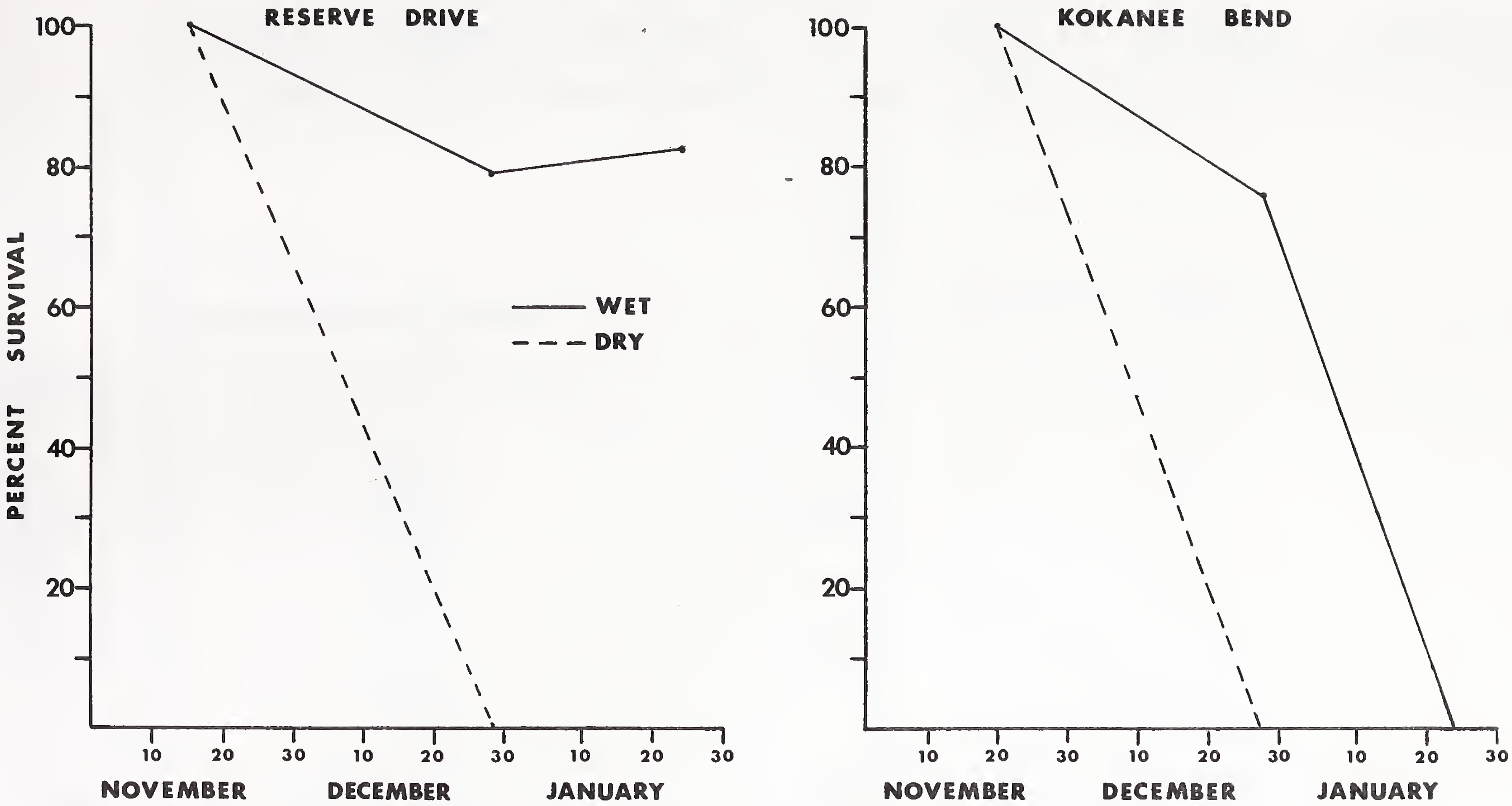


Figure 19. Survival of kokanee eggs buried in fiberglass screen bags at Reserve Drive (a spring influenced area) and Kokanee Bend, 1979.

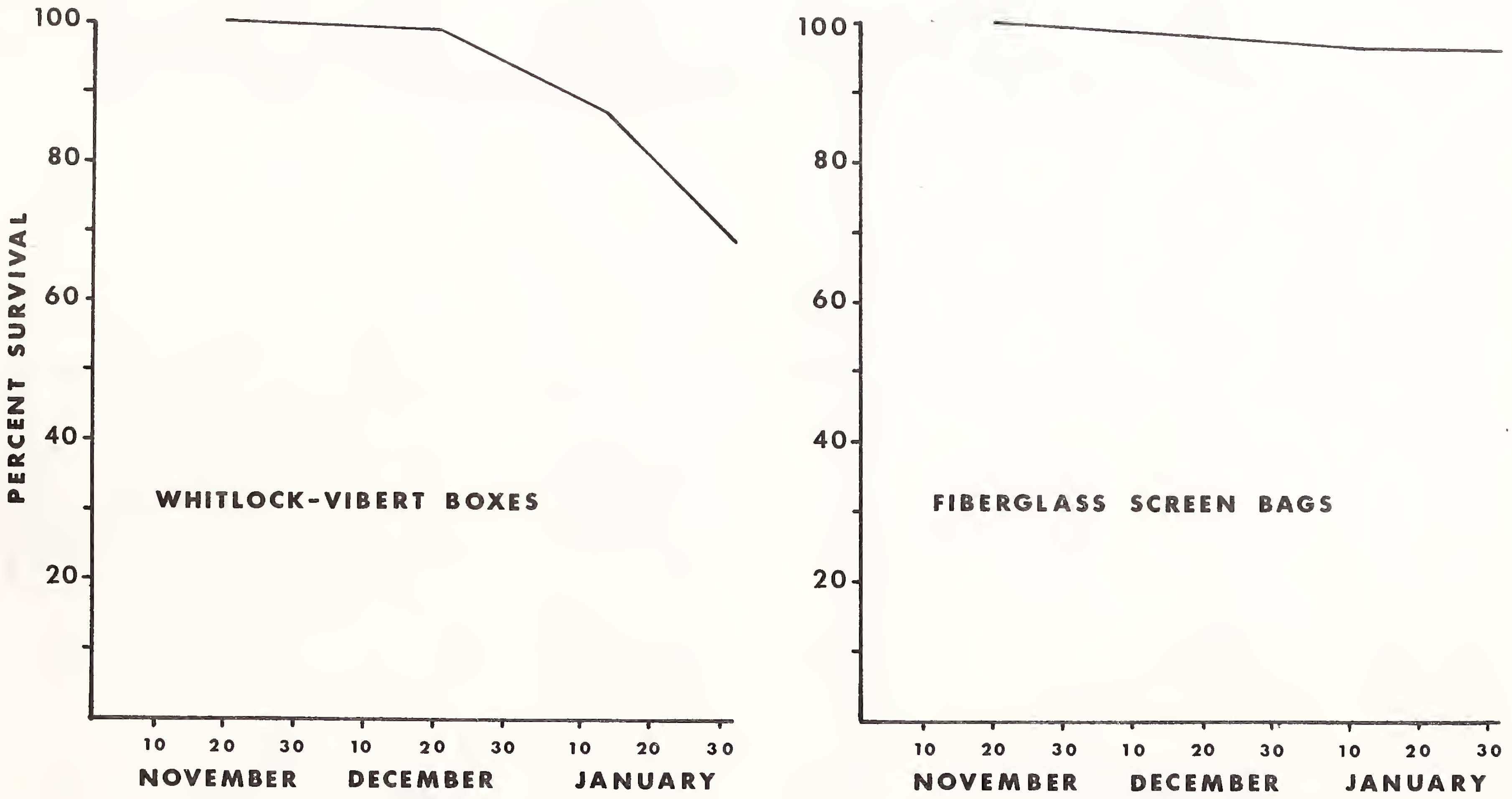


Figure 20. Survival of kokanee eggs buried in Whitlock-Vibert boxes and fiberglass screen bags in Beaver Creek (Middle Fork drainage) 1979.

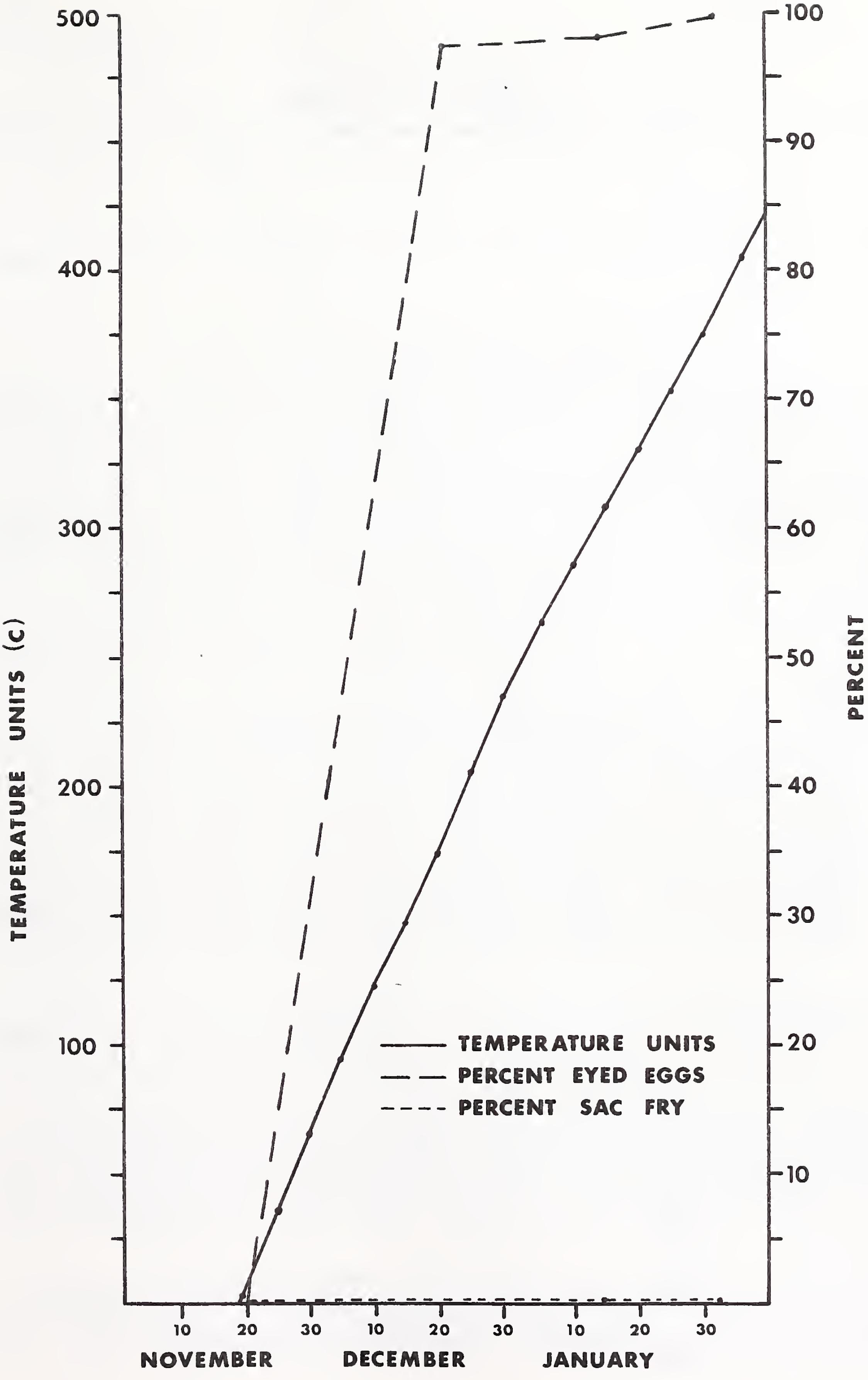


Figure 21. Accumulated temperature units (C), percent eyed kokanee eggs and percent kokanee sac fry in Whitlock-Vibert boxes and fiberglass screen bags buried in Beaver Creek, 1979.

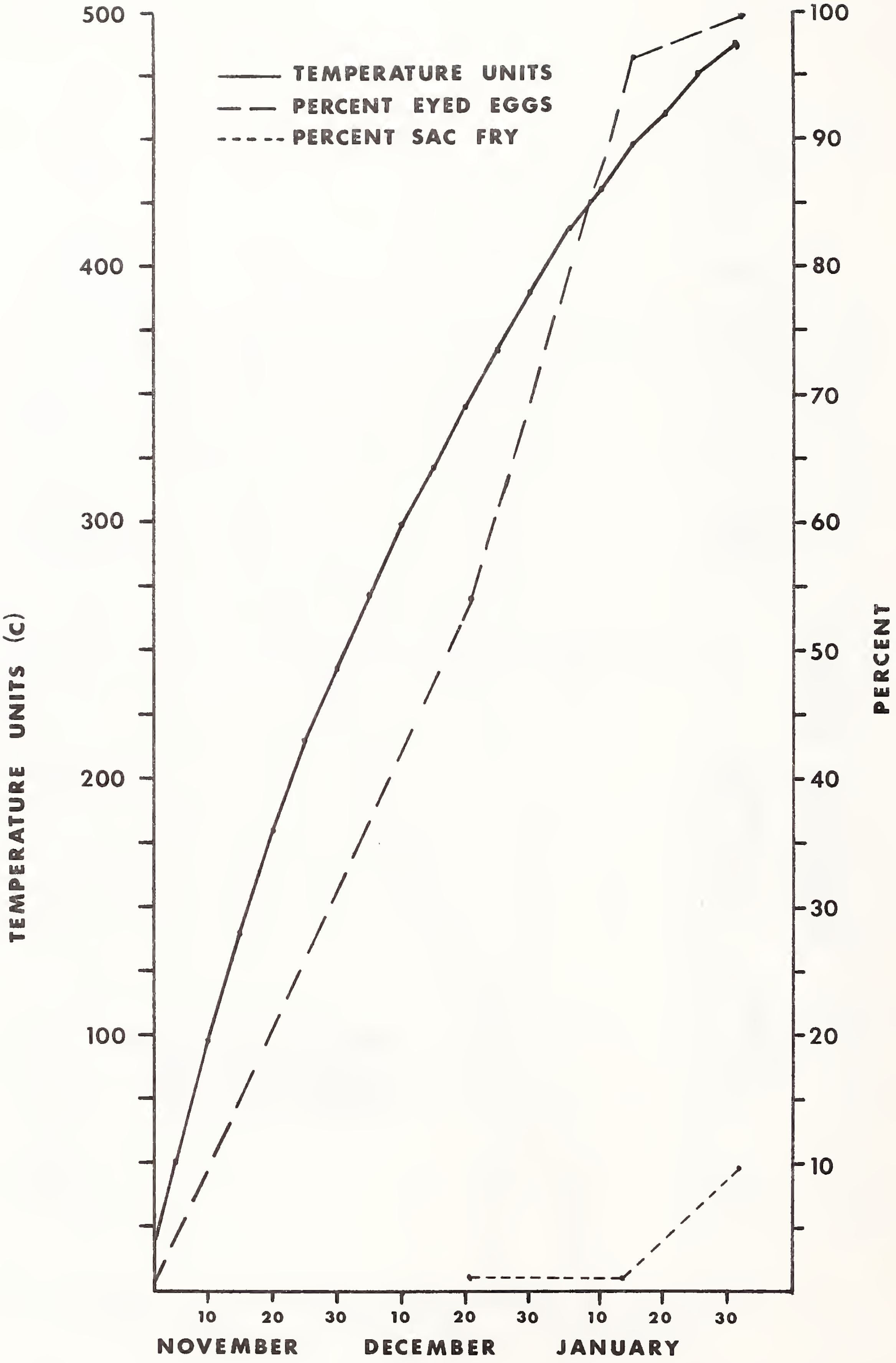


Figure 22. Accumulated temperature units (C), percent eyed kokanee eggs and percent kokanee sac fry in samples taken from natural redds in McDonald Creek, 1979.

most of the live eggs we sampled could have been deposited by kokanee spawning after November 1.

Hatching in McDonald Creek appears to have begun in mid-January. Although we collected a few sac fry as early as December 21 (all in one sample), a substantial increase did not occur until February 1 (Figure 22).

We could not document rate of development of eggs in the main stem Flathead River. Insufficient temperature data and difficulty in access due to ice conditions prevented accurate determinations.

Stream Flow:Fish Length Correlation

Both the November flow:fish length and flow ratio fish:length correlations indicated a strong relationship between flows and kokanee year class strength (Figure 23). The relationship between November flow and length of male kokanee was: $L = 250.0 + 0.445Q$, where L = mean length of male kokanee spawners and Q = mean November flow of main stem Flathead River at Columbia Falls. The correlation coefficient (r) of 0.89 indicates the strength of the relationship. The relationship between flow ratio and length of male kokanee was: $L = 365.7 - 27.92\ F$, where, L = mean length of male kokanee spawners and F = mean December - March flow/mean November flow, both in main stem Flathead River at Columbia Falls. The flow ratio-length correlation coefficient was -0.92.

The strong positive correlation between November flows and kokanee length was probably a result of higher incubation mortality when November flows were high. Because kokanee selected shallow areas for spawning, redds were frequently constructed well above the low water mark when Hungry Horse powerplant was discharging at peak capacity. Eggs were then subject to periods of desiccation and/or freezing during the incubation period. Extended periods of low flow have been common during the winter months. Down periods at Hungry Horse powerplant lasting at least 72 hours have occurred during the winter months of every water year since 1966. When November flows were lower, redds were constructed in areas less frequently dewatered and consequenlty, mortality was lower.

A strong negative correlation between flow ratio and kokanee length would be expected. A high flow ratio resulted when incubation flows were higher than spawning flows. Thus, eggs would be dewatered infrequently.

Using the relationships we have developed, it would be possible to manage flows in the Flathead River to produce optimum spawning and incubation conditions. Our goal has been to produce adult kokanee averaging 315-320mm. Based on the information presently available, this could be achieved with mean November flows of 146-157 m^3/s(5,155-5,544 cfs) and a flow ratio of 1.64-1.82.

It is worth noting that the relationships discussed above were based on mean flows and consequently, would not always represent actual conditions. Steady, unchanging conditions would be more favorable for egg survival than fluctuating conditions even though mean flows may be identical. For example, if Hungry Horse

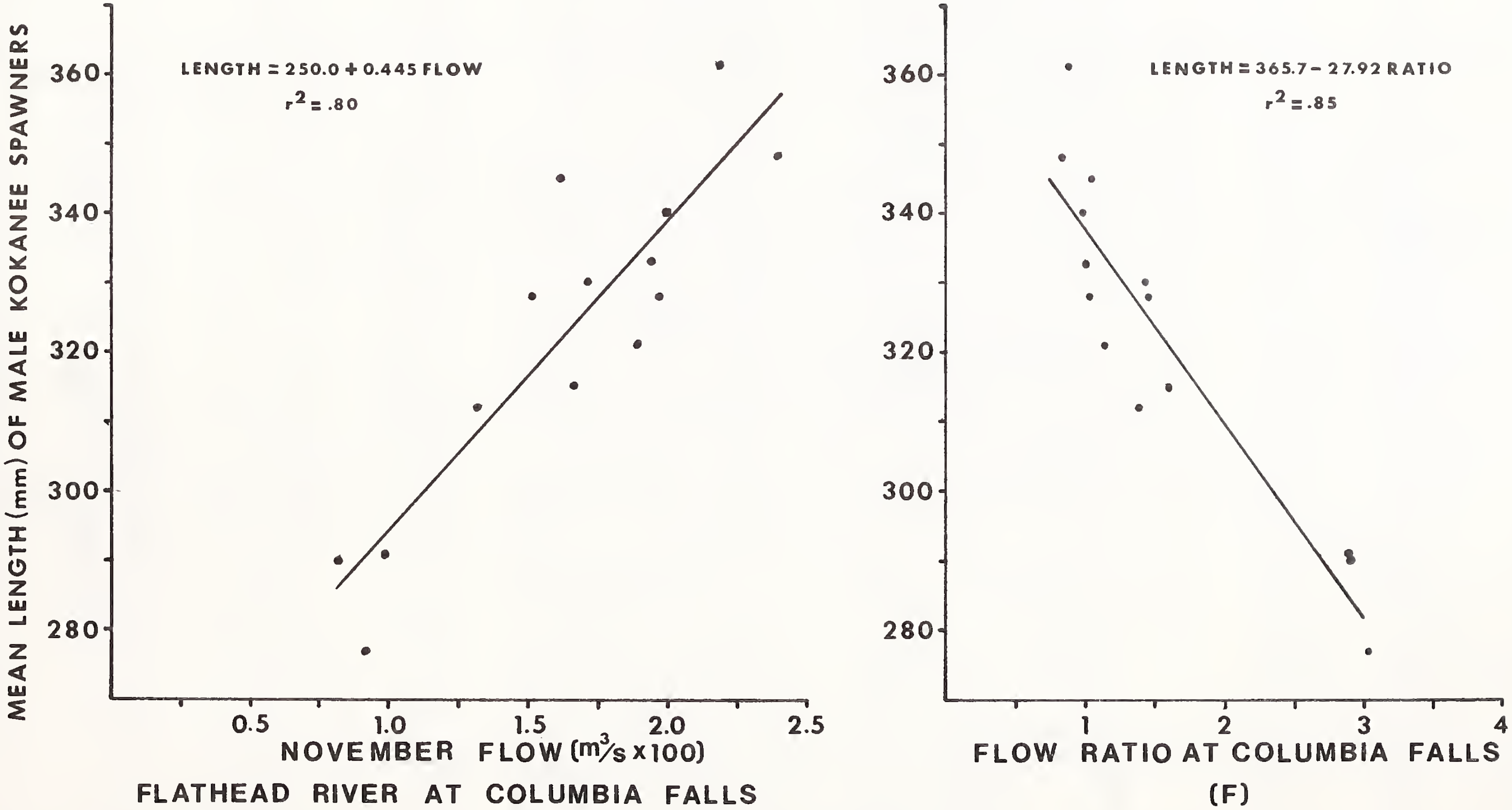


Figure 23. Relationships between length of male kokanee spawners and mean daily flow of the Flathead River at Columbia Falls during November (left) and the ratio of mean daily flows for the period Dec. - March to mean daily flows for November (right). Flow data are from water years 1962-1977. Kokanee length data are from spawn years 1966-1979.

powerplant peaked at 283 $m^3/3$ (10,000 cfs) for 8 hours and then dropped to 12 m^3/s (500 cfs) for 16 hours, the 24-hour mean flow would be 111 m^3/s (4667 cfs). The mean flow would be in the favorable range of November flows. However, due to the delay in changing flows downstream of Hungry Horse, the flow in the main stem Flathead River at Kokanee Bend (near much of the main stem's best spawning area) might remain at near peak levels up to 3 hours later (Figure 24). The water level at Kokanee Bend would not begin to drop until 2 to 3 hours after the beginning of shut down at Hungry Horse and would not reach minimum levels for 4 to 6 hours. Peak kokanee spawning activity generally occurs during the period just after sunset. Consequently, kokanee could be spawning at peak or near peak flows even though mean daily flow was much lower.

A more desirable option would be if Hungry Horse power plant limited its operations to half of capacity during November. This would not prevent the majority of kokanee from spawning above the low water mark, but would provide water to supplement minimum flows during the incubation period. Another option would be to shut down earlier in the day, thus reducing flows in critical spawning areas prior to peak spawning activity during the post-sunset hours. If a re-regulation dam was eventually constructed downstream of Hungry Horse Dam, it could be used to help regulate spawning flows.

Anticipated Research

In 1980, we plan to continue our effort to assess kokanee migration, spawning and incubation. We hope to tag 400 to 500 kokanee in the Kalispell area. Four groups of kokanee, tagged with colored, blank anchor tags will be sampled through the period of migration. An intensive media campaign will be used to inform anglers of the program and encourage tag returns.

Redd counts will again be made during ground-level surveys of the main stem Flathead River. Selected areas will be closely monitored in an effort to identify time of kokanee spawning. Two high density spawning areas will be surveyed and mapped. Frequent observation of these areas will allow us to determine spawning dates for individual redds which can then be excavated at a later date to determine mortality and stage of development. Mapping and surveying in key kokanee spawning areas will result in quantification of spawning habitat at several places.

We hope to cooperate with researchers at Glacier National Park and the University of Montana to operate a trap near the mouth of McDonald Creek. Enumeration of kokanee spawners in McDonald Creek will allow us to make more accurate determinations of incubation mortality and potential production in an unregulated stream. This information is a prerequisite to determining losses in regulated areas of the Flathead River.

We also hope to continue snorkeling and SCUBA surveys in the lower Middle Fork and North Fork. If possible, we will identify spawning areas in both rivers.

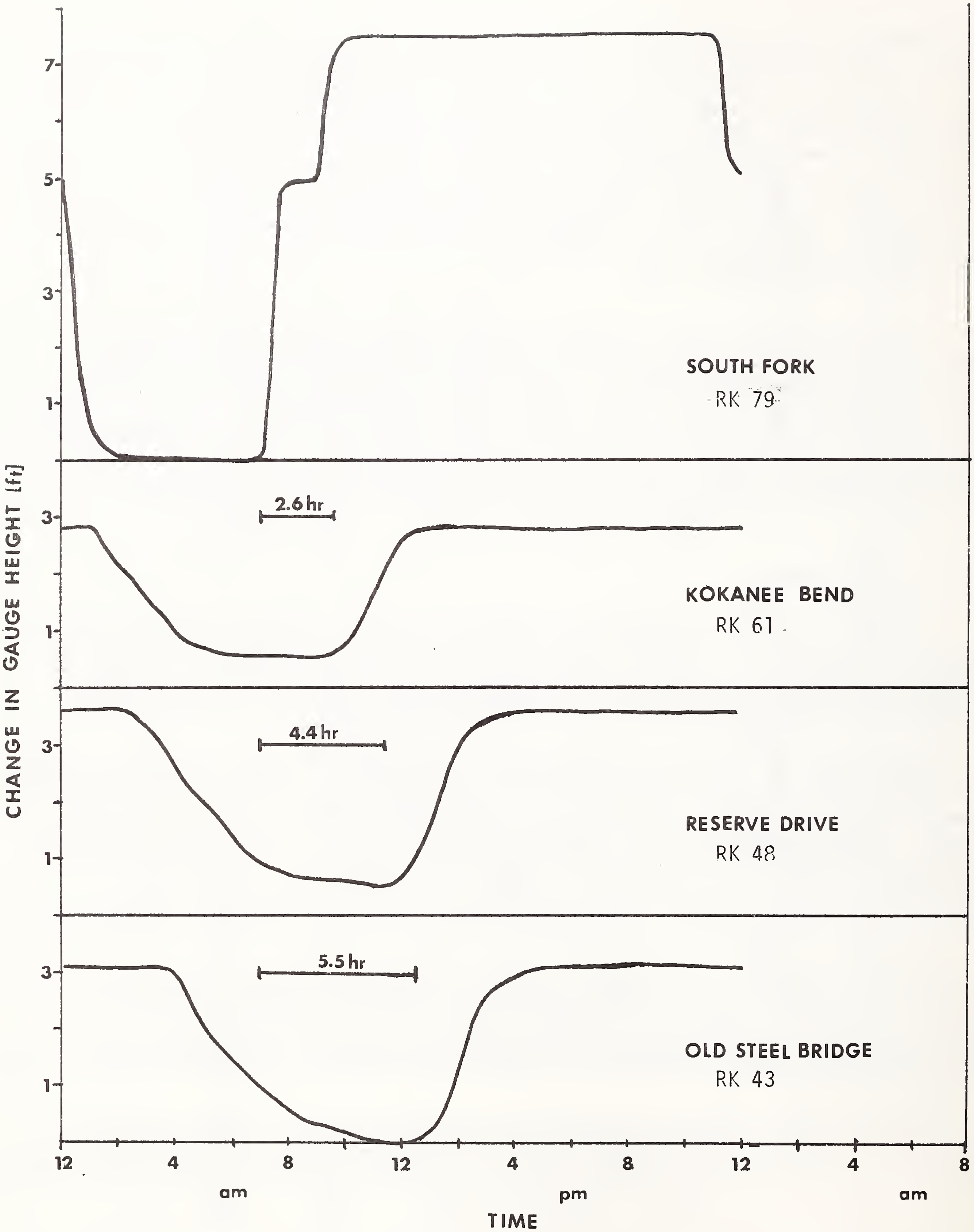


Figure 24. Diel changes in gauge height at one station in the South Fork and three stations in the main stem Flathead River caused by release of peaking discharges at Hungry Horse powerhouse, August 2, 1979 (South Fork flows ranged from 164 cfs to 9,100 cfs main stem). Flows at Columbia Falls ranged from 3,210 cfs to 12,100 cfs.

Our incubation studies will be similar to those of 1979, with some modifications. We will select high density spawning areas as survey sites in 1980 so that we may estiamte density of egg deposition. This will allow better comparisons of the effects of regulation on egg/alevin mortality. With the cooperation of the Water and Power Resources Service, we will design and execute a controlled flow experiment to determine the length of time kokanee eggs can tolerate dewatering.

FISH FOOD ORGANISMS

Introduction

This portion of the study involves the assessment of impacts of discharge from Hungry Horse Dam on fish food organisms in the Flathead River. The impact of the various alternatives on the aquatic invertebrates will be evaluated. Flow recommendations will be based on optimizing flows which, 1) cause the least catastrophic drift, 2) provide the most insect habitat, and 3) provide the best criteria for the growth and emergence of important fish food species.

The initial phase of the study includes the collection of baseline data to compare the biomass, species diversity and composition of the macroinvertebrates at a control site and in regulated areas of the Flathead River. Phase One will be continued throughout the rest of the study period. A second phase or study will begin in April, 1980. This will include fish food habit studies to document possible seasonal changes in diet and food availability in the regulated areas of the Flathead River.

Certain changes in the discharge regime from dams can benefit invertebrate populations (high minimum flows, predictable flows, selective withdrawal systems, etc.) and thereby increase fish production. The effects of regulation on the life histories of selected insects out of various project alternatives on macroinvertebrate habitat loss and on insect drift will be studied during the second year of the project. Insect drift will be measured in conjunction with fish food habit studies and in relation to proposed discharge regimes. It will be necessary for the Water and Power Resources Service to provide test flows to simulate anticipated peaking regimes and various rates of increase and decrease of flows at different times of the day.

The construction of Hungry Horse Dam has resulted in a number of downstream modifications which are of significance to river zoobenthos. Rapid, short-term fluctuations due to hydropower production have profoundly altered biological processes in the South Fork. The hypolimnial releases from the dam have produced extreme temperature modifications; presumably many species of insects cannot complete their life cycles in this constant thermal regime. The lack of trophic and habitat diversity also contributes to the severely altered invertebrate composition in the South Fork. The main stem Flathead River is affected by the addition of waters from the South Fork, but the abnormal effects on the macroinvertebrates are tempered due to dilution by the North and Middle Forks. Limited studies of the manifestation of reservoir operation on tailwater benthos, primarily the insect orders Plecoptera and Trichoptera, have been made (Stanford 1975, Stanford and Hauer 1978, Stanford et al 1979).

Temperature is an important environmental factor affecting the benthos in the regulated areas of the Flathead River. The marked reduction in thermal amplitude in the South Fork as compared to the unregulated North Fork (during the period of the study for which thermograph data is available) is shown in Figure 25. This greatly modified thermal regime may be the major factor contributing to the absence of most species in the South Fork. The lack of appropriate thermal criteria for hatching, growth, and emergence is sufficient cause for elimination of most species. Ward and Stanford (1979) consider some of the thermal modifications downstream from deep-release dams under the following categories: 1) increased diurnal constancy, 2) increased seasonal constancy, 3) summer cold conditions, 4) winter warm conditions. The thermal regime in the South Fork exemplifies these conditions in the extreme.

The above factors may affect invertebrates in a number of ways. Diurnal constancy may lead to low growth efficiency. The reason for this may be that different physiological and behavioral components have different temperature optima (Ward, 1974). Sweeney (1978) found that the development rate of eggs and larvae of the mayfly (*Isonychia bicolor*) were positively correlated with the magnitude of the diel temperature fluctuation. Constant seasonal temperatures are thought to eliminate many species which depend on temperature maxima or minima to break diapause or to stimulate hatching, growth, and emergence (Ward, 1976b). Summer cold conditions may mean that total degree days may not be adequate for some species to complete their life cycles, or temperatures may not be high enough to cue emergence. The time between oviposition and hatching and the length of the hatching period may be greatly extended by low summer temperatures (Elliott, 1972). Species requiring winter chill (0°C temperatures) to break egg or larval diapause will be eliminated if winter temperatures are elevated (Lehmkuhl, 1972). Premature emergence may eliminate species if air temperatures are lethal to the adults (Nebeker, 1971).

The summer depression and fall and winter elevation in river temperatures can also be seen in the Flathead River below the mouth of the South Fork (Figure 26). In the partially regulated areas of the river, severe thermal fluctuations over short periods of time may occur as power releases peak and wane. In the summer during periods when there is no generation, river temperatures warm quickly since most of the flow is from the North and Middle Forks. Mean water temperatures were very low during the latter part of August when generation was almost continual.

Water discharge is a factor of key importance to the benthos, especially due to its influence on temperature, current velocity, composition of the substrate and availability of food. The discharge regime in the regulated Flathead River has been discussed in the fisheries part of this report. The manipulation of discharge affects the total lotic ecosystem. Due to the relatively low slope of the terrain, the riffle areas in the main stem Flathead River are often shallow and broad. The wide riffle extending across the entire east channel at the head of Eleanor Island (Kokanee Bend benthic sampling site) is characteristic of this part of the river. Riffles are typically the areas which are richer both in number and biomass of invertebrate species (Hynes, 1970). Loss of riffle habitat thus has the most marked effect on the production of fish food organisms. During minimum water releases from Hungry Horse Dam, a substantial percentage of the channel is dewatered. We will determine the extent of this area using aerial photos taken during full and no generation from Hungry Horse.

We will begin to evaluate the effects of regulation on the composition of streambed material in the South Fork in respect to maintenance of hyporeic macroinvertebrate communities during the second year of the study. The Flathead River has an extensive hyporheic zone in which the channel and adjacent substrata are composed of loosely compacted floodplain gravels. Water circulates deep within the substrata and laterally from the river channel. This subterranean habitat is colonized by certain species of macrobenthos. Stanford and Gaufin (1974) discovered the existance of a detritus-based community of invertebrates in the water which circulates through gravels, which in one location extends 4.2 meters below and 50 meters laterally from the channel of the Tobacco River (northwest Montana). The extent to which this hyporheic zone may have been reduced in the South Fork has not been quantified. The prolonged reduction in discharge during the winter months may not provide sufficient water for extensive lateral hyporheic development. Stanford (1975) suggests that continual clearwater sluicing of the substrate, without redeposition of sediments during spring runoff has armored the river channel, thus terminating hyporheic developments.

The South Fork supports a dense growth of periphytic algae in the permanently

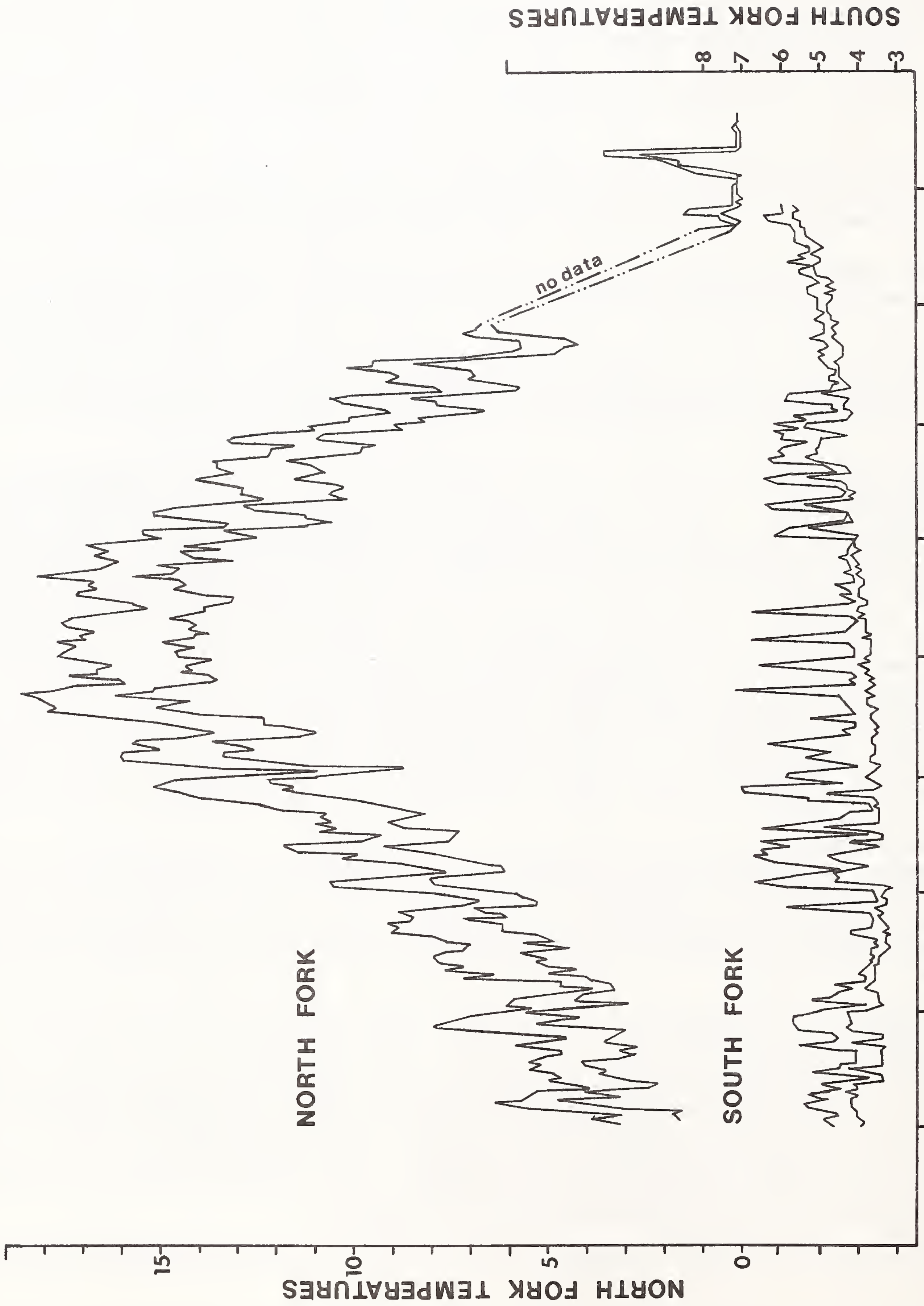


Figure 25. Daily maximum and minimum temperature recorded at USGS stations on the North and South Forks of the Flathead River in 1979

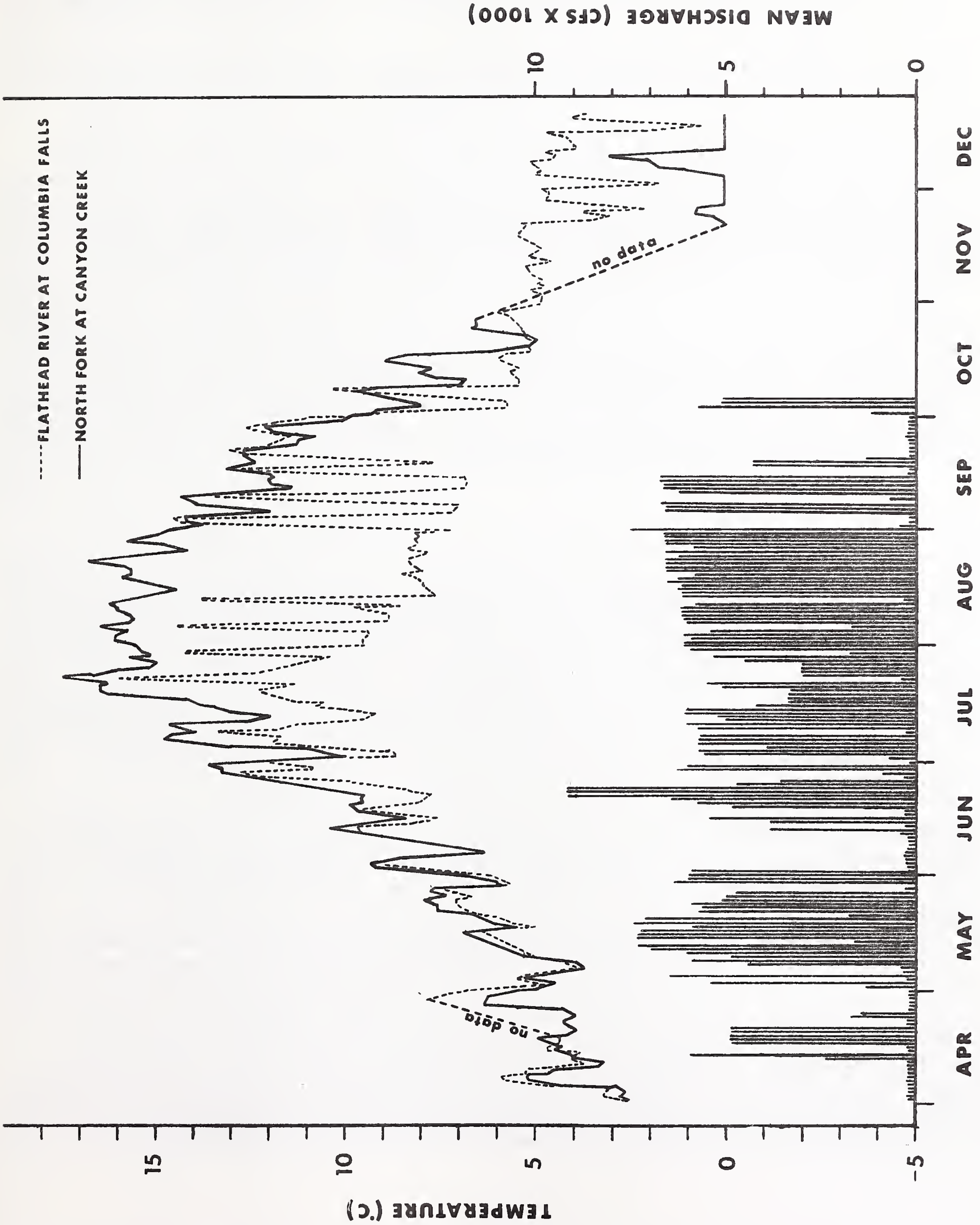


Figure 26. Mean daily temperatures in the unregulated (North Fork) and partially regulated (Columbia Falls) area of the Flathead River, and mean daily discharges are indicated below the temperature data, 1969.

wetted area of the river. Inorganic sediments settle out in the reservoir, reducing turbidity and sediment scour in the South Fork and main stem Flathead River. Periphyton also appears to be more abundant in the partially regulated areas of the river.

Reservoir seston is not abundant in the tailwater areas below Hungry Horse Dam, since water is withdrawn only from the unproductive hypolimnion of the reservoir. Plankton is not as available for filter-feeding species as is the case in natural lake outlets and reservoirs with epilimnetic or selective withdrawal discharges. More data are needed on the dynamics of organic carbon in the regulated areas of the Flathead River. The availability of various sized particles to filter feeders, shredders and detritivores needs further study. We will use a wet filtration method to size fractionate sestonic particles during the second year of this study.

Debris jams consisting of small sticks and organic matter were encountered much more frequently when sampling the Kokanee Bend than the control site. The water fluctuations in the regulated areas may collect more wood from the shoreline areas, which are not in contact with the river during much of the year (i.e. after spring runoff) in unregulated areas. These debris packs may provide more habitat for depositional species of invertebrates.

Methods

Monthly sampling of benthic invertebrates at the three permanent sites was begun after the runoff period in July, 1979. Eight to ten samples were taken at each site each month by a combination of systematic sampling (the transect method) and stratified random sampling (selection of habitat types) techniques. Mean current velocity (taken with a Price AA current meter at the 0.6 depth) and water depth were taken just upstream from each benthic sample. The maximum depth which could be sampled was about 45cm. All samples were taken at conditions of minimum discharge from Hungry Horse Dam, 150 cfs (4.2m^3/sec) from July to December and 450 cfs (12.7m^3/sec) in January and February.

Two different samplers were used in an effort to reduce biases associated with any one sampling device. Sampling in the Flathead System was difficult due to the large substrate sizes, so conventional samplers were modified.

Our most efficient sampler was a modified kick net which was also being used by the Flathead Research Group in the ongoing Flathead Basin Environmental Impact Study. The kick net was constructed of an outer square 97cm wide and 89cm high, made of Nitex with a 355 µm mesh. A bag (72cm long) with an opening 44cm by 42cm extended from the net. The bag was constructed of 150 µm mesh which retained many of the smaller insect instars. The net was held downstream from the sampling area, which was delineated by a square made of one-quarter inch strap iron and encompassed one-third m^2. The net was curved around the square with the bottom taut. Rocks in the sampling area were individually lifted inside the bag and brushed clean by hand. After all of the larger rocks were removed, the collection area was disturbed by kicking for 15 seconds. Organisms were retained in a clear acrylic bucket (with a drain made of Nitex with a 150 μm mesh) at the cod end of the net. They were then transferred to bottles and preserved in 10 percent (or stronger) formalin to which Rose Bengal stain had been added (South Fork samples were not stained due to the large amounts of algae which also absorbed the dye).

The other sampler employed in this study was a circular depletion sampler described by Carle (1976). The total area sampled was also one-third m^2. The height of our sampler was 54cm and the inside circumference and diameter were 205 and 65cm, respectively. The collecting net was made of Nitex with 150 μm mesh. Our sampler was made of aluminum, which was flexible and allowed the sampler to be wedged in around large rocks. Heavy rubber was riveted to the bottom of the sampler to provide a seal. An exact sample site was chosen by attempting to find a location where large rocks did not intersect the sampler edge. The sampler was then rapidly thrust down and turned into the substrate. If the sampler could not be stabilized and sealed within a few seconds by moving rocks, the site was abandoned. The procedure was the same as with the kick net, brushing all the large rocks and removing them and then kicking the substrate within the sampler for 15 seconds. Where current velocities were low, hands were used to promote the flow of water through the sampler.

There were some differences in sites the two samplers could be used. The kick net functioned better than the circular sampler in shallow areas with large rocks where certain insects (e.g. Hydropsychidae) were often most abundant. The circular sampler functioned more efficiently in deeper water and faster current velocities. If a complete seal was not obtained with the circular sampler, loss of insects could occur,particularly when working in areas with a large substrate. Some loss of insects might have occurred due to the backwash resulting from the small mesh size used in the construction of the kick net. Immigration or emigration of insects to and from the sample area was possible when using the kick net.

Benthic macroinvertebrates were handpicked from the algae, detritus, and inorganic material, sorted to order and placed in vials containing 75 percent alcohol. All of the larger insects were removed and then the sample was picked with the aid of a microscope. When the sample contained many small nymphs (less than 2mm in length) a one-quarter or one-eighth subsample was picked. A number of workers were employed to sort samples,so quality control procedures were adopted to insure consistency. All samples were checked by a supervisor and subsampling methods were standardized.

All insects were identified to the lowest taxonomic level possible and enumerated using a laboratory counter. Chrionomidae have not yet been identified to genus due to time considerations. Selected samples will be mounted on slides and identified later in this study. Volumetric measurements were made with the use of a 50 milliliter self-zeroing burette. Volumes were measured by displacement, with any volume less than 0.05ml assigned to a trace value of .01.

Three drift nets have been constructed, but only preliminary sampling of the drift has been done to date. These nets had a rectangular opening measuring 45.7 by 30.5cm and a Nitex bag with 355 μm opening which was 1.5 meters long. The frame was made of angle iron with holes for steel rods which were driven into the substrate; it was also anchored upstream with guy wires attached to heavy stakes. Rubber flanges projecting backward from the edge of the net prevented large insects from walking out of the net.

Qualitative samples of insects were also collected incidentally in a large boat sampler which is routinely used to sample larval salmon during the runoff period in May and June. Certain hyporheic species which were about to emerge may only be collected during that time. The kick and circular samplers could not be used during those months due to high water.

Results and Discussion

To date 158 quantitative samples from three sites have been picked and analyzed. The benthic invertebrate composition was grossly different in the South Fork than at the main stem stations. Species diversity was low in the South Fork. Midges (Chironomidae) and oligochaetes predominated; small numbers of a few species of mayflies, stoneflies and caddisflies were collected. Reductions in species diversity in the tailwater areas downstream from hypolimnial release reservoirs have been found by a number of researchers (e.g. Pearson et al 1968; Hilsenhoff 1971; Hoffman and Kilambi 1971; Isom 1971; Spence and Hynes 1971; Fisher and LaVoy 1972; Lehmkuhl 1972; Ward 1974, 1976b; Young et al 1976 and Wade et al 1978).

Both the control and partially regulated stations on the main stem Flathead River have diverse insect faunas. To date (July - November) 50 species of Ephemeroptera, Plecoptera, Trichoptera and Emphemeroptera have been collected at the control site and 36 species of these orders were identified from the partially regulated site. The total number of species at each site will be much higher when the taxonomic work on the dipterans has been completed and after adult collections have been made and identified (many insects cannot be identified to species in their immature stages). The species lists for the control and partially regulated sites are similar, but there are a number of differences in the abundance of species at the two sites.

The fauna in the South Fork was dominated by the dipteran family Chironomidae (Appendix D). Reproducing populations of turbellarians, nematodes, oligochaetes, and water mites were also present. These non-insect invertebrates do not have an aerial adult phase and their life cycles would not be affected by the lack of emergence cues (Ward and Short 1978). A few other insect species could probably complete their life cycles under the constant temperature conditions that exist in the South Fork, although their populations were very small. These included the stoneflies, *Zapada columbiana* a few species of *Capia* and *Utacapnia*, *Taenionema pacificum*, and *Sweltsa sp.* and the mayflies *Baetis tricaudatus*, *Baetis bicaudatus*, and *Cingymula sp.* These species were consistently found in South Fork samples in various stages of growth Small *Rhyacophila* and pupae of *Rhyacophila verrula* were found in the South Fork but it is not known whether trichoperans are able to emerge under these conditions. Collections of adults will help clarify which species have reproducing populations.

To date a total of at least 18 species of Plecoptera, 12 species of Ephemeroptera and 8 species of Trichoptera have been collected in small numbers in the South Fork. The fact that only one or a few individuals of many of these species makes it highly improbable that they have reproducting populations in the South Fork. Most of these probably drifted downstream from Fawn Creek, a tributary of the South Fork. In September, five qualitative samples were taken in Fawn Creek (Appendix C). All but two of the species found in the South Fork during the fall season were collected in the Fawn Creek samples, providing circumstantial evidence that they could be drifters from Fawn Creek. Some of the species collected in the South Fork were characteristic of smaller streams like Fawn Creek and have not been reported in rivers as large as the Flathead River (other than as components of the drift from tributary streams).

The extend to which variations in discharge from Hungry Horse Dam affect numbers and biomass of invertebrates in the South Fork (due to sloughing of the periphyton and the consequent increase in invertebrate drift during periods of high discharge) cannot be delineated until the life cycles of the major invertebrates involved are known. Month-to-month fluctuations in numbers (Figure 27) and biomass (Figure 28) of invertebrates followed a different pattern in the South Fork from that in the main Flathead River. Much of the variance in the South Fork was probably due to normal seasonal variations in numbers of the dominant midge species. Based on numbers of pupae and adults in the benthic samples, there appear to be emergences from August through October. Life cycles are generally altered under the condition of a constant thermal regime. Insects living in natural, constant temperature springs have either longer emergence periods or tend to emerge earlier than the same species living in rivers (Nebeker and Gaufin 1967; Smith 1968; Thorup and Lindegaard 1977). However, certain species appear to be capable of adapting metabolically to conditions found below dams. *Baetis rhodeni* exhibited similar growth in isothermic and normal streams in Ireland (Fahy 1973).

To date there has been little evidence of stranding of immature insects in the South Fork. Rocks close to the water line were checked for stranded invertebrates at each sampling date and essentially no specimens were found near the surface. It appears that most insects colonize only the permanently wetted areas (i.e. those wetted at minimum flows). It probably takes at least a month of constant flow for substantial invertebrate recolonization of areas subject to fluctuating flows to occur. If the water level is dropped even occasionally during that time interval, recolonization does not occur. In the South Fork much of the invertebrate fauna was associated with the dense mat of periphyton which occurred only in the permanently wetted area.

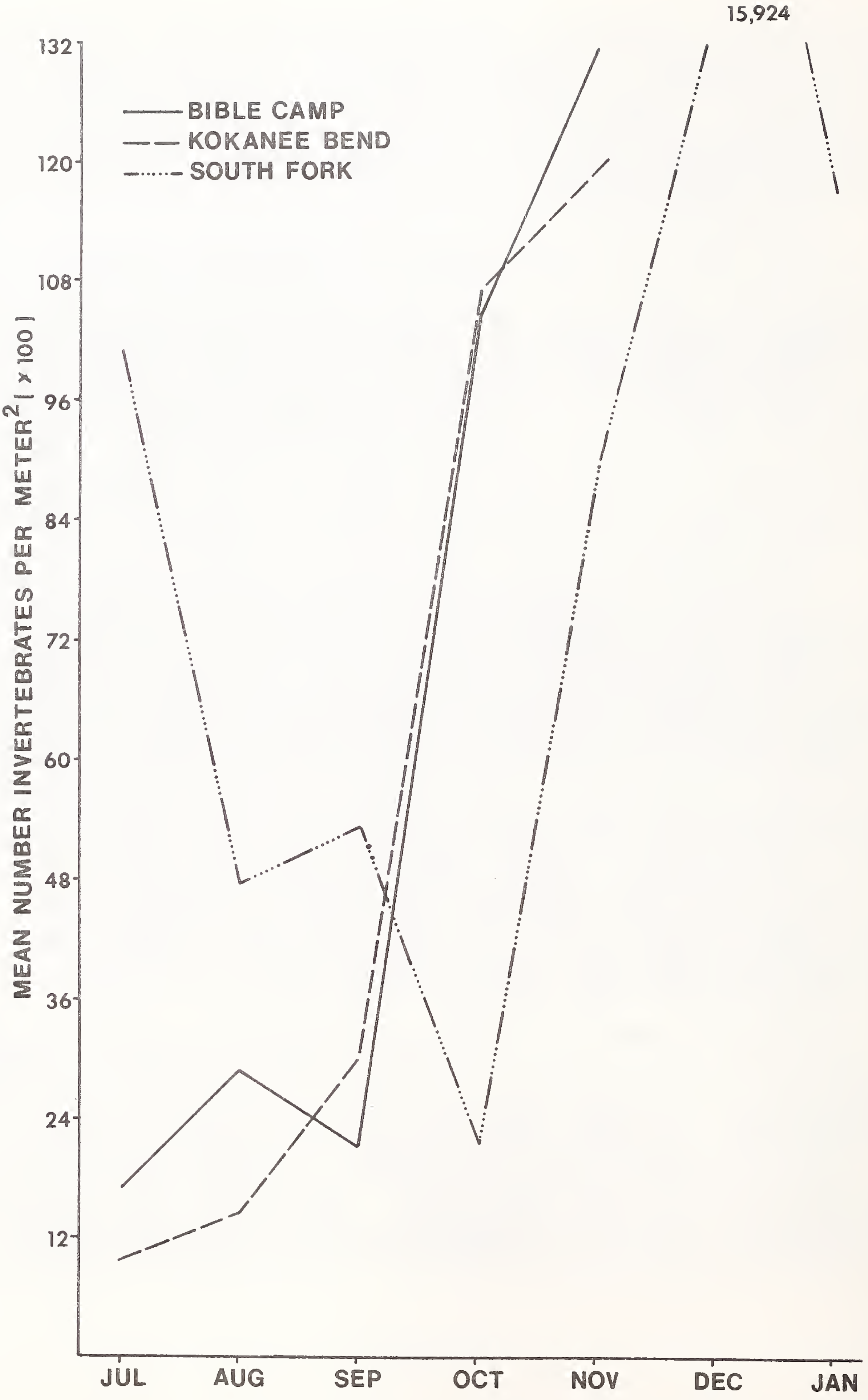


Figure 27. Mean number of invertebrates per m^2 - July 1979 to Jan.1980

The areas without the protective algal mats probably did not provide suitable food and cover for these species. Fisher and LaVoy (1972) found that the benthic community is able to tolerate brief periods of exposure. Brusven, et al. (1974) found considerable taxonomic variation in stranding susceptibility and tolerance to exposure. Stoneflies, caddisflies, and mayflies do not readily colonize shore regions which are in a daily state of fluctuation. Chironomids, however, have a greater flexibility in habitat selection and are the principal insect inhabitants in zones of fluctuation. Basket samplers will be buried in the areas subjected to fluctuating flows to quantify the amount of subsurface colonization.

Accurate quantification of total biomass of the zoobenthos in the main Flathead River was not possible because the hyporheic zone was not sampled with our gear (we sampled the top 10-20cm). Comparison of the control (Bible Camp) and the partially regulated (Kokanee Bend) stations was probably valid for surface benthos, although flow fluctuations could cause more insects to move into the hyporheic zone at the Kokanee Bend site. Most of the biomass in the South Fork would be within the sample area if the hyporheic zone has been eliminated or reduced. Gross underestimation of biomass at the other two sites due to extensive hyporheic habitat would mean that biomass estimates in the main Flathead River and South Fork would not be comparable.

The total number of invertebrates collected each month paralleled each other rather closely at the Bible Camp (control) and Kokanee Bend sites (Figure 27). The fall increase at both sites reflects the life cycle pattern of the insects. Many mayflies and caddisflies and some stoneflies emerged in the late spring, summer and early fall months. Numbers in collections were low in July and August when many species were in the aerial, egg, or early instar stages. Mayfly numbers tended to peak in October and stoneflies in November. Numbers then started to decrease as normal demographic events led to fewer, larger insects of any species.

Total volumes were higher at the Bible Camp site in July and at the Kokanee Bend site in October and November. The larger volumes in the fall at the partially regulated site were mainly due to the fact that the large stonefly, *Pteronarcella badia*, and the large caddisfly, *Arctopsyche grandis*, occurred there in larger numbers than at the control site.

In July the Diptera were the numerically dominant group at Kokanee Bend (49% of total) and the mayflies were the dominant group at the Bible Camp (50% of total) (Figure 29). In October the dipterans were reduced in numbers at both sites due to the fall emergences of the dominant midge family Chironomidae. The mayflies continued to dominate numerically at the Bible Camp (52%) and the stoneflies were dominant at Kokanee Bend (45%).

The stoneflies constituted a larger biomass at Kokanee Bend than at the Bible Camp in all three months for which volumetric data has been taken (Figure 28).

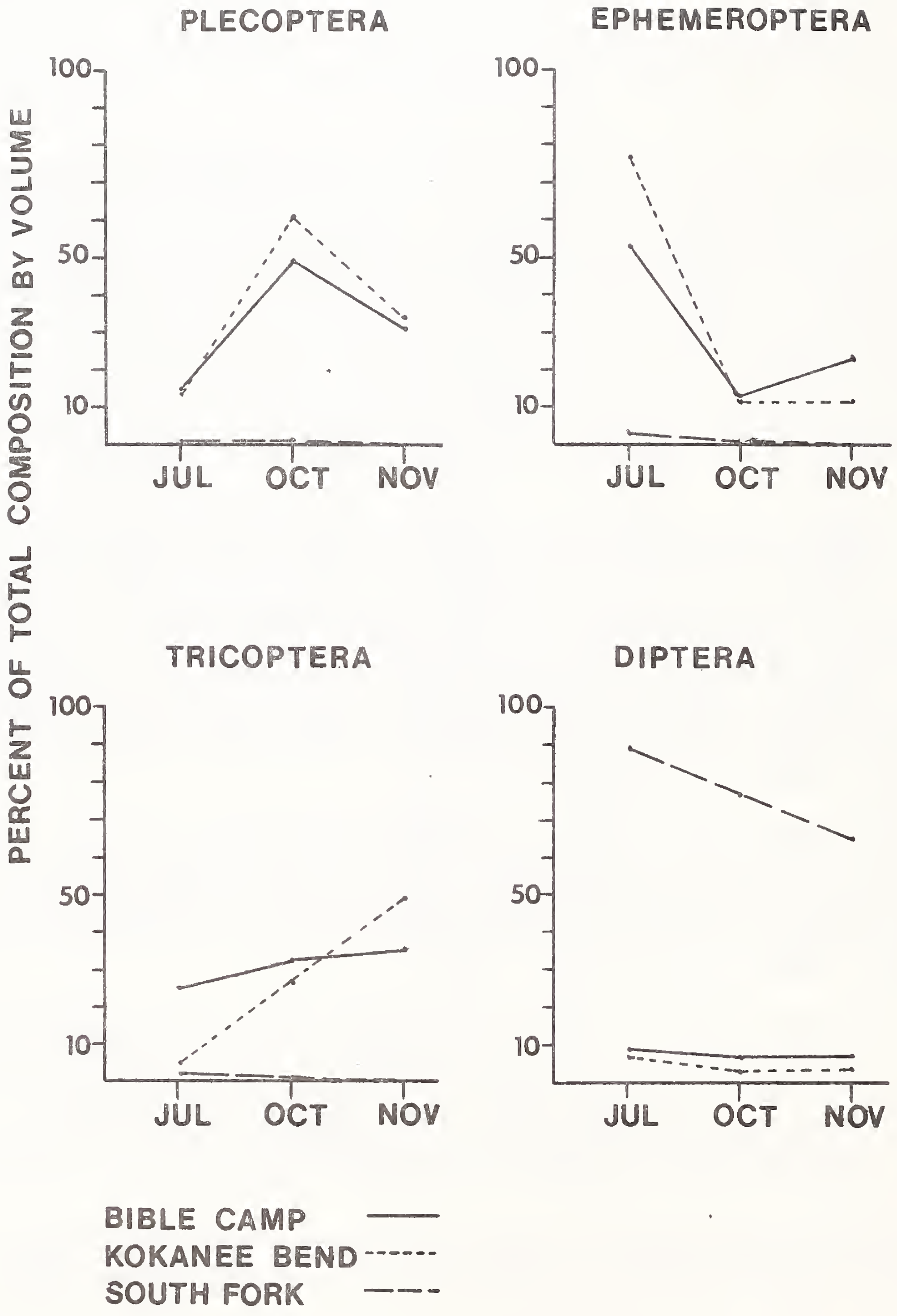


Figure 28. Percent of total volume displaced by insect order in 1979.

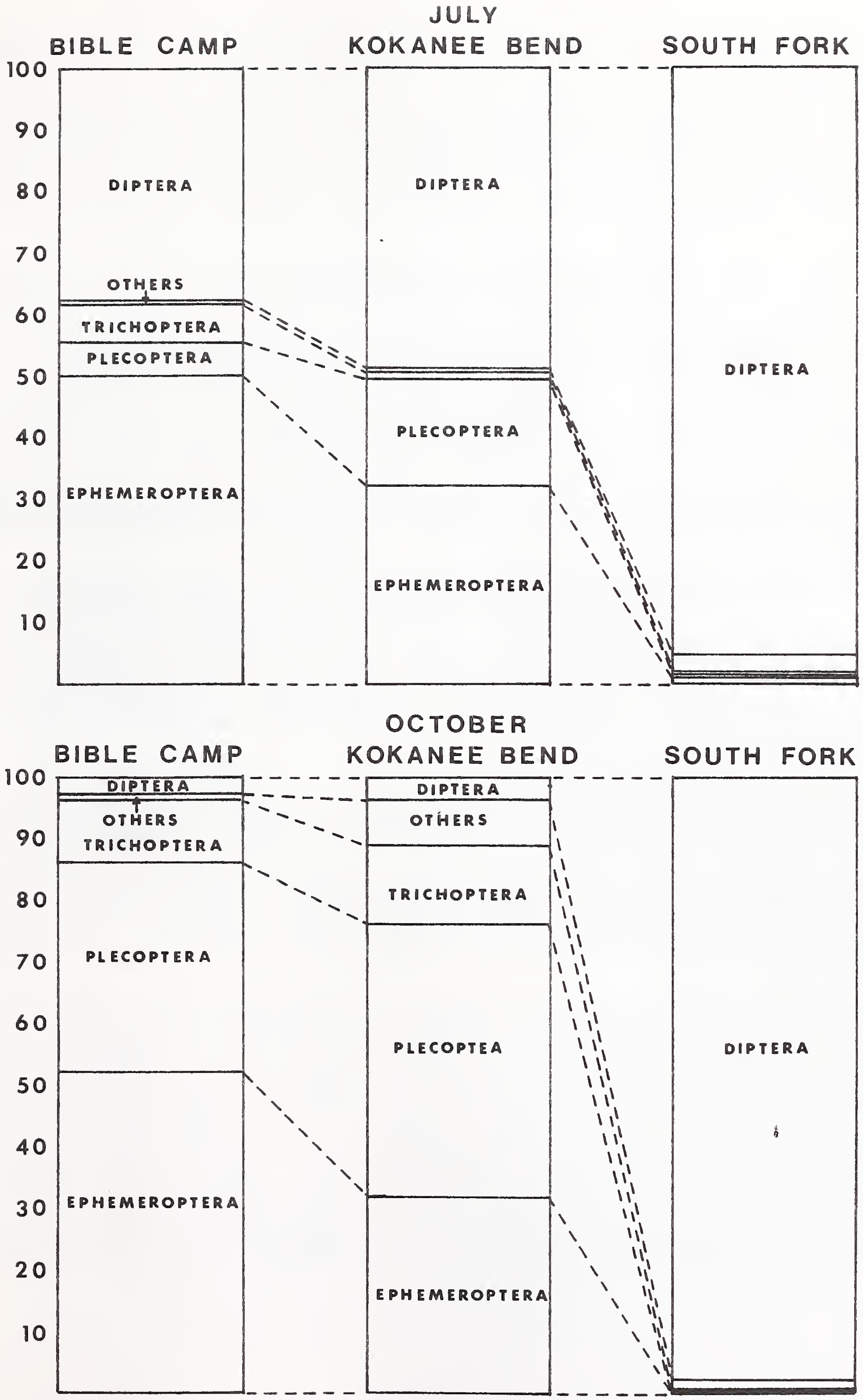


Figure 29. Percent of total number of invertebrates represented by insect order in July and October, 1979.

The mayflies had a larger biomass at Kokanee Bend in July - mainly due to the later emergence of certain mayfly species at that site; in October and November biomass as well as numbers of mayflies was larger at the Bible Camp site. The biomass of caddisflies was larger at the Bible Camp in July and September. In October the large abundance of the caddisfly, *Arctopsyche grandis*, at the Kokanee Bend site resulted in a larger biomass there even though other hydropsychid species were much more abundant at the Bible Camp.

The species lists were similar for the Bible Camp and Kokanee Bend sites (Appendix D). Very small specimens (generally 2mm or less) could be identified only to family (e.g. small Heptageniidae probably included mostly *Rhithrogena hageni* in the summer months and *Cinygmula sp.* in the fall months; small Perlodidae in August and September were mostly *Isoperla fulva;* small Taeniopterygidae included *Taenionema pacificum* and *Doddsia occidentalis;* small Capniidae included mainly *Utacapnia* (4sp.) and *Capnia* (4sp.) Species of *Isocapnia* were hyporheic and have not been collected in benthic collections until the final instar (Stanford 1974)). *Ephemerella inermis* refers to the *E inermis* - *E infrequens* complex. *Baetis tricaudatus* probably included specimens of *B. intermedius* which could not be differentiated in the smaller instars.

About the same number of species were found only at one site or the other (Table 6). Many of these were rarer species which may occur at both main river sites. The species of Siphlonuridae (*Siphlonurus*, *Ameletus*) were collected almost exclusively at the Bible Camp site. These species were found in the slow water's edge areas which have been largely eliminated at Kokanee Bend due to the water fluctuations. These slow-water species were infrequently collected with our sampling gear; an attempt will be made to better quantify them on future sampling trips.

Most dipterans appeared to be more abundant at the Kokanee Bend site (e.g. Blephariceridae, Deuterophlebiidae, *Antocha*, *Atherix variegata*, the rare, primitive cranefly, *Protanyderus*, and the Chironomidae). The first two families have suckers which would enable them to hold on during velocity changes; they are algal scrapers and periphyton was more abundant in regulated areas. *Atherix*, *Protanyderus* and the Chironomidae are burrowers which would not be as subject to catastrophic drift during the quick velocity changes due to regulation.

Most mayfly species were more abundant at the control site (Table 7). Mayflies are scrapers or gatherers and might be expected to increase in regulated areas due to increases in periphyton; this did not seem to be the case. *Baetis bicaudatus* and *Baetis tricaudatus* appear to be able to maintain moderate levels in the South Fork in the dense algal growths. However, *Baetis spp.* were more abundant at the control site in the main river. The heptageniid mayflies showed decreased numbers at the partially regulated site. Two of the most common heptageniid species, *Rhithrogena hageni* and *Epeorus albertae* have their gills arranged to form a suction cup which assists in maintaining their position on rock surfaces. Rapid water fluctuations and increased algal growths probably impair the efficiency with which they can maintain their positions in the

Table 6. Species or family found at one site only.

Species found at Bible Camp only	Species found at Kokanee Bend only
Siphlonurus sp.	Ephemerella heterocaudata
Ameletus connectus	Ephemerella spinifera
Ameletus oregonesis	Isoperla patricia
Ameletus cooki	Cultus aestivalis
Ephemerella hysptrix	Rhyacophila vepulsa
Paraleptophlebia bicornuta	Neophylax rickeri
Amphinemura sp	Antocha sp
Kogotus modestus	Blephariceridae
Rhyacophila vaccua	Deuterophlebia sp
Ochrotrichia sp.	Dytiscidae
Brychius sp.	

Table 7. Circular and kick samples combined. Mean number of individuals per meter^2. Mean = $\bar{x}$. Standard deviation = (s.d.). Flathead River, 1979.

Species most abundant at Kokanee Bend (partially regulated site).	July		August	
	Bible Camp x=5	Kokanee Bend x=8	Bible Camp x=9	Kokanee Bend x=9
	$\bar{x}$(s.d.)		$\bar{x}$(s.d.)	
Plecoptera				
Pteronarcella badia	49.8(57.3)	34.8(19.8)	10.2(12.6)	42.0(37.2)
Trichoptera				
Arctopsyche grandis	74.4(45.6)	0 (0)	21.6(26.4)	26.1(20.4)
Glossosoma sp.	0 (0)	0 (0)	5.7(8.4)	24.3(20.7)
Species most abundant at Bible Camp (control site).				
Ephemeroptera				
Rhithrogena hageni	328.2(364.2)	90.9(38.7)	225.9(245.1)	94.8(55.8)
Epeorus albertae	78.0(31.5)	18.3(14.7)	0.6(1.2)	3.6(3.3)
Baetis tricaudatus	688.2(612.0)	72.0(49.5)	191.1(228.3)	235.8(167.1)
Baetis hageni	55.8(61.2)	10.2(12.9)	13.2(29.4)	1.0(3.0)
Paraleptophlebia heteronea	4.2(5.1)	1.8(2.1)	0 (0)	0.3(0.9)
Trichoptera				
Symphitopsyche oslari	82.2(62.4)	6.3(6.6)	35.7(31.2)	6.6(5.1)
Symphitopsyche cockerelli	0 (0)	0 (0)	96.3(85.2)	16.2(27.3)

Table 7. Continued.

Species most abundant at Kokanee Bend (partially regulated site).	September		October	
	Bible Camp x=10	Kokanee Bend x=9	Bible Camp x=9	Kokanee Bend x=10
	$\bar{x}$(s.d.)		$\bar{x}$(s.d.)	
Plecoptera				
Pteronarcella badia	54.6(52.5)	157.8(141.6)	12.6(17.7)	149.7(124.8)
Trichoptera				
Arctopsyche grandis	22.5(35.4)	174.6(93.0)	16.8(24.3)	293.7(205.2)
Glossosoma sp.	8.1(15.9)	210.9(223.8)	20.4(49.2)	808.8(543.0)
Species most abundant at Bible Camp (control site).				
Ephemeroptera				
Rhithrogena hageni	707.4(641.1)	253.8(109.2)	1218.0(847.5)	354.6(296.1)
Epeorus albertae	0 (0)	5.1(7.8)	165.9(183.9)	4.8(6.6)
Baetis tricaudatus	95.1(65.4)	146.7(90.6)	1305.6(601.8)	770.4(517.5)
Baetis hageni	18.9(40.8)	0 (0)	422.4(220.8)	60.6(77.1)
Paraleptophlebia heteronea	11.1(15.9)	2.7(8.1)	74.9(81.0)	1.8(2.4)
Trichoptera				
Symphitopsyche oslari	123.6(136.8)	5.7(8.4)	426.6(383.4)	19.8(25.8)
Symphitopsyche cockerelli	193.5(168.6)	24.6(20.7)	86.1(93.6)	28.5(34.8)

Table 7. Continued.

Species most abundant at Kokanee Bend (partially regulated site).	November Bible Camp x=10	November Kokanee Bend x=10	5 month mean Bible Camp $\bar{x}$	5 month mean Kokanee Bend $\bar{x}$
	$\bar{x}$(s.d.)		$\bar{x}$(s.d.)	
Plecoptera				
Pteronarcella badia	9.3(15.6)	66.9(28.5)	27.3(22.8)	90.2(59.3)
Trichoptera				
Arctopsyche grandis	12.0(8.7)	493.5(937.8)	29.5(25.5)	197.6(203.6)
Glossosoma sp.	15.3(21.0)	199.5(215.1)	9.9(8.0)	248.7(327.8)
Species most abundant at Bible Camp (control site).				
Ephemeroptera				
Rhithrogena hageni	1867.2(1512.6)	246.6(197.7)	869.3(680.1)	208.1(113.6)
Epeorus albertae	195.6(152.4)	8.7(18.9)	88.0(91.0)	8.1(6.0)
Baetis tricaudatus	1261.8(762.3)	726.9(850.8)	708.4(571.6)	390.4(332.5)
Baetis hageni	788.7(553.5)	53.1(119.7)	259.8(341.6)	25.0(29.5)
Paraleptophlebia heteronea	66.3(68.1)	12.6(17.4)	31.3(36.2)	3.8(5.0)
Trichoptera				
Symphitopsyche oslari	345.3(302.1)	102.6(215.7)	202.7(172.6)	28.2(42.0)
Symphitopsyche cockerelli	60.9(45.0)	32.1(48.3)	87.4(70.1)	20.3(12.8)

boundary later on the surfaces of rocks. The reduction in mayflies at Kokanee Bend could indicate a reduction in fine particulate organic matter in the substrate. The clearwater discharges from the dam would be expected to remove the finer organic sediments on which some species of mayflies feed. Many mayflies are found in the shallow water along the edge during their early developmental stages. These shoreline areas are particularly affected by fluctuating flows. Not many data are yet available on the species (e.g. some Ephemerellidae) which overwinter as eggs or small quiescent nymphs deep in the substrate. These species may be better preadapted to regulated conditions since they are exposed to flow fluctuations for only a short time as active, full-grown numphs (Henricson and Muller 1979).

The perlid stoneflies appear to be either unaffected (*Hesperaperla*) or decreased (*Classenia*) by regulation. Stanford (1975) found that no major emergence of *Classenia* occurred in 1973, since discharges from Hungry Horse Dam reduced the daily mean water temperatures enough to delete emergence cues.

The data on *Pteronarcella badia* showed a marked increase in this species at the Kokanee Bend site (Table 7). It is a shredder which is often found in depositional areas. Wood and large particulate matter was collected much more frequently in our sample nets at Kokanee Bend and there are indications that course particulate organic matter was more abundant in the regulated areas. This may be related to the fact that fluctuating flows can collect more debris from shoreline areas. After the spring runoff the river channel is removed from shoreline vegetation in unregulated areas.

Our data show larger numbers of capniid and chloroperlid stoneflies in the fall at the Kokanee Bend site. It may be that hatching occurred sooner there due to warmer late fall temperatures in the regulated areas (they appeared to reach maximum numbers one month earlier at Kokanee Bend).

Winter data will need to be analyzed before their relative abundances at the two sites can be evaluated. It is known that many of the hyporheic species were abundant in the regulated areas (Stanford 1975). Comparative emergence data between the two sites will give a better indication of abundances of the hyporheic species. They were probably unaffected or increased by regulation since they are found deep in the substrate where flow fluctuations have less of an effect. Also, discharges from Hungry Horse Dam are generally minimal during their growth period (late fall, winter and early spring).

Caddisflies often show compositional changes in regulated areas (Henricson and Müller 1979). In the Flathead River, *Arctopsyche granids* was abundant in the regulated site and the other hydropsychid species (e.g.*Symphiltopsyche oslari S. cockerelli*) were much more abundant at the control site (Figure 30). Stanford et al. (1979) found the same situation in the unregulated North and Middle Forks and further downstream in the regulated main stem river. *Arctopsyche* is a large particle feeder (mesh net openings generally vary from 400-500 μm)

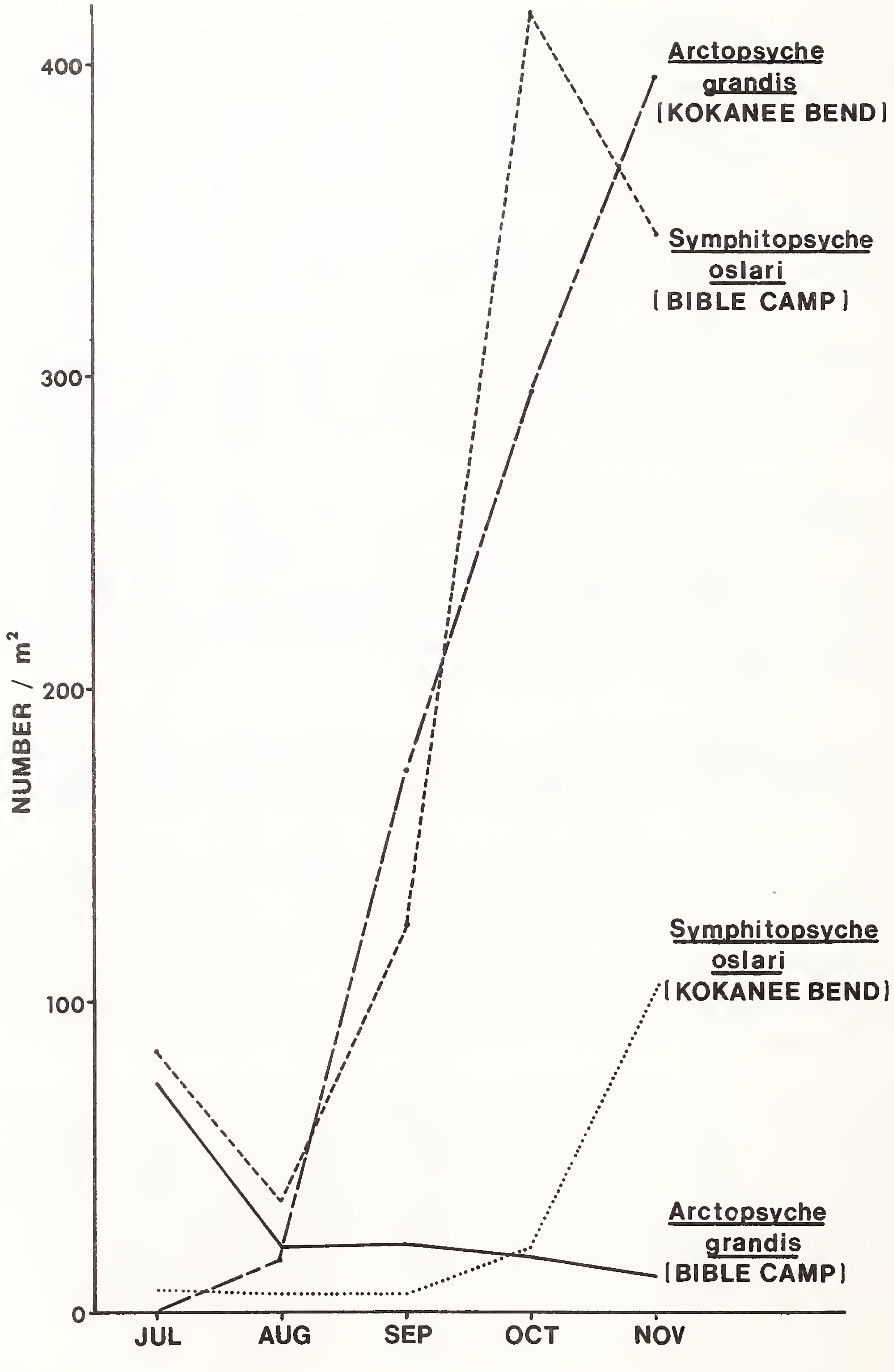


Figure 30. Number $/m^2$ of the caddisflies Arctopsyche and Symphitopsyche at the partially regulated (Kokanee Bend) and control (Bible Camp) sites, 1979.

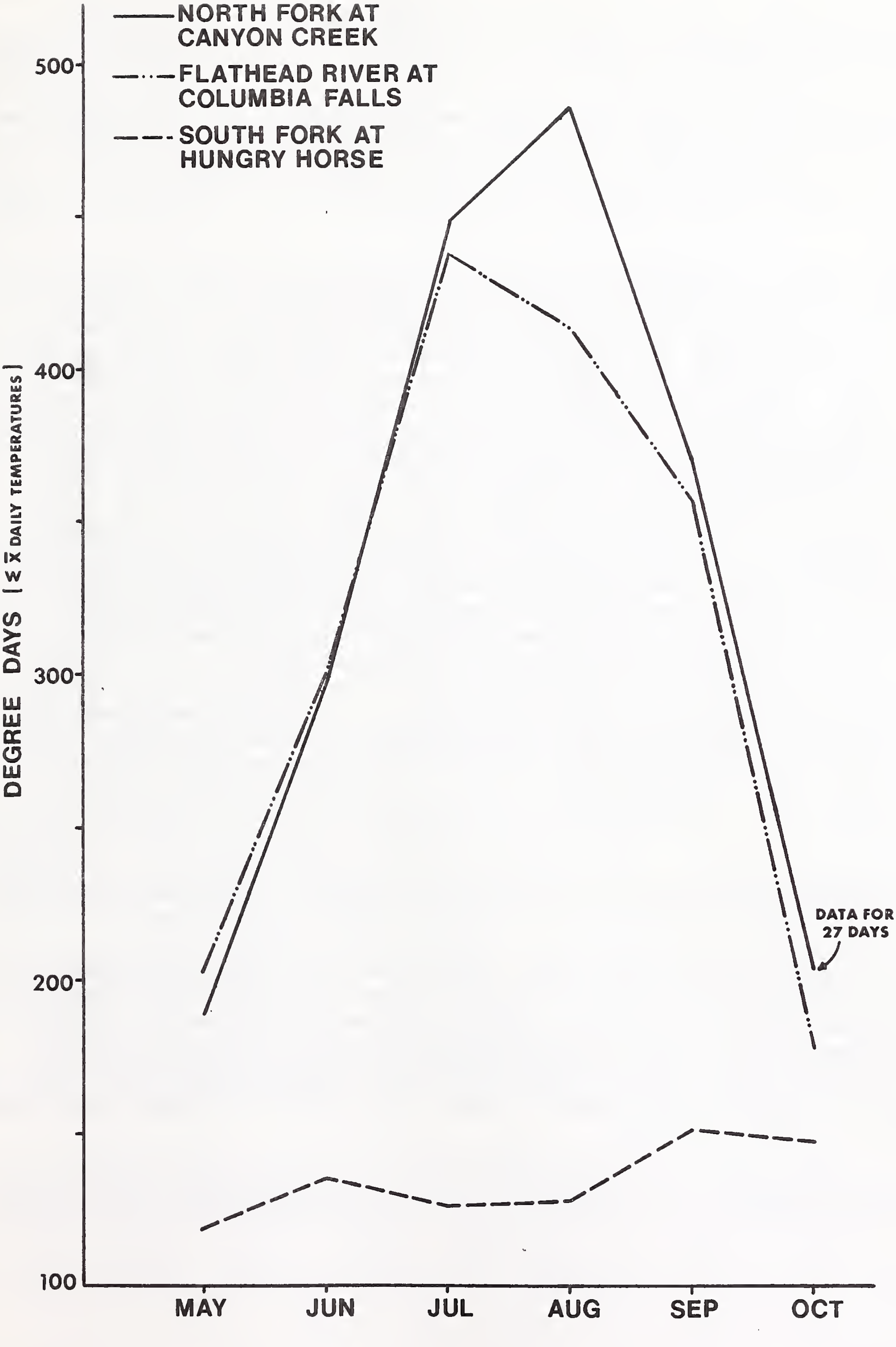


Figure 31. Degree days (mean daily temperatures) summed by the month for control, partially regulated and regulated areas of the Flathead River, 1979.

(Wallace et al. 1979). There may be differences in available particle sizes at the two sites. Carbon fractionation studies which will be done on a seasonal basis may clarify this. It may also be that *Arctopsyche* is more resistant to current fluctuations (perhaps because their nets are stronger).

Glossosoma sp. showed an increase at the regulated site in our studies (Table 7). It is an algal scraper and is probably more abundant due to increased periphytic growth in the regulated areas. The saddle cases it builds would also make it more resistant to displacement or desiccation due to flow changes.

Our data indicate possible changes in growth rates and emergence times of some insects due to regulation. Life history studies (head capsule measurements, adult collections) are needed to verify this. The estival species (Brinck, 1949, estival species emerge in the summer and fall, then the eggs stay in diapause until late spring) appear to be emerging earlier at the Bible Camp. Colder summer temperatures at Kokanee Bend would slow summer growth rates. The total number of degree days (mean daily temperatures summed by the month) was less in the regulated sections of the river during July, August and September due to cold water discharges from Hungry Horse Dam (Figure 31). Several species of *Ephemerella* appear to emerge later at the regulated site. *Ephemerella tibialis*, an estival species, is a particularly good example of this. This species was being used for temperature shock and temperature tolerance experiments in another study and could be collected in larger numbers at the Kokanee Bend site than at the Bible Camp site in September. *Simulium arcticum* was found in the pupal stage in August at the Bible Camp and in September and October at Kokanee Bend.

Species which are growing during August and September, when temperatures were warmer at the control site, obtained maximum numbers one month later at Kokanee Bend than at the control site (e.g. *Classenia sabulosa*, *Isoperla fulva*, *Ephemerella doddsi*, *Symphitopsyche oslari* and *Symphitopsyche cockerelli* (see Appendix D). The reverse situation appears to occur in species which are growing later in the fall (October and November) when temperatures are warmer in the regulated areas. Small capniid and chloroperlid stoneflies reach their maximum abundance one month later at the Bible Camp. These observations need to be documented by emergence data and head capsule measurements.

Our sample variance was large - mainly due to non-randon (clumped) distribution of insects in the river. The sites where some samples were taken (e.g. those along the edge or on large rocks in the shallower parts of riffles) provided much better habitat and thus had much larger numbers of insects. Certain species, such as blackflies, have narrow habitat requirements and were densely clumped. The sampling methods used did not give good quantitative estimates of their abundance.

Our kick sampler consistently collected larger numbers of insects than the circular sampler. This was partly due to the fact that the kick sampler could be used more efficiently in the shallow areas where insects were more abundant. Most quantitative samplers (e.g. circular samplers) were not nearly as efficient in the larger substrate found in the Flathead River because of problems in obtaining a good seal. Under these conditions, the kick net which is often used only as a qualitative sampler, appeared to sample more efficiently.

Velocity and depth measurements were taken with each sample. We are using them to determine velocity preferences for the abundant species of insects. These data have been tabulated, but to date not enough data points have been entered at certain velocity ranges to draw accurate histograms. Some of the curves are bimodal, possibly indicating a preference of the younger instars for the slower current speeds (0-20m^3/sec) at water's edge and of the later instars for somewhat faster currents or deeper water (e.g. 40-60m^3/sec.). Examples of the histograms we are developing are shown in Figures 32 and 33. These are designed to give mean current preferences, since we are not measuring the microhabitat current speeds. If possible, this data will be used to calculate weighted useable area (the carrying capacity of the area based on physical conditions alone) for key species at several discharges (Bovee and Cochnauer 1977).

Insects select areas within the river which have the most favorable combinations of hydraulic conditions (important habitat parameters are depth, velocity, substrate and temperature). We have observed that insects are concentrated along the edge of the river at both sites, but particularly at the Kokanee Bend site. This is more marked in the winter months when very few insects could be collected nearer the middle of the river. In January we removed some overhanging sheets of ice at Kokanee Bend and found large concentrations of insects under them. This could have serious consequences for the insects during periods of winter discharge from Hungry Horse Dam. Ice scour would occur in just those areas where the insects concentrate.

Conclusions

Seasonal fluctuations in numbers and biomass of zoobenthos were different in the South Fork and main stem Flathead River. A full year of data will be necessary to determine whether overall numbers and biomass were reduced or increased due to regulation. The faunal composition was markedly changed and the number of species was decreased in the South Fork. Seldom can a single factor be identified as the major cause of the increase of a species under altered conditions, since organisms respond to a combination of factors. The severe changes in the temperature regime in the South Fork, however, were sufficient to prevent most species of insects from completing their life cycles.

Due to the addition of water from the North and Middle Forks of the Flathead River, the changes were much less marked in the partially regulated areas of the river (the temperature was modified, flushing and redeposition of sediments occurred during spring runoff; eggs and drifting insects could be supplied from upstream, etc.). However, there were compositional changes in the partially regulated portion of the river. Differences in total numbers and

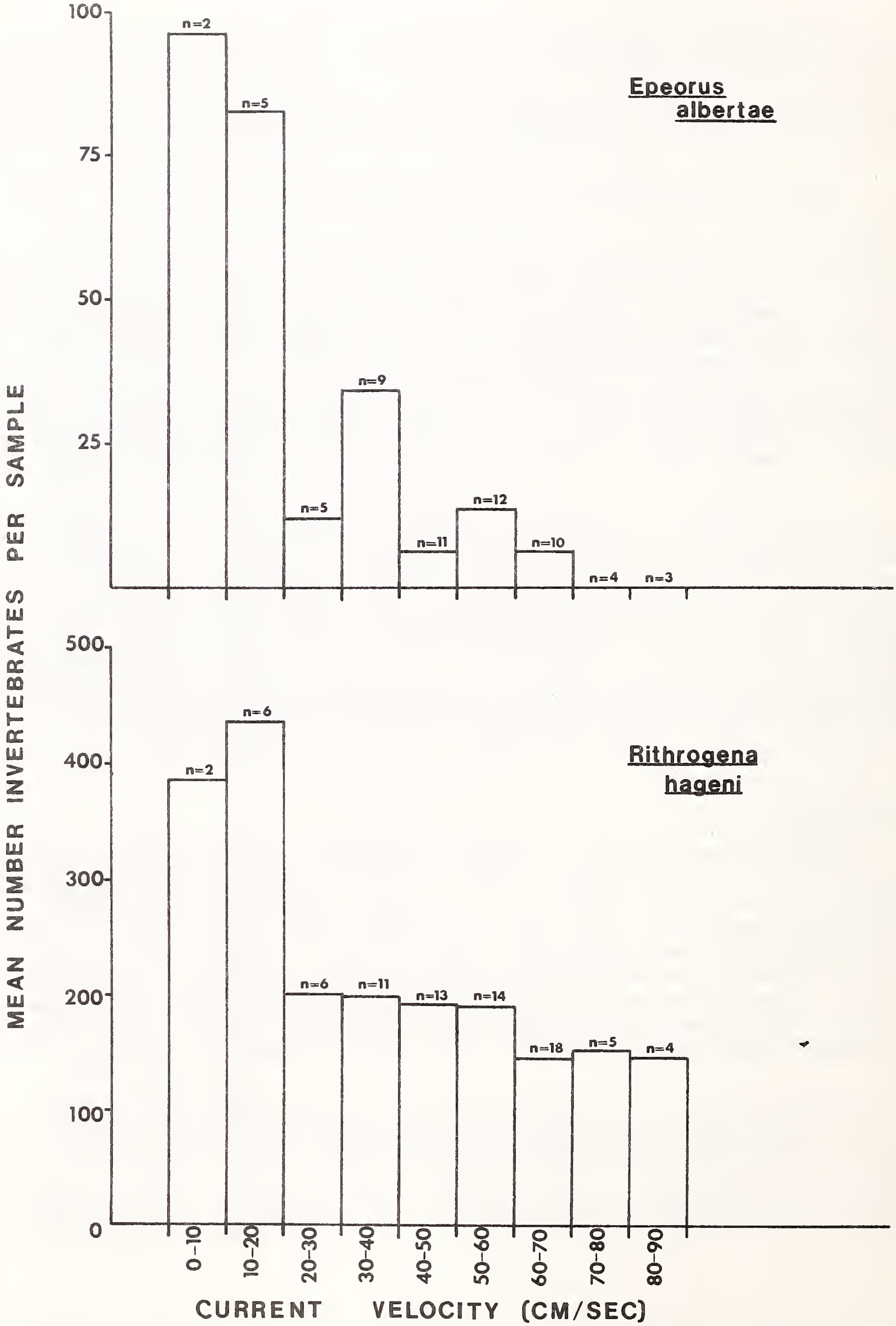


Figure 32. Mean velocity preferences of two mayfly species. The number of samples included in each velocity range are given above the bars.

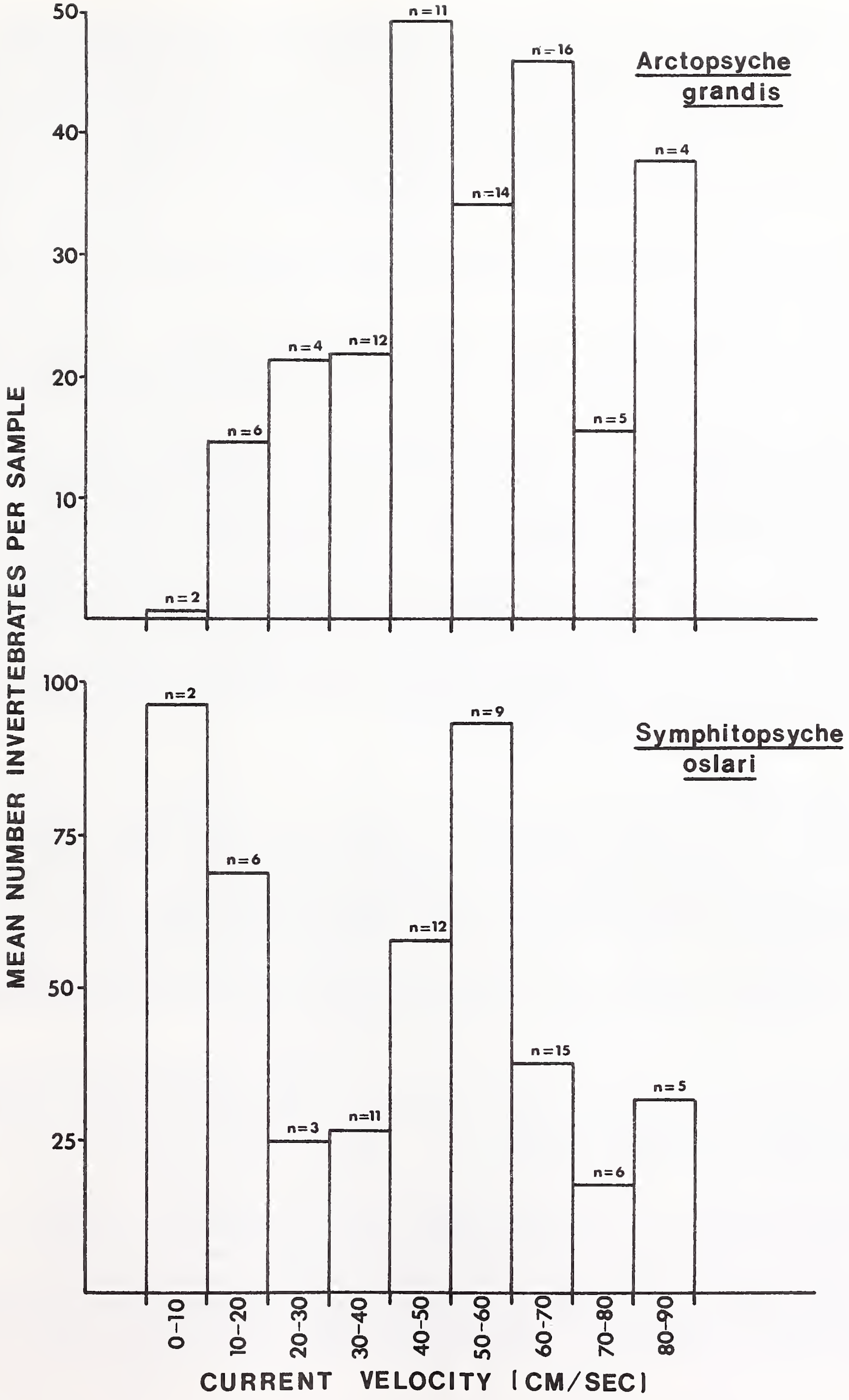


Figure 33. Mean velocity preferences of two caddisfly species. The number of samples included in each velocity range are given above the bars.

biomass between the control and partially regulated sites reflectes these compositional changes, due in part to differences in the life cycles and relative size of the dominant species at each site. The delineation of the factors responsible for these compositional differences requires further study, but it is hypothesized that they are related to temperature differences, to the ability of a species to withstand rapid fluctuations in water velocity, and to changes in food availability in regulated areas (i.e. changes in the amounts of periphyton and detritus and changes in the size of sestonic food particles.) The type of life cycle a species has is also a determinant factor in its ability to adapt to regulation. There are indications that the timing of events in the life cycle was different due to seasonal temperature differences at the two sites.

The ameliorative effects of the North and Middle Forks are limited during seasons of lower flows from natural areas. Major changes in the discharge regime from Hungry Horse Dam during certain times of the year could substantially alter the composition of invertebrates in the main stem river. Marked increases in discharge during certain seasons (e.g. during the summer emergence and growth season or during the winter) could cause species extinctions and marked compositional changes. Many of the species which were abundant at the partially regulated site are absent in most rivers with hypolimnial or even temperature selected outlets (e.g. most stonefly species (*Arctopsyche*). Until more information is available on what environmental factors are important for the maintenance of a habitat suitable for specific groups of species, caution should be exercised in altering discharge regimes. Even though the partially regulated areas of the Flathead River are still relatively species rich and complex despite perturbations, they are not resistant to species deletion (see Pimm, 1979).

Anticipated Research

A number of additional studies will be done during the second year of the project. The inordinate amount of time required for obtaining invertebrate biomass estimates has demanded full attention during the first year. Good baseline data are being obtained and will enable us to proceed with other facets of the study. These include the following prioritized areas of research.

1. Complete baseline data to meet objectives as stated in grant proposal i.e. diversity, biomass and life history data.

During the second year the number of quantitative samples collected monthly at each site will be reduced from 8 - 10 to 3. Additional qualitative samples will be taken at each site to insure that adequate numbers of insects will be available for life history studies.

Computer analysis of community structure will be performed after a full year of collections have been enumerated. Selected samples of the abundant midge family Chrionomidae will be identified to genus for inclusion in diversity indices. Calculations will be made for species diversity, maximum and minimum diversity, redundance, evenness, equitability and species richness (Shannon-Weaver and Brillouin - programs available in Montana State University computers detailed by Newell, 1976). Wet weights of insects will be obtained after head capsule measurements have been made and several methods of estimating production (i.e. removal-summation, Hynes/Hamilton) will be applied to selected species displacement and wet weight estimates of productivity are being used in place of estimation of biomass by the carbon content method which cannot be used on preserved specimens. Also, the carbon content method destroys the specimens, and it is desirable in studies such as this to save the specimens for future reference.

Work on changes in insect life histories will be done in an attempt to predict further compositional changes which are possible under changed discharge regimes. The effect of possible compositional changes on the availability of food items for fish will be predicted. Studies will be concentrated on the Plecoptera, Ephemeroptera, and Trichoptera because these insect orders are sensitive to regulated conditions.

Life cycles will be documented for the species of insects which appear to be most affected by regulation (i.e. baseline data indicate that abundance and timing of life cycles are significantly different in the unregulated and partially regulated areas of the Flathead River). The following common species which show compositional changes in regulated areas are possible subjects: *Pteronarcella badia, Classenia sabulosa, Isoperla fulva, Sweltsa coloradensis, Ephemerella inermis, Ephemerella tibialis, Rhithrogena hageni, Epeorus albertae, Baetis tricaudatus, Baetis hageni, Paraleptophlebia heteronea, Arctopsyche grandis, Symphitopsyche oslari, Symphitopsyche cockerelli, and Glossosoma sp.* Head capsules of immature insects will be measured monthly on 50-100 individuals of each selected species to determine growth rates. Samples collected during the first year of the study will also be used for head capsule measurements.

The effects of prolonged generation during times of major hatches (e.g. possible species eliminations) will be predicted An intensive effort will be made to collect adult insects in order to document differences in the timing of emergence. Pit traps (buried cans containing formalin covered with a thin film of diesel fuel) will be placed along the shore and checked weekly; shoreline vegetation will be swept weekly. Light traps which are operated by photocells will be run nightly during periods of peak emergence. Adult collections will also be used to compile species lists, since some taxa cannot be identified to species in the immature stages and certain species are present only in the hyporheic environment and are therefore not collected using conventional methods.

2. Fish food habits studies

Seasonal studies (April, July, October) on the food habits of trout and whitefish will commence in April, 1980. Fish will be collected using electrofishing methods. Insect drift nets will be set just upstream from electroshocking reaches to determine insect availability, so that electivity indices can be applied. Hourly drift samples will be taken two hours before sunset and two hours after sunset (during the hours the fish we collect would be feeding). Samples will be collected at the Bible Camp site (control),at the Columbia Falls aluminum plant, and above the Old Steel Bridge at Kalispell. During July a 24-hour drift study will be done. Food items will be identified to the lowest taxonomic level possible and analysed using numerical, frequency of occurrence and volumetric methods.

3. Quantification of substrate size

The substrate in a given area of the river is largely a function of the flow regime. Substrate variations due to regulation will be quantified by randomly selecting ten one-third m^2 areas at each of the three permanent sampling sites. The surface area of the larger rocks will be measured and samples of the finer sands and gravels will be run through a series of graduated sieves to separate particles by size, and then each size fraction will be weighed. The Wentworth size classification will be followed as closely as possible (see Cummins, 1962). This will be done in late summer 1980 at minimum flows.

4. Quantification of macroinvertebrate habitat

Estimates of macroinvertebrate habitat available at full, half and no generation will be made using aerial photographs. The reduction in area between half-generation and minimum flows will be measured with a planimeter on the photos. Estimates of the loss of riffle, run, and pool biomass of insects measured in field collections in selected areas of the river will be used to estimate loss in insect production at different minimum flows. Minimum flows are significant because few insects can survive in zones of fluctuation. Limited sampling with the use of SCUBA gear will be done in the deeper runs and pools in selected areas of the river in the summer of 1980. Collections will be made in April and July, 1980 to determine the composition of invertebrate taxa in the riffles in the main stem Flathead River immediately downstream from the mouth of the South Fork. The effects of the warmer winter and cooler summer temperatures in the South Fork waters would be most profound in the areas where mixing with the regulated discharge is incomplete.

Sampling to get a rough estimate of insect production in backwater areas of the Flathead River will be made in April, 1980. The insects in these areas are particularly vulnerable when there is no generation from Hungry Horse for extended periods of time. Qualitative samples will be taken from several sites during a one day period. The biomass of insects in areas of fluctuating flows will be quantified by placing barbeque basket samplers at various distances from the area wetted during minimum flows at the South Fork and Kokanee Bend sampling sites. The amount of colonization which occurs during a month in which flows are fluctuating will be measured.

5. Experimental work on insect drift

Test flows will be requested in November, 1980, and possibly in late March, 1981, (in conjunction with fisheries studies) to determine the effects of various discharge regimes on catastrophic drift of aquatic invertebrates. Specific requests for flows will be made after all studies have been coordinated.

Artificial stream channels, which will be constructed for fisheries work, will also be used to study drift of insects in relation to discharge. Emphasis will be on using species which are reduced in number at the Kokanee Bend sampling site to determine if they are more sensitive to flow fluctuations. Several experimental flow patterns which emulate discharge practices at Hungry Horse Dam will be used (i.e. raising and lowering the water level at several rates which would correspond to Hungry Horse discharge alternatives). This work will be done in the summer of 1980.

Five-minute tows to sample kokanee fry will be taken in April and May; the drifting insects collected in these samples will be picked and enumerated. In May a 24-hour drift study will be made. Two 5-minute tows will be taken every three hours. This work will give us information on the numbers and species of drifting insects during periods of normal high flows.

6. Experimental work on insect stranding

The artificial stream channels will also be used to study the effects of dessication on selected species of insects. The channels will be dewatered for periods of 8, 12, 24, and 72 hours and the resulting mortalities will be quantified.

In situ field experiments will also be done to study the effects of dewatering under summer and winter conditions. Several species of insects will be placed on rocks within fiberglass mesh bags of the same type which were used successfully in our salmon egg experiments. These bags will be placed in the substrate (within barbeque baskets in situations where rigidity is needed to protect the insects) at successive intervals from the low water line. Controls will be placed in the permanently wetted zone. The amount of time the insects were dewatered may be measured with the use of temperature probes. The dessication tolerances of several species will be determined.

The stranding work will be done mainly in the winter and summer of 1981.

7. Determination of sestonic carbon particle sizes

The concentration and size of food particles available to insects in the regulated main stem river is dependent upon the discharge from the South Fork. In order to determine the particle sizes which are available to hydropsychid filter feeders, a wet filtration method will be used to size fractionate samples of the seston from the control and partially regulated sites. Measured volumes of water will be filtered through a series of stainless steel buckets with decreasing mesh sizes and the carbon content will be determined. This analysis will be done seasonally (April, August and December, 1980).

8. Periphyton sampling

The standing crop of periphyton will be measured by scraping natural and artificial substrates from a given area at the three benthic sampling sites and obtaining ash-free dry weights and chlorophyll values. Replicate samples will be taken at three depths at the three sites in late August, 1980. The autotrophic index (chlorophyll A/ash-free dry weight) will be applied to the data.

MIGRATION OF ADULT WESTSLOPE CUTTHROAT TROUT
AND MONITORING OF FISH POPULATIONS IN THE MAIN STEM FLATHEAD RIVER

Introduction

Previous studies of cutthroat movement in the Flathead drainage have been limited to information generated by recapture of tagged fish (Block 1955; Johnson, 1963; Huston and Schumacher 1978). Mark and recapture techniques are limited to information gained at two points in time and can be misleading. A cutthroat, recaptured at a later date in the same location it was tagged, may have actually traveled over 100km upstream, spawned and returned.

Our research is concerned primarily with adfluvial cutthroat that migrate from Flathead Lake to tributaries of the North and Middle Forks to spawn. Although spawning in tributary streams occurs in late May or June, mature cutthroat appear in the Kalispell area as early as February. Huston and Schumacher (1978) suggest cutthroat may move upstream earlier than they otherwise would due to peaking operations at Hungry Horse powerplant. The freshet effect created by release of a large volume of warmer water from Hungry Horse Reservoir may act as a migration cue.

We are attempting to use biotelemetric techniques to track adult cutthroat as they move through the study area. Radio tracking should allow us to determine if cutthroat continue their migration beyond the mouth of the South Fork or if they hold in warmer water below the South Fork.

We are also concerned with the effects of Hungry Horse discharges upon the bull trout, mountain whitefish and other fish species in the main stem Flathead River. Frequent electrofishing samples are being taken in three areas of the main stem Flathead River. These samples allow us to monitor trends in fish population abundance and to monitor movement through mark and recapture methods.

Methods

Biotelemetry

We used boat-mounted electrofishing gear to capture adult westslope cutthroat trout for radio tracking. Handling procedures after capture were varied.

The first cutthroat equipped with a radio transmitter was a 417mm male, weighing 760g. It was captured near the Old Steel Bridge at 2100 hours on April 16, 1979. The fish was held in a cage until 1100 hours on April 18.

We anesthetized the fish, placed it ventral side up in a specially constructed box containing a sponge cradle. We added water to the box, keeping the sponge and fish gills wet. A rectangular, temperature sensisitve transmitter (20mm x 45mm x 13mm) weighing 21.3g (2.8% of fish body weight) was inserted into the abdominal cavity through an incision in the ventral body wall between the vent and pectoral girdle. An incision of approximately 40mm was required to admit the transmitter. The surgical procedure lasted approximately 20 minutes due to inexperience of the crew and the large size of the incision (12 sutures were required to close the wound). Nevertheless, the fish regained equilibrium and was swimming strongly 30 minutes after the operation. We held the fish for two more days to allow it to recover from surgery before releasing it. After release, the fish was tracked from a jet boat. We followed the fish for 8 to 10 hours per day for several days and then checked its location once a day from shore or from an airplane until we could no longer locate the signal.

The second radio-tagged cutthroat was a female, 409mm in total length, weighing 590g. It was caught at 0900 hours on May 1, near the Old Steel Bridge. A longer, thinner transmitter (battery attached to end rather than top of transmitter) was surgically implanted at 1000 hours on May 2. The thinner tag was inserted through a smaller incision (approximately 30mm) which was closed with six sutures. The fish was released at 1000 hours on May 4.

We attempted an oral implant on the third fish, a 401mm female caught at 0100 hours on May 14 near the Old Steel Bridge. An immediate release was planned, but after insertion the fish could not maintain equilibrium. We held the fish in a cage until the following day when it died. An autopsy revealed extensive hemorrhaging from a torn esophagus.

The last fish we radio-tagged was a 389mm female, weight 600g. It was caught at 0730 hours on May 18 near Pressentine Bar. The transmitter was surgically implanted at 0920 hours and the fish released at 2015 hours the same day.

The main stem Flathead River was near flood stage in late May. Because of the high water and our lack of success radio-tagging cutthroat in the river, we made experimental implants in westslope cutthroat in Young Creek, a tributary of Lake Koocanusa (Kootenai River drainage). Montana Department of Fish, Wildlife and Parks maintains a permanent upstream-downstream fish trapping facility near the mouth of Young Creek.

Two cutthroat were radio tagged in Young Creek. A rectangular tag with the same dimensions as the first tag described was surgically implanted in a male (394mm, 600g). A smaller, cylindrical tag (11mm x 43mm, 7.4g) was surgically implanted in a female (378mm, 600g). Both fish were caught in the upstream trap. We attempted to minimize the time required for surgery by making incisions as small as possible and closing them with as few sutures as possible. The fish were held for one hour after surgery and released.

Fish Population Monitoring

Three sections in the main stem Flathead River were electrofished on a more or less monthly basis from June through December, 1979. Two of the sections were in the regulated portion of the river. The Kalispell section is 3,050m long. It is located in the area of the U.S. Highway 2 Bridge and the Old Steel Bridge. The Columbia Falls section is 2,400m long, extending upstream from the Montana Highway 40 Bridge. The Upper River section is located in an unregulated area. It is 2,250m long and extends from the boat ramp at Flathead River Ranch to just above Glacier Bible Camp.

We used a catch/effort index to compare catches in each section by month. The index was based on catch, length of sampling section and hours of electrofishing effort expended.

Shoal areas in each section were electrofished at night from a jet powered boat. Anodes were suspended from booms in front of the boat. Although not all of a section was sampled, each section was sampled in the same manner every sampling trip.

We attempted to net all fish that responded to the electric field. We tagged all trout and whitefish longer than 225mm with numbered, anchor tags. We used yellow tags for westslope cutthroat and rainbow trout, international orange tags for bull trout and blue tags for mountain whitefish. Fish shorter than 225mm were cold-branded. A different brand or location was used in each section.

Results and Discussion

Biotelemetry

None of the westslope cutthroat trout we radio tagged in 1979 moved upstream after being released. One fish, with a surgically implanted transmitter, was found near death two days after it had been released. The other two surgically tagged fish were presumed to have died. One fish was orally tagged but it died prior to release.

Many factors could be involved in our lack of success. Biotelemetric techniques for fish were first developed for large anadromous salmonids. Size and weight of the transmitter was not a problem because the transmitter was minute compared to the fish. Oral insertion was the most common method of transmitter attachment. Groot et al.(1975) and McMaster et al.(1977) were successful with oral implantation of transmitters in sockeye salmon, chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Salmo gairdneri*).

Oral implants have been made successfully on smaller, predacious fish that have large mouths adapted for swallowing large food items. Kelso (1974) was successful with oral implants in brown bullhead (*Ictalurus nebulosus*) and Hasler et al.(1969) with white bass (*Morone chryseps*). Successful oral implants have even been made in fish as small as Atlantic salmon (*Salmo salar*) smolts (McCleave and Stred 1975, Fried et al. 1976) but only with very small transmitters with an expected life of one week or less.

Death of the one westslope cutthroat we tagged orally resulted from a torn esophagus because the transmitter was too large. Westslope cutthroat trout normally feed on small invertebrates (Behnke 1979) and rarely feed on large food items such as fish. Thus, their digestive tract is not adapted to swallowing large food items. A radio transmitter small enough to be inserted into a westslope cutthroat stomach would not have a long enough life to yield the information we seek.

McCleave and Horrall (1970) attempted oral implantation with Yellowstone cutthroat trout (*Salmo clarki bouvieri*) but without success. They attached transmitters externally. External attachment was also used by Knight and Marancik (1977) on juvenile American shad (*Alosa sapidissima*) and by Shepherd (1973) on coastal cutthroat (*S.C. clarki*). External tag attachment reduces swimming speed and stamina (McCleave and Stred 1975) which essentially precludes the possibility of external attachment on Flathead River cutthroat that must migrate long distances.

The only alternative to oral or external attachment is surgical implantation. Coon et al (1977) were successful with surgical implantation in large white sturgeon (*Acipenser transmontanus*). A standard technique for surgical implantation in smaller fish was developed by Hart and Summerfelt (1975) working on Flathead catfish (*Pylodictis olivaris*). Ziebell (1973) successfully implanted transmitters in the abdominal cavities of channel catfish (*Ictalurus punctatus*). Prince and Maughan (1978) modified the techniques of Hart and Summerfelt (1975) to surgically implant transmitters in bluegill (*Lepomis macrochirus*) as small as 195mm.

Our lack of success with surgical implantation was probably a result of too much stress on the fish. The fish were probably stressed by our electrofishing (Schreck et al.1976) and by anesthesia (Allen and Harman 1970). In addition, the length of time required to perform surgery probably stressed the fish. Holding the fish during their migration period may have been a contributing factor.

Our experimental implants in cutthroat at Young Creek were designed to evaluate procedures and equipment. The fish were caught in a trap instead of by electrofishing. A male cutthroat was held for two days before a rectangular (20mm x 45mm x 13mm) transmitter was surgically implanted. The smallest incision that would allow insertion was approximately 40mm in length and was closed with three sutures. The surgical procedure lasted approximately eight minutes. A slightly smaller female was held for less than one-half day before we implanted a cylindrical (11mm x 43mm) transmitter. An incision of approximately 20mm was required. It was closed with two sutures. Less than five minutes were required for the surgical procedure. Both fish were released one hour after surgery.

Both fish remained in the pool created by the traps for four days. On the fifth day after surgery, the female began moving upstream while the male remained. The female eventually moved upstream 2.5km and was observed digging a redd. The male did not leave the trap area during the experiment and was recaptured 11 days after the surgery. The incision showed no signs of healing. We were not able to recapture the female.

Fish Population Monitoring

Westslope Cutthroat Trout

Electrofishing in the main stem Flathead River for the purpose of monitoring fish populations began after peak runoff as flows were receding. Few westslope cutthroat were caught in the Upper River and Kalispell sections during summer (Figure 34). In the Columbia Falls section, however, we caught cutthroat at a rate of nearly 2 fish/km/hour in late June and nearly 6 fish/km/hour in August.

Nearly all the cutthroat we caught during summer were juveniles. Three adult cutthroat (mean length = 397mm) were caught at Columbia Falls in June. They appeared to be spent fish. Mean coefficient of condition (C) of the three adult fish was 0.84, a low value compared to adfluvial westslope cutthroat in Lake Koocanusa (McMullin 1979).

Juvenile cutthroat caught in all three sections of the main stem river averaged 60 to 80mm longer than juvenile cutthroat migrating out of Trail and Red Meadow Creeks (North Fork drainage) in summer, 1979 (Graham et al, 1980). The reason for the disparity in size is not clear at this time. Sampling bias may be a factor in the problem. Although we sample large numbers of mountain whitefish as small as 100mm, it is possible that cutthroat less than 200mm total length are not fully recruited to our gear. Either the smaller cutthroat are not present or their habitat preferences are such that we do not sample them.

Further downstream movement of juvenile cutthroat occurs in fall. Catch/effort declined to less than one fish/km/hr at Columbia Falls in early October while increasing from zero in September to over 5 fish/km/hr in December at Kalispell (Figure 34). Catch/effort in December at Kalispell was bolstered by the capture of four mature cutthroat (mean length -- 398mm). Appearance of several large cutthroat in the December sample at Kalispell may be indicative that mature cutthroat begin their upstream movement even earlier than we thought. However, we are not able to determine at this time whether the mature cutthroat in the December sample moved upstream, downstream or were in the area throughout the sampling period. The latter possibility is not likely, as we captured only one mature cutthroat at Kalispell in four sampling trips between June 28 and October 29.

We did not recapture any marked cutthroat during 1979. Anglers returned three of our cutthroat tags. Two adults tagged in the Columbia Falls section were caught by anglers. One was tagged on June 27 and caught August 8, approximately 2km downstream. The other was tagged on October 3 and caught on November 29, approximately 1km downstream. A juvenile cutthroat (244mm) was tagged on June 25 in the Upper River section and caught July 9 in the same area.

Rainbow Trout

Previous sampling by Montana Department of Fish, Wildlife and Parks personnel indicated rainbow trout were present in the main stem Flathead River but were relatively scarce. Our samples in 1979 indicate rainbows may be more abundant than originally thought. We frequently caught more rainbow than cutthroat in the Upper River section (Figure 34). Late fall catches of rainbow increased in all three sections.

Future catches of rainbow trout will be watched closely to determine the status of the rainbow population in the main stem river. Increases in rainbow abundance could result in increased hybridization with cutthroat.

Mountain Whitefish

Mountain whitefish were generally the most abundant species found in our sampling sections. With the exception of kokanee spawners in fall, whitefish were nearly always several times more abundant than all other species, especially in the regulated sections.

Catch/effort fluctuated widely, but low points generally coincided with peak kokanee abundance (Figure 35). Peak whitefish abundance occurred in late fall when many spawners were encountered.

Five mountain whitefish we marked were subsequently recaptured. All but one were recaptured in the area where they had been tagged. A whitefish tagged at Columbia Falls on June 27 was recaptured on December 4 at Kalispell. Only one of the recaptures was made by an angler. We also recaptured a whitefish with a clipped right pectoral fin. It was marked in Coal Creek during the summer of 1979.

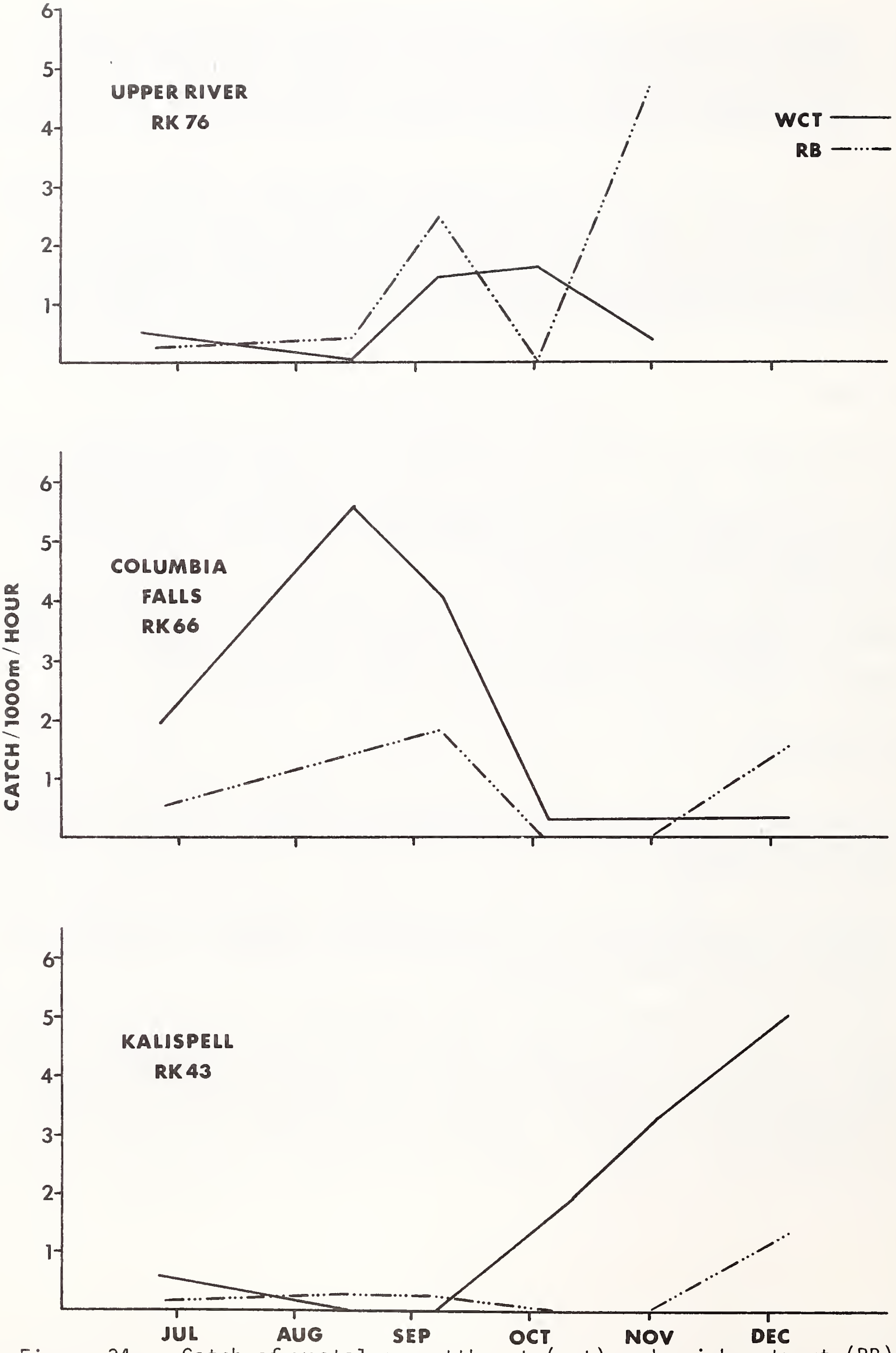


Figure 34. Catch of westslope cutthroat (wct) and rainbow trout (RB) per kilometer per hour of electrofishing effort at night in the area of the main stem Flathead River, 1979.

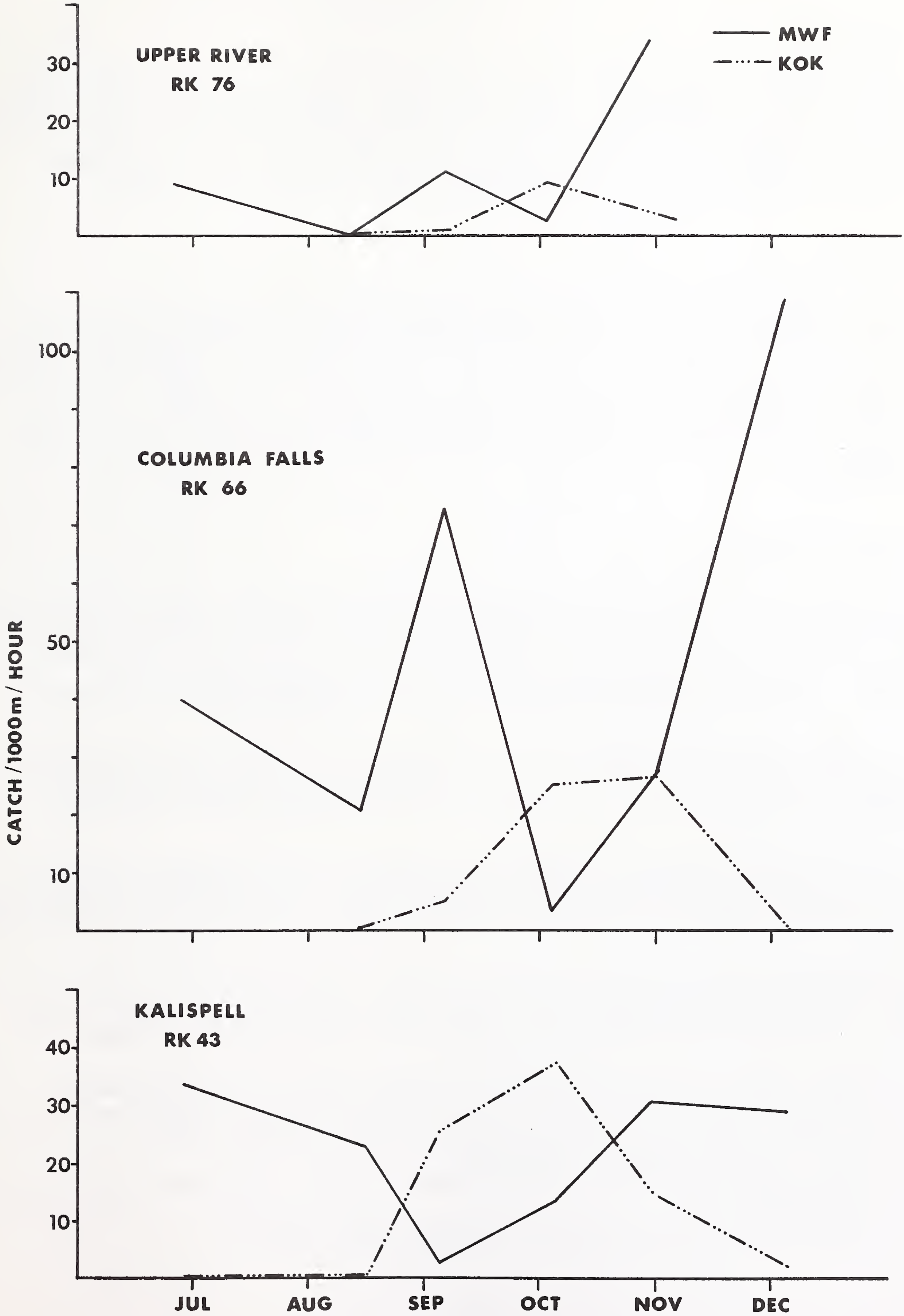


Figure 35. Catch of mountain whitefish (MWF) and kokanee (KOK) per kilometer per hour of electrofishing effort at night in three areas of main stem Flathead River, 1979.

Bull Trout

Catch/effort of bull trout was generally too low to draw any conclusions regarding trends in abundance. Large adult bull trout were seen in all three sections during our June sampling but few were captured. As with cutthroat, juvenile bull trout we caught were significantly larger (60-90mm) than those trapped in Trail and Red Meadow Creeks (Graham et al. 1980).

Nongame Fish

Few nongame fish were captured during our electrofishing trips. Largescale suckers were the most common nongame species encountered. We also captured northern squawfish, peamouth and longnose suckers. Largescale suckers are probably more abundant than our samples indicate. Large schools of suckers were seen in deep pools during our snorkeling surveys in September. Suckers are probably as abundant, if not more abundant, than any other species in the river with the exception of mountain whitefish and kokanee during their spawning seasons.

Anticipated Research

In 1980, we plan to sample the main stem Flathead River more frequently than we did in 1979. More frequent sampling should allow us to better determine movements of cutthroat trout. In addition, we hope to collect a large sample of scales from juvenile cutthroat. Snorkeling in the main stem will be attempted. Snorkeling observations will be used to supplement electrofishing data.

If flows and weather permit, we will continue our population monitoring throughout the winter months. Low flows and ice prevented winter sampling in 1979-80.

It will not be possible to quantify mountain whitefish spawning habitat, but we will assess whitefish spawning qualitatively. Kick samples in several areas of the main stem will be used to identify areas utilized by whitefish for spawning.

Biotelemetric monitoring of migrating adult cutthroat will be continued in 1980. Based on the success of our experimental work at Young Creek in 1979, we plan to utilize the following procedure in the Flathead River in 1980.

1. Allow fish to recover overnight from the effects of electrofishing.
2. Use cylindrical transmitters with a 28-day expected life (approximately the same size as the 14-day transmitter used at Young Creek.
3. Use a buffered anesthetic solution.
4. Implant the transmitter and close the incision in less than five minutes if possible.
5. Release the fish as soon as it regains equilibrium.

APPENDIX A

Correspondence -- U.S. Fish and Wildlife

Correspondence -- Water & Power Resources Service

STATE OF MONTANA

DEPARTMENT OF

FISH AND GAME

Region One
490 N. Meridian
Kalispell, MT 59901
March 10, 1980

Larry Vinsonhaler
U.S. Dept. of Interior
Water and Power Resources Service
Fed. Bldg., 550 W. Fort St. Box 043
Boise, Idaho 83724

Attn: Rich Prange

Subject: Comments on potential peaking power capabilities -- Hungry Horse Reservoir

In response to a phone conversation we had with Roger Larson on February 25, 1980, we discussed the assumed inability for Hungry Horse to follow the recommended approximate equal monthly discharges we proposed for peaking power. Also of concern was the minimum flow of 500 cfs we used in our calculations. The use of 500 cfs was used as it was the recommended minimum flow of the Fish and Wildlife Service.

The information we provided the Bureau in our memo of Febrary 27 indicated in crude calculations that, Hungry Horse Reservoir with a reregulating dam, could provide peaking power capabilities under three discharge schedules for the rereg with three alternatives of added peaking power capabilities.

We have recalculated Table 1 for subheadings A and B using a minimum flow of 150 cfs and enclosed penciled new figures.

We have given careful deliberation to the tables Roger provided and especially the average monthly discharge, cfs for the years 1929 through 1967 or "Study Number 7895" data.

We are seriously concerned with the management philosophy which I thought I heard Roger Larson state in our latest phone conversation (about February 25 or 26). I cannot recall the other person(s) on your end of the conference call. It may have been Bill Mullin. I understood, in essence, that even under peaking power, the average monthly discharge would have to remain at about the same percentage or the average yearly discharge that it is now, or be about the percentages listed in Table X-1, line 3. Our concerns are that either with or without added power capability if Hungry Horse is to go to peaking power, then it would seem the best cost benefit ratio would be had by regular 5-day weeks and discharge during the 8 a.m. to 4 p.m. peak use period.

Based on the diel changes in spawning activity we feel that a change from peak discharge to minimum flow from the rereg dam should start about three hours prior to sundown or between 2 p.m. and 3 p.m. during the November spawning period (see Figure 1). In order that full peaking discharge from Hungry Horse Dam can continue to 4 p.m. we would suggest that refilling the rereg should be started about 1 p.m. with a filling rate of; 1) 11,417 cfs inflow, 2) 3,000 outflow and 3) 8,417 cfs net filling rate. This would result in a 3,000 cfs discharge from the rereg structure for downstream spawning areas.

It is believed the major spawning activity occurs during the first four or five hours after sundown. We would like to keep discharge at the rereg at about 3,000 cfs until 7 or 8 p.m. which would confine spawning to the wetted sutiable areas available at a discharge of about 4,500 cfs at Columbia Falls gauge station. Main river flows excluding the South Fork are about 1,500 cfs in November.

At 8 p.m. the rereg discharge would drop to 2,000 cfs and could be maintained at about that flow until Hungry Horse Dam came on line between 7 and 8 p.m. The rereg would pass the full Hungry Horse discharge without any filling from 8 a.m. until 1 p.m. at which time the cycle would be repeated and continued for the 5-day peaking week. Figures 1 through 4 illustrate possible discharge and power alternatives discussed in the paragraphs immediately preceding for reregulation for November 1 through April 15 for all waters of average or above predicted runoff.

The proposed discharge of 3,000 cfs to 8 p.m. illustrated in Figures 1 through 4 would be the recommended mode of operation from November 1 to at least April 15. This is deemed better thangradually decreasing the flow over that time because it will keep the spawned eggs submerged for a longer period of time each day. This pattern could be maintained for 48 weeks in a year with average or better precipitation. We assumed that no discahrge for generation would be made during the approximate one month of flood stage in the Flathead River.

In attempting to relate these potential peaking power alternatives with salmon reproduction and survival, we have assumed that average annual discharge from Hungry Horse Reservoir would be 2,571,000 acre feet per water year. Looking at Table 1, Section A, it appears that adequate water would be present for all alternatives except rewind and powerhouse plus reregulation for 52 weeks peaking per year. There might be enough water for the combined rewind and powerhouse alternative if peaking was suspended for a week or two during the highest river floodstage.

Table 1 B, a 48-week peaking program would have water for all four power alternatives. In addition, there would be water to provide the main river with 1,000 cfs minimum flow for the 24 weeks of major growth and emergence of macroinvertebrates for April and July through September for existing and rewind alternatives.

It appears that there would be benefits over present "good years" for all but rewind and powerhouse alternative for 52 weeks under average or better runoff conditions.

During low water years discharge operations would have to be modified for example to peaking for 5 days per week at 6 hours peaking per day (Figure 5) or 4 days a week at 8 hours peaking per day (Figure 6). Water requirements for a 5-day, 6-hour per day discharge are shown in Table 2A. All four alternatives would have enough water to operate at a runoff of about 75 percent of normal. Table 2B gives our estimate of water needed to discharge peaking power 5 days per week at 6 hours per day. Figures 5 and 6 illustrate the largest power alternatives (powerhouse plus rewind) quantified in Table 2.

If a 4-day week at 8 hours per day is more in line with peaking power needs than 5 days at 6 hours the additional off-day could be scheduled for Wednesday to avoid having the river bed exposed to minimum off-day flows for more than two consecutive days. This would be most useful in maintaining bank storage levels during off-days. Notice that according to our calculations during a water year that is 75 percent of normal, when peaking 5 days for 6 hours, water would be available for all power alternatives (74% on rewind and powerhouse) while peaking 4 days for 8 hours would require 76 percent or more of average runoff for both powerhouse and rewind plus powerhouse alternatives (Table 2).

A revision of the FSU (Fisherman Satisfaction Units) first given in the memo to the U.S. Fish and Wildlife Service on May 3, 1979 was necessary in light of the changed concepts of power alternatives in respect to options for power peaking other than on a regular 8-hour, 5 days a week schedule for 52 weeks of 48 weeks per year. Table 5 of that May, 1979 memo should be replaced by the estimates given in Table 3 comparing benefits which could be expected from each alternative in comparison to FSU's derived during existing good years from the period 1968-79.

For low water years, all power alternatives with reregulation would have better FSU's than low water years under existing discharge patterns. These are generally expected to be better than twice the poor year's under existing operation. Although benefits during low water years would be less than for existing "good years" they do approach it with both the rereg only and rereg plus rewind alternatives.

It should be mentioned that when the U.S. Fish and Wildlife Service calculated expected angler expenditures, their data should apply for every year with reregulation although under the existing operation of Hungry Horse Dam, poor years can be 50 percent of the time or five out of ten years. Table 1 of the U.S. Fish and Wildlife Service memo to the Bureau of Reclamation (June 20, 1979) will likely be revised and included in their report to the Water and Power Resources Service (Bureau of Reclamation) soon.

Power alternatives without reregulation

One of the misunderstandings from early discussions centered around the concept that peaking power with no reregulation would be limited to the same 8-hour day, 5 days per week as would occur under the rereg dam concept. I think we can definitely say that limiting peaking power to a rigid 8-hour day for 5 days per week would have less impact on the kokanee than the existing prolonged periods of 12-18 hours generation followed by consecutive weeks of no generation at all. Determining how much the impacts will change brings another set of unknown variables into the process. We do have crude data on angler harvest which illustrates that during years with high generation in November and low flows in March and early April result in low numbers of adults from that year-class which is probably poor egg survival while the reverse in flow patterns tends to provide larger numbers of adults. Egg survival also appears to depend on the number of consecutive days without generation during incubation.

One of the main advantages the rereg dam would offer is the ability to reduce water levels on the spawning grounds to 4,500 cfs (3,000 rereg and main river 1,500 cfs) between 5 and 6 p.m. and hold it at a constant 4,500 cfs on the spawning grounds from 5 to 10 p.m. In addition, the rereg would allow a minimum flow of 3,500 cfs over the spawning grounds 5 days per week.

Without reregulation an 8-hour peaking day (8 a.m. to 4 p.m.) would result in flows on the spawning grounds of 11,417; 12,060; 13,367 or 13,783 cfs for 2 to 5 hours during prime spawning time 5 days per week. This would result in salmon spawning higher on the gravel banks where bank storage and spring seeps supply little or no water during the days of no generation.

Some very preliminary data gathered by the U.S. Fish and Wildlife Service and Montana Dept. of Fish and Game on September 27 and 28, 1978 indicated the necessary low velocities for kokanee spawning were found from about 0.5 feet to no more than 1.75 feet of depth in the partial cross-sections of kokanee spawning habitat. Preferential spawning velocities compiled mainly from the literature and some local observations were plotted and showed that spawning occurred primarily between 0.4 and 1.2 feet per second velocity. This habitat only occurs near the margins of large rivers such as the Flathead. It is imperative that flows during prime spawning time be low enough to ensure that kokanee are confined to areas where redds will be wetted under low flows or in areas where bank storage or spring seep can keep the eggs wetted during intervals when Hungry Horse is off-line or at half generation.

Although there are some areas of acceptable depth and velocity at discharges which occur during the nonpower generation period such redds would likely be swept away during peak discharges. Flows in November of 1,500 cfs can presently be increased by 10,000 cfs and to a proposed 13,783 cfs could increase water depths by 5 feet and increase velocities in excess of 5 feet per second near the thalweg. Increased spawning flows during off-line time would reduce impact of peak flows on redds as well as increasing the overall quantity of acceptable spawning.

At this time it appears to Department of Fish, Wildlife and Park biologists that flows most likely to provide optimum quantity of spawning habitat and the lowest mortality of eggs in the redds is about 4,500 cfs on the spawning grounds. These flows could best be provided with a discharge of 3,000 cfs starting about 2 p.m. at the reregulating dam.

The comparison of Table 3 with Table 4 of the Montana Department of Fish, Wildlife and Park's memo of June, 1979 will show the nearly complete disaster of peaking and peaking with added power but without reregulation. The principal reason the timing of flow releases and secondarily because salmon redds spawned at any flow larger than minimum flows would be exposed to freezing and desiccation for 18 hours each day, plus the regular 2-day weekend. This poor situation could be improved if daily peaking hours would start at 6 a.m. and end at 2 p.m.. In this schedule, redds would all be confined to the areas wetted at low flows. Redds would at least stay wetted but production would be very low because of limited spawning habitat at that flow level and the probable egg mortality resulting by many pairs reworking previous pair's redds. In addition, the macroinvertebrate population would probably be restricted to areas wetted only at the minimum flow.

Possible solutions to existing problems prior to alternative power and reregulating dam construction

Even with best of intentions and planning under the present process of getting authorization for construction if the alternatives are found feasible, we believe it is likely that completed construction and fishery mitigation are a minimum of ten years down the road. A more likely time estimate would be 15 to 20 years. It should also be pointed out that predictable, scheduled peaking discharges are necessary to manage the fishery and power resources with any sense of consistency. This would require that water in Hungry Horse be reserved strictly for power peaking use rather than for unscheduled base load needs elsewhere in the power system. Prolonged periods of peaking on off-line use of the Hungry Horse System would completely disrupt the estimated benefits resulting from a reregulating dam.

We have mentioned in previous discussions the possibility of constructing a kokanee spawning channel as a means of stabilizing salmon incubation at some reasonable level. In 1978-79 water year, power generation was off for nearly five weeks in December and January and in the 1979-80 water year we have seen more long periods of no power generation. In this year's spawning data, we have already found 100 percent egg mortality in redds spawned above the minimum flow level. This was quite common because peak discharges occurred 24 hours a day in November this year.

A spawning channel could be built in a single season and placed in operation to provide salmon for the years before the rereg and power determination were possible. We would start preliminary sizing and location estimates of such a structure if requested. We are enclosing some leaflets on the Meadow Creek spawning channel of Kootenai Lakes, British Columbia. They have constructed several successful artificial spawning channels in British Columbia and feel they are placed where they are strongly cost beneficial.

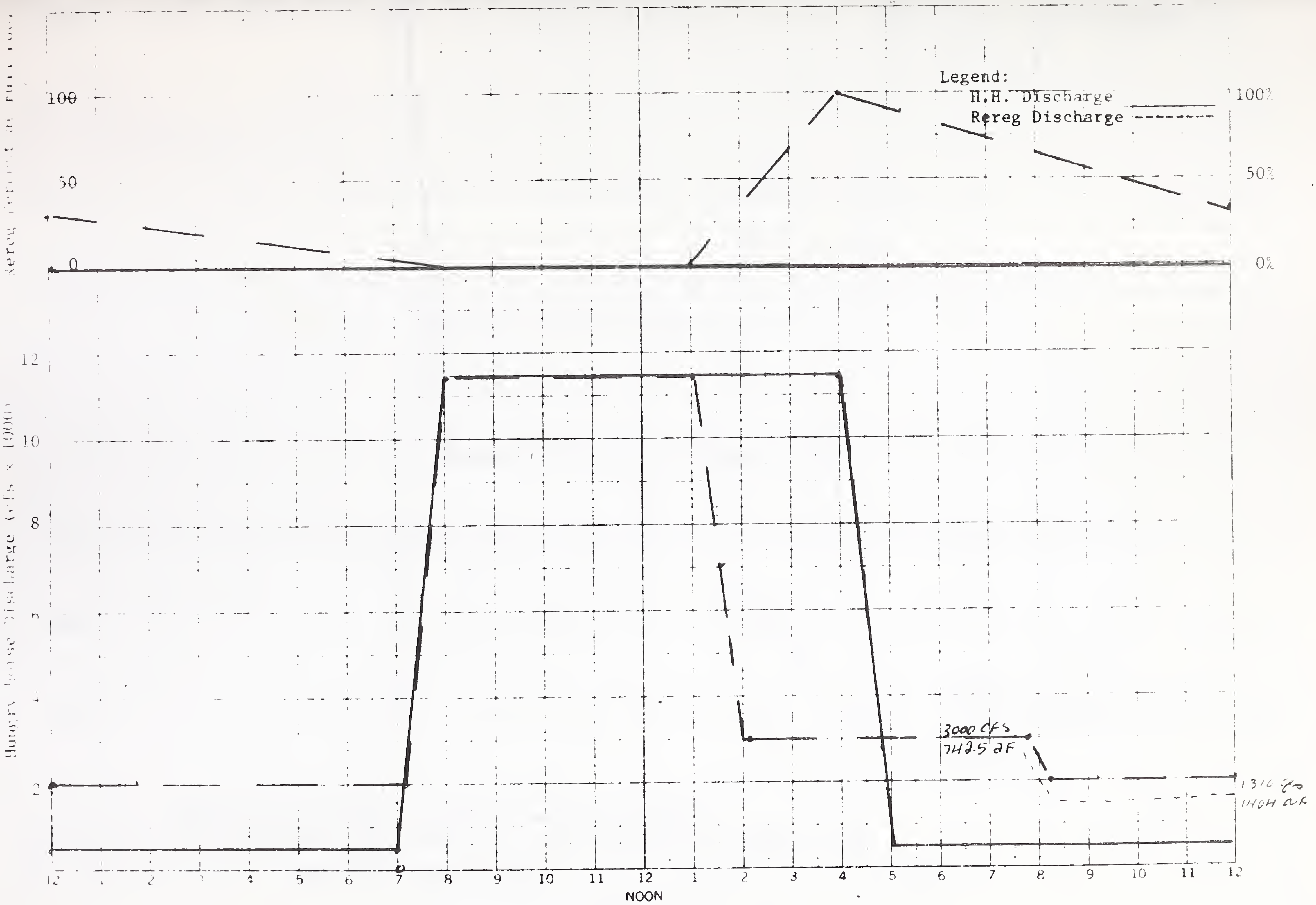
Sincerely,

Thomas R. Hay
Regional Supervisor

By:________________________
Robert E. Schumacher
Regional Fisheries Manager

TRH:RES:ns
Encls:
cc: John Lloyd

Figure 1. Power Alternative at 11,417 cfs, 5 days per week at 8 hours per day
Hungry Horse Reservoir and Rereg Reservoir Discharge



3000 cfs
7425 aF

1310 cfs
1404 af

K•E 1 DAY BY HOURS x 100 DIVISIONS
KEUFFEL & ESSER CO MADE IN U.S.A. 46 2050

Figure 2. Power Alternative at 12,060 cfs , 5 days per week at 8 hours per day
Hungry Horse Reservoir and Rereg Reservoir Discharge

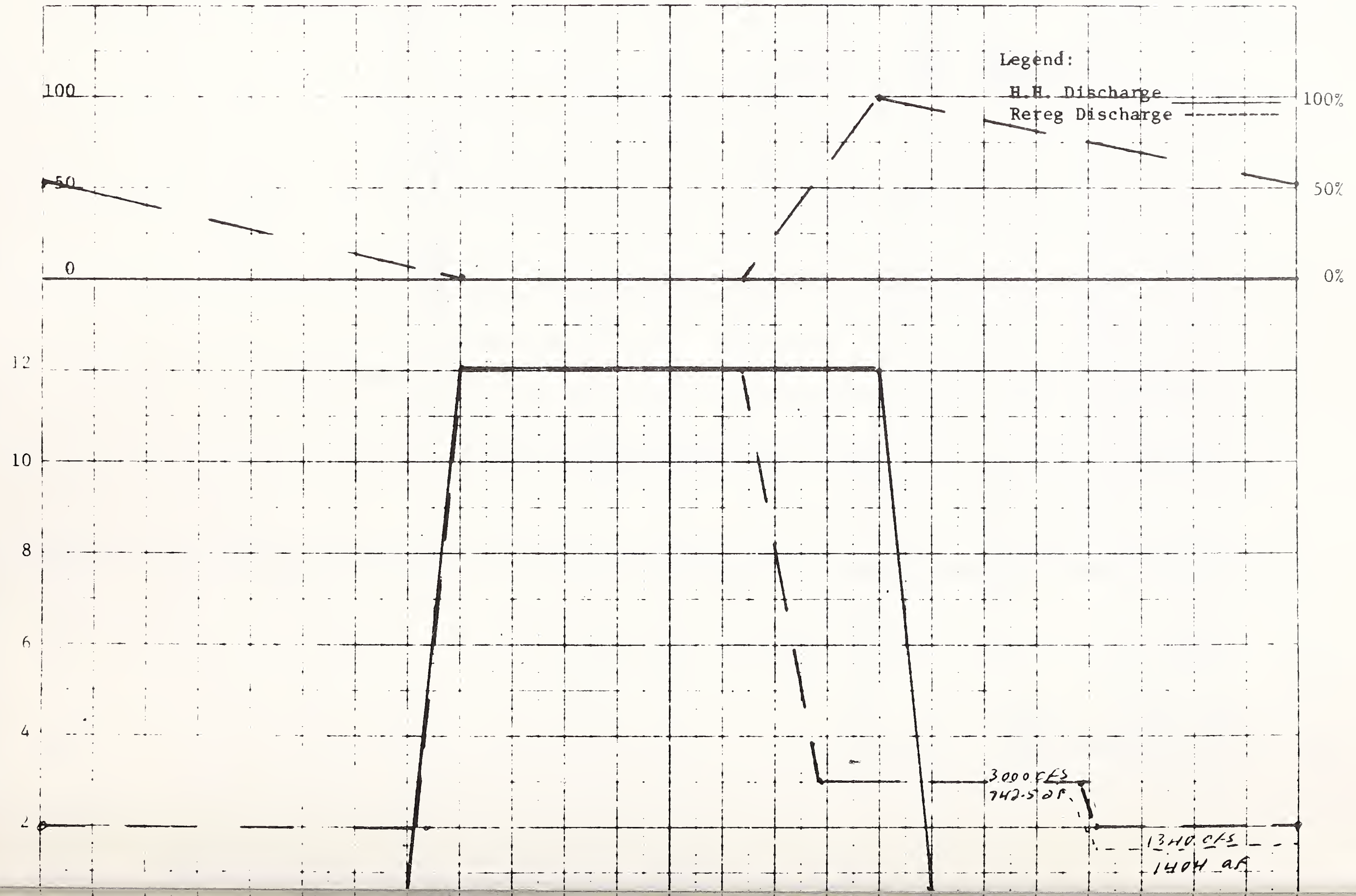


Figure 3. Power Alternative at 13,367 , 5 days per week at 8 hours per day
Hungry Horse Reservoir and Rereg Reservoir Discharge

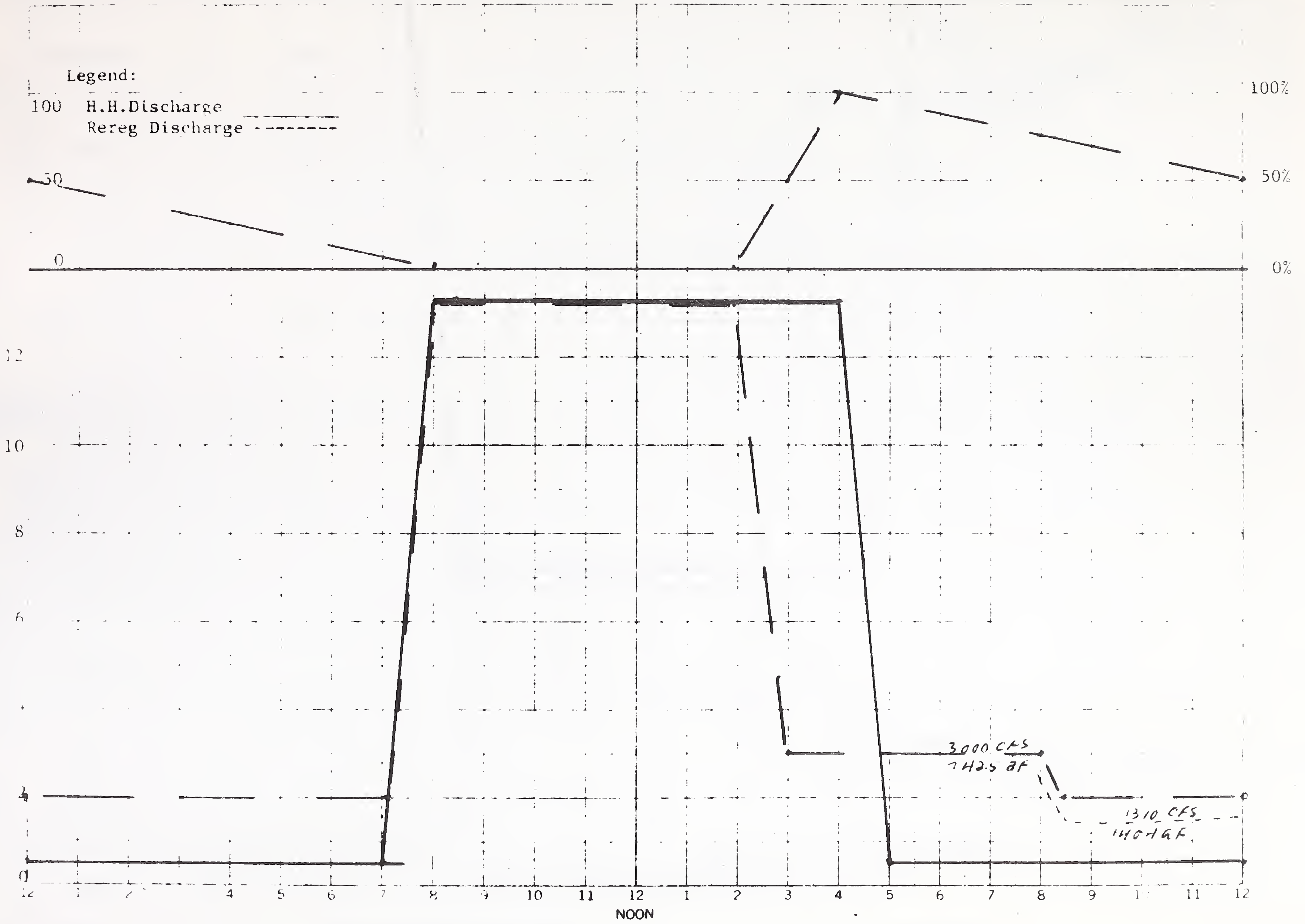


Figure 4. Power Alternative at 13,783 cfs, 5 days per week at 8 hours per day
Hungry Horse Reservoir and Rereg Reservoir Discharge

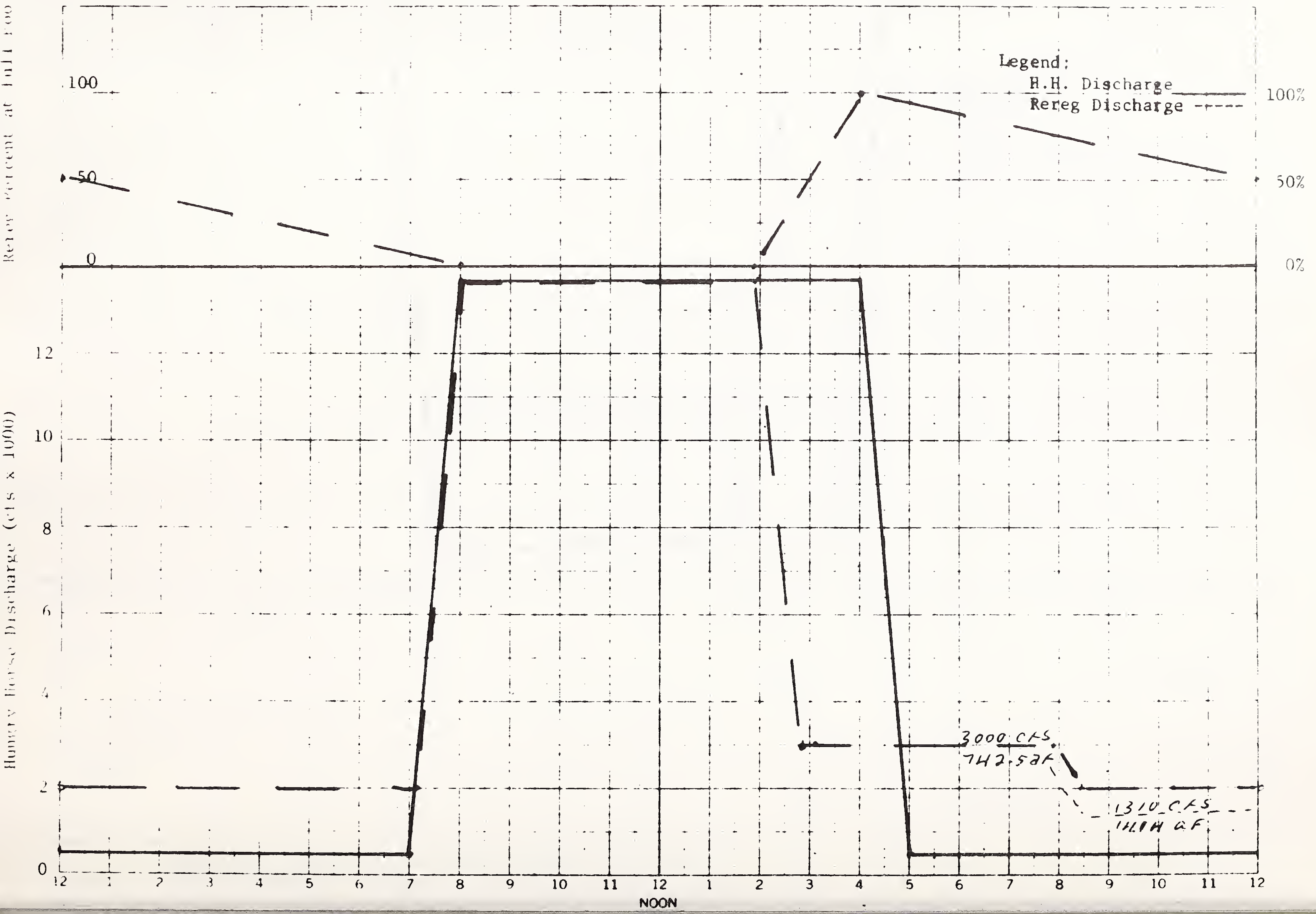


Figure 5. Power alternative at 13,783 cfs 5 days per week at 6 hours per day
Hungry Horse Reservoir and Rereg Reservoir Discharge

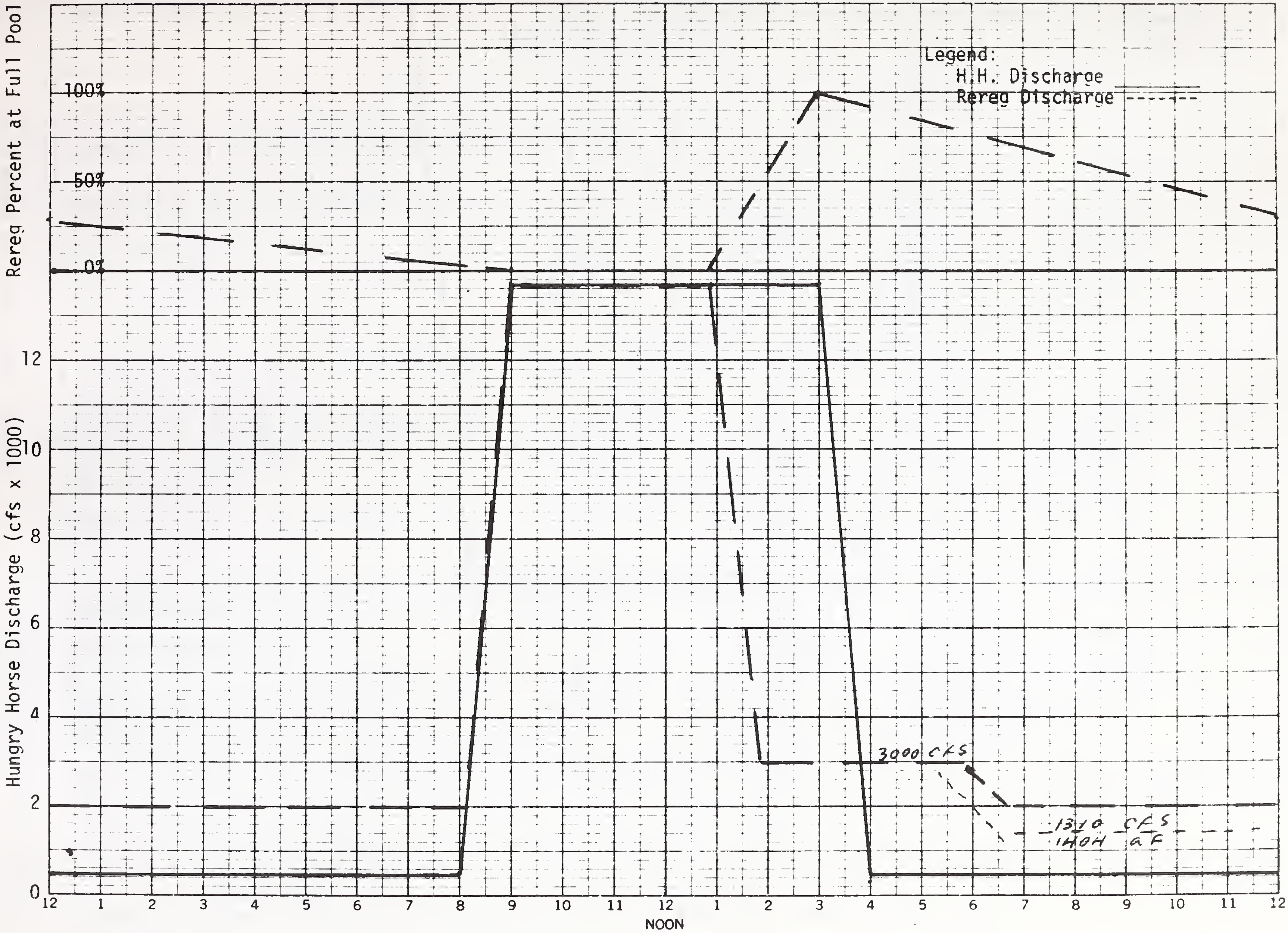


Figure 6. Power alternative at 13,783 cfs, 4 days per week at 8 hours per day
Hungry Horse Reservoir and Rereg Reservoir Discharge

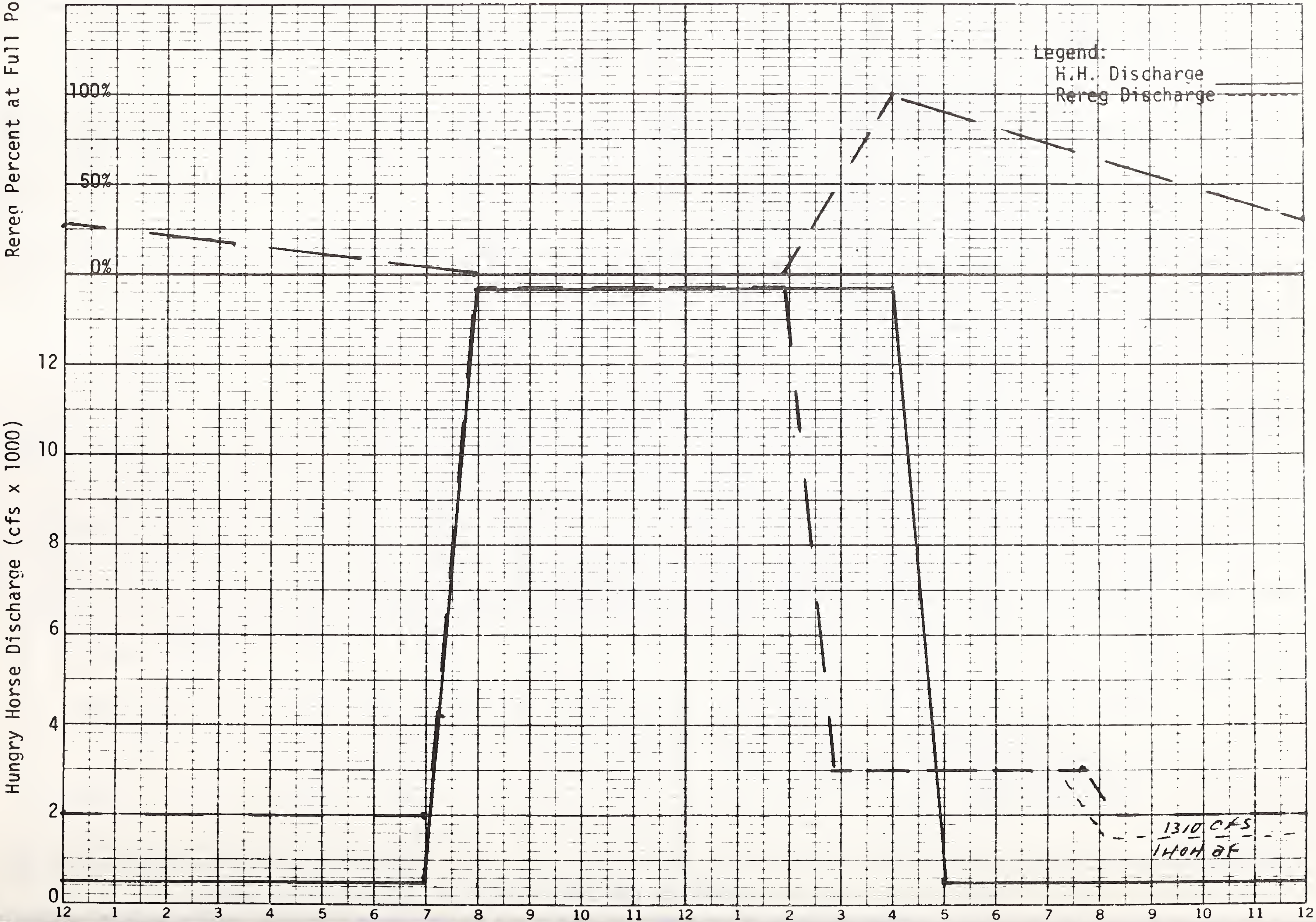


Table 1. Expected possible Hungry Horse Reservoir and potential reregulating dam discharge pattern with useable storage 2,125,100 acre feet and average annual discharge 2,571,000 acre feet

DISCHARGE IN ACRE FEET

	Existing	Rewind	Powerhouse	Rewind and Powerhouse
A. Peaking 5 days per week for 52 weeks at 8 hours per day				
Instantaneous discharge	11,417 cfs*	12,060 cfs	13,367 cfs	13,783 cfs
Minimum flow 500 cfs per 16 hours per day	171,600 af*	171,600 af	171,600 af	171,600 af
Minimum flow 500 cfs per 48 hours per week	102,960 af	102,960 af	102,960 af	102,960 af
Total minimum discharge	274,560	274,560	274,560	274,560
Peaking discharge	1,959,157	2,069,496	2,293,777	2,365,162
Total discharge	2,233,717	2,344,056	2,568,337	2,639,722
B. Peaking 5 days per week for 48 weeks at 8 hours per day (minimum flows of 500 cfs)				
Instantaneous discharge	11,417 cfs	12,060 cfs	13,367 cfs	13,783 cfs
Minimum flow 500 cfs per 16 hours per day	171,600 af	171,600 af	171,600 af	171,600 af
Minimum flow 500 cfs per 48 hours	102,960	102,960	102,960	102,960
Total minimum discharge	274,560	274,560	274,560	274,560
Peaking discharge	1,808,452	1,910,304	2,117,333	2,183,227
Total discharge	2,083,012	2,184,864	2,391,893	2,457,787
C. Peaking 5 days per week for 48 hours at 8 hours per day 24 weeks minimum flows at 500 cfs and 24 weeks at 1000 cfs				
Instantaneous discharge	14,417 cfs	12,060 cfs	13,367 cfs	13,783 cfs
Minimum flows 500 cfs per 24 weeks	148,720 af	148,720 af	148,720 af	148,720 af
Minimum flows 1000 cfs per 24 weeks	274,560	274,560	274,560	274,560
Total minimum flow discharge	423,280	423,280	423,280	423,280
Peaking discharge	1,808,452	1,910,304	2,117,333	2,183,227
Total discharge	2,231,732	2,333,584	2,540,613	2,606,507

cfs = cubic feet per second
af = acre feet

Table 2. Expected possible Hungry Horse Reservoir and potential regulating dam discharge pattern with useable storage 2,125,100 acre feet and average annual discharge of 75% of 2,571,000 acre ft.

	Existing	Rewind	Powerhouse	Rewind and Powerhouse
A. Discharge in acre feet, peaking 5 days per week, 6 hours per day 48 weeks -- 500 cfs minimum flow.				
Instantaneous discharge	11,417 cfs	12,060 cfs	13,367 cfs	13,783 cfs
Acre feet minimum flows 18 hours per day at 500 cfs	178,200 af	178,200 af	178,200 af	178,200 af
Acre feet minimum flows 48 hours per week at 500 cfs	95,040	95,040	95,040	95,040
Total minimum discharge acre feet	273,240	273,240	273,240	273,240
Peaking discharge acre feet	1,356,339	1,432,728	1,587,994	1,637,420
Total discharge acre feet	1,629,579	1,705,968	1,861,234	1,910,660

Table 2. Continued:

	Existing	Rewind	Powerhouse	Rewind and Powerhouse
B. Discharge in acre-feet, peaking 4 days per week at 8 hours per day 48 weeks -- 500 cfs minimum flow				
LOW WATER YEAR				
Instantaneous discharge	11,417 cfs	12,060 cfs	13,367 cfs	13,783 cfs
Acre-feet discharge 16 hours 4 days per week	126,720	126,720	126,7 0	126,720
Acre-feet minimum discharge 72 hours per week	142,560	142,560	142,560	142,560
Acre -feet peaking discharge	1,446,762 1,716,042	1,528,243 1,797,523	1,693,866 1,963,146	1,756,582 2,025,862

Table 3. Expected Fisherman Satisfaction Units (FSU) and the gain or loss that would be expected in respect to existing "good years" as determined for various discharge patterns, power options, and water years that could occur.

Variables	FSU expected	FSU gained or lost
WATER YEARS -- AVERAGE, ABOVE AVERAGE		
A. Peaking for 52 weeks at 500 cfs at minimum flow		
Existing *	634,800	no gain
Existing plus rereg	793,500	+ 158,700 (25%)
Rewind plus rereg	793,500	+ 158,700
Powerhouse and rereg	793,500	+ 158,700
Rewind and powerhouse and rereg	634,800	no gain
B. Peaking for 48 weeks at 500 cfs minimum flow		
Existing *	634,800	Existing
Existing plus rereg	793,500	+ 158,700 (25%)
Rewind plus Rereg	793,500	+ 158,700 (25%)
Powerhouse and rereg	793,500	+ 158,700 (25%)
Rewind and powerhouse and rereg	793,500	+ 158,700 (25%)
C. Peaking discharge for 48 weeks with increased minimum flows Minimum flow of 1,000 cfs November through March Minimum flow of 500 cfs April 1 through October		
Existing *	634,800	Existing
Existing and rereg	825,240	+ 190,440 (30%)
Rewind and rereg	825,240	+ 190,440 (30%)
Powerhose and rereg	825,240	+ 190,440 (30%)
Rewind and powerhouse and rereg	793,500	+ 158,700 (25%)
WATER YEARS - 75% OF AVERAGE		
D.		
Existing (poor year)	211,388	33% of good year
Existing with rereg	595,125	39,675 loss (6.25%)
Existing with rewind	601,473	33,327 loss (5%)
Existing with powerhouse and rereg	527,916	106,884 loss (17%)
Existing with rewind and powerhouse and rereg	482,850	151,950 loss (25%)

Table 5 in memo to Fish and Wildlife Service of May 3, 1979 is hereby revised -- 2/27/80
Existing with peaking power in Table 3 and Figure 1.

* Existing = good years without peaking power -- five out of ten years.

Table 4. (Revised 3/10/80[*]) Estimated FSU with peaking power without reregulation

Alternative	Good Year[**]		Poor Year[**]	
	FSU	% Change	FSU	% Change
Existing				
Non-peaking	634,800	---	211,388	---
Peaking	169,364	[***] - 60%	190,250	- 10%
	+ 190,250			
	359,614	- 43% of total		
Rewind	105,852	[***] - 75%	179,680	- 15%
	+ 179,680			
	285,533	- 55% of total		
Powerhouse	84,682	[***] - 80%	169,110	- 20%
	+ 169,110			
	253,792	- 60% of total		
Rewind and Powerhouse	42,341	[***] - 90%	147,972	- 30%
	+ 147,972			
	190,312	- 70% of total		

---

[*] Revised and modified from memo to U.S. Fish and Wildlife Service 6/79 and to replace Table 4 of memo to Bureau of Reclamation of 2/27/80

[**] Good Years -- five out of ten years (1968-1978)

[***] Percent loss from 423,412 FSU

STATE OF MONTANA

DEPARTMENT OF

FISH AND GAME

Region One
490 N. Meridian
Kalispell, MT 59901

March 10, 1980

Larry Vinsonhaler
U.S. Dept. of Interior
Water and Power Resources Service
Fed. Bldg., 550 W. Fort St. Box 043
Boise, Idaho 83724

Attn: Rich Prange

Subject: Comments on potential peaking power capabilities -- Hungry Horse Reservoir

In response to a phone conversation we had with Roger Larson on February 25, 1980, we discussed the assumed inability for Hungry Horse to follow the recommended approximate equal monthly discharges we proposed for peaking power. Also of concern was the minimum flow of 500 cfs we used in our calculations. The use of 500 cfs was used as it was the recommended minimum flow of the Fish and Wildlife Service.

The information we provided the Bureau in our memo of Febrary 27 indicated in crude calculations that, Hungry Horse Reservoir with a reregulating dam, could provide peaking power capabilities under three discharge schedules for the rereg with three alternatives of added peaking power capabilities.

We have recalculated Table 1 for subheadings A and B using a minimum flow of 150 cfs and enclosed penciled new figures.

We have given careful deliberation to the tables Roger provided and especially the average monthly discharge, cfs for the years 1929 through 1967 or "Study Number 7895" data.

We are seriously concerned with the management philosophy which I thought I heard Roger Larson state in our latest phone conversation (about February 25 or 26). I cannot recall the other person(s) on your end of the conference call. It may have been Bill Mullin. I understood, in essence, that even under peaking power, the average monthly discharge would have to remain at about the same percentage or the average yearly discharge that it is now, or be about the percentages listed in Table X-1, line 3. Our concerns are that either with or without added power capability if Hungry Horse is to go to peaking power, then it would seem the best cost benefit ratio would be had by regular 5-day weeks and discharge during the 8 a.m. to 4 p.m. peak use period.

The Department is of the opinion that, with major changes in discharge toward a peaking power regime, this would be the time to make such other changes as minor alterations in mean monthly discharge. Also, we would suggest selecting schedules for peaking power discharges in low water years which would give consideration to the fishery and aquatic resource as well as meeting other contracts of storage and release commitments. The Environmental concerns must not be made to carry the full sacrifice in years of low water.

We recognize that in any one year the maximum benefits come from generation use of all stored water which can be predicted to be replaced in that water year. For instance, in Table 1A, under Power House (2/27/80 memo) or Rewind and Power House, my figures would indicate only 92 and 95 percent, respectively, would be used of an average discharge year with a 150 cfs minimum flow. We would suggest that the balance of unprogrammed water could be used effectively by adding a half hour before 8 a.m. and a half hour after 4 p.m. for any month desired except for November. This would make best use of this water as peaking loads probably extend at least another hour into the afternoon as shorter daylight periods develop and also as most of BPS power sales are west of Kalispell and, therefore, in a later time zone where peak times also move an hour later.

It is imperative that November discharge patterns be as close as possible to those shown in Figures 1 through 6. An extra hour or two a day could be added to days in December through April or summer months without impacting the fisheries resource. We are most concerned that non-generation days occur no more than two days per week during the winter incubation period.

It is also imperative that April discharges maintain river flows at Columbia Falls of at least 5,000 cfs to allow hatched free swimming fry to escape the gravel redds into a flowing water environment. Emergence of fry will occur daily for a month or six weeks in April and May. Whereas eggs can survive only if wet, the hatched fry have to be able to express water past the gill arches to respire. Days of non-generation, even on weekends, are likely to exert some unknown percent mortality on the total fry population. It could be as high as 2/7th each week of attempted emergence.

Table Y also illustrates the percent of average existing monthly flows (line 2, Table X1) which would be used for generation to provide the uniform monthly discharges under various peaking power schedules (Table X2).

$$\frac{186{,}143 \text{ acre-feet} = 58.9\%}{316{,}124 \text{ acre-feet}} \qquad \frac{186{,}143 + 125.2\% = \text{etc.}}{148{,}690}$$

It can be seen that November, March and April have been months of considerably lower than the existing mean average monthly discharge. We would recommend the April flows be as shown on the same Figures 1 through 4, at least for the first half of the month or until North and Middle Fork combined with Hungry Horse minimum discharges exceed 6,000 cfs during off-generation hours.

We have also recommended a 500 cfs minimum flow. Whereas this might not be economically feasible from a power viewpoint, it did add some FSU benefits plus an unknown amount of benefits in insect/macroinvertebrate habitat. It could be found to be economically feasible if a 500 cfs power unit were added in the power house and rewind with power house alternatives. Although it would be producing base load power in off hours, the power probably could be used by Montana Power at Kerr Dam, for instance and perhaps be exchanged for peaking power.

There would be some change in FSU and probably in the economic value if the peaking power schedule were mixed with partial use of the water for base load. We find it nearly impossible to conceptualize in meaningful numbers if the mix does change between months or within months during the kokanee spawning and incubation season. It is possible to hypothesize that FSU's could drop to as low as those for poor years in Table 4(February 27 and revised this memo) if flows change significantly from our Figures 1 through 4 during November of April. Whereas two consecutive days off may cause an unknown mortality, more than two consecutive days off generation from December 1 through April could cuase the 100 percent loss in egg mortality we are seeing in most redds this year (1979-1980).

The FSU benefits which 500 cfs minimum flow added to hose which 150 cfs would provide are small, even if both are subject to regularly scheduled discharge and reregulation. Here the actual minimum flow of 500 or 150 cfs would impact the aquatic habitat on weekends (48 hours) but would probably impact the macroinvertebrate and primary productivity the most. Macroinvertebrates are most likely to be limited to the habitat which is continuously flooded for prolonged periods, much longer than 5 days at a time. Therefore, it would seem the weekend 150 cfs minimum would control macroinvertebrates.

The FSU benefits to the fishing would occur primarily in holding the daily minimum rereg discharge to 2000 cfs daily during the off generation hours 5 nights a week instead of the 1,310 cfs minimum rereg discharge. Considering a main river flow of 1,500 cfs plus 2,000 cfs or plus 1,310 cfs, the 150 minimum would cause a reduction of only 20 percent of the total minimum flow 5 days per week.

The 2,000 cfs can be maintained overnight, starting with the rereg full and with a continuing 500 cfs Hungry Horse discharge. A Hungry Horse discharge of 150 cfs would provide 1,310 cfs overnight.

Salmon redds covered by 2,000 cfs rereg discharge plus 1,500 cfs (main river) would be more numerous than redds which could be covered by a discharge of 1,310 cfs plus 1,500 cfs (main river).

Regarding John Lloyd's question about Table 4(3/27/80) and the reason the FSU in "poor years" exceeds that of "good years" this was an error (thanks John).

Obviously I have mixed two ideas in concept but neglected to mix the FSU's. Enclosed is a suggested new set of figures for Table 4 based on these concepts.

1. 634,000 FSU is for "good year" which under (existing) has only occurred five out of ten years.

2. 634,000 FSU includes the 1/3 or 211,388 FSU from other areas principally the Middle Fork tributaries, McDonald Creek and Nyack area.

3. The 211,388 FSU (poor years) is the result of production from areas other than the spawning habitat below the confluence of the South Fork and the main Flathead. As a consequence, the production of FSU's in poor years is projected on the basis of relatively small losses due to stranding of fry under rubble cover in daytime (negative phototrophic) during migration to Flathead Lake. This rubble bed is dewatered to an ever increasing percent with increasing maximum flows under various power alternatives.

4. The principal reduction of FSU in "good years" would occur to the 423,411 FSU (634,800 - 211,388 = 423,411) resulting from unregulated Hungry Horse discharge flows continuing 3 - 4 hours into the prime spawning hours or 3 - 5 hours after dark on the main river spawning habitat. Assuming that Hungry Horse went off line at 4 p.m., the reduction from 11417, 12060, 13367 or 13783 cfs would not reach spawning areas until 7 or 9 a.m.. Sunset occurs from 4:30 to 5:00 p.m. here in November.

5. The FSU numbers for Good Years should be the sum of FSU of fry incubated from other sources (poor year) and added to the percent of surviving fry from the area influenced by South Fork discharges.

In conclusion, it seems we must always end up treating with average values, average days, average monthly flows, average maximums or minimums. All living forms including man are restricted by the minimum life necessities not averages. It is the minimums imposed for hours or days that cause mortality and limit populations of aquatic forms. It is not the average of a daily or monthly minimum. The revised Table 4 is attached.

Sincerely,

Thomas R. Hay
Regional Supervisor

By:____________________
Robert E. Schumacher
Regional Fisheries Manager

TRH:RES:ns
cc:John Lloyd

Table [illegible] (Revised 3/10/80[*]) Estimated FSU with peaking power without reregulation

Alternative	Good Year[**] FSU	Good Year[**] % Change	Poor Year[**] FSU	Poor Year[**] % Change
Existing				
Non-peaking	634,800	---	211,388	---
Peaking	169,364	***- 60%	190,250	- 10%
	+ 190,250			
	359,614	- 43% of total		
Rewind	105,852	***- 75%	179,680	- 15%
	+ 179,680			
	285,533	- 55% of total		
Powerhouse	84,682	***- 80%	169,110	- 20%
	+ 169,110			
	253,792	- 60% of total		
Rewind and Powerhouse	42,341	***- 90%	147,972	- 30%
	+ 147,972			
	190,312	- 70% of total		

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[*] Revised and modified from memo to U.S. Fish and Wildlife Service 6/79 and to replace Table 4 of memo to Bureau of Reclamation of 2/27/80

[**] Good Years -- five out of ten years (1968-1978)

[***] Percent loss from 423,412 FSU

STATE OF MONTANA

DEPARTMENT OF

FISH AND GAME

Region One
490 N. Meridian
Kalispell, MT 59901
May 3, 1979

Burton Rounds, Area Manager
U.S. Fish and Wildlife Service
Billings Area Office
Federal Bldg., Room 3035
316 N. 26th St.
Billings, MT 59101

Attn: John Lloyd

Subject: Economic estimate of Hungry Horse project with added power and reregulation.

The Flathead River and Lake fishery are of high economic value and a very high aesthetic value to northwestern Montana and adjacent states. As most game fish species in the system are migratory salmonids neither the lake fishery or the stream fishery could be sustained separately. The North Fork and Middle Fork and tributaries provide the spawning and small juvenile rearing areas for westslope cutthroat trout, Dolly Varden, and mountain whitefish while the main Flathead River below the junction of the South Fork provide the principal spawning area for kokanee salmon and some whitefish and limited rainbow trout populations. The main Flathead River is strongly influenced by fluctuating water discharges from the Hungry Horse Reservoir six miles up the South Fork and by modified stream temperatures from the 40° hypolimnial reservoir discharges.

This statement is preliminary estimate of the economic assessment of the expected impacts of the project with various power alternatives. As more hard data from the newly started study are acquired and analyzed, it seems likely that changes in the economic estimates will be required.

In 1975 the Department of Fish and Game conducted a creel census of the free-flowing river tributaries (Hanzel 1977). The Department also conducted a statewide mailout questionnaire for a pressure estimate for the years 1967-77, 1975-1976, and 1967. Pressure data for 1975 were coupled with the bag creel census of that year to allow for full expansion to total estimate harvest.

Westslope cutthroat and Dolly Varden adults migrate through the main Flathead River starting in March with cutthroat adults and ending in July with Dolly Varden. Subadult smolts (7" to 12") emigrate from nursery tributary streams to Flathead Lake at a slow rate from June through October. Stream fishing seasons start in mid-May and end November 30. Flathead Lake fishing is continuous for the entire year. The break-point for pressure census from the mail forms is May 1 through September 30 as the summer season and October 1 through April 30 as the winter season.

Table 1. Pressure estimates from mail form survey -- Flathead River

	1975 - 1976		1976 - 1977	
	ALL ANGLERS	RESIDENT ONLY	RESIDENT ONLY	
Summer	21,493	18,861(87.8%)*	(20,580)*	18,070
Winter	24,700	16,217(84.4%)*	(14,513)*	12,249

* Data from non-resident license holders unuseable for pressure census 1976-77. Angler estimate calculated from resident anglers 1976-77 and percent resident anglers were of the 1975-76 totals.

Dolly Varden in the river

A total river estimate from the 1975 creel census (Hanzel 1977) gave 7,284 caught of which 5,300 were caught in the main Flathead River (72.8 percent). Approximately 42 percent were kept and were over the 18-inch total length size limit. Dolly Varden 24 inches and longer are considered trophy fish and are rated higher in Fisherman Satisfaction Units (FSU) see Table 2 for all species.

Table 2. Assigned Fisherman Satisfaction Units (FSU) for species and size in the Flathead River. Values assigned only to fish kept for creel.

Dolly Varden	less than 24"	(3.0)*	more than 24" (10.0)*	
Wct Trout	less than 9"	(2.0)*	less than 14" (3.0) &	more than 14" (5.0)*
Rainbow trout	less than 12"	(1.0)*	less than 18" (2.0)*	more than 18" (3.5)*
Mtn. Whitefish	all sizes	(1.0)*		
Kokanee	prespawning adults	(2.0)*	spawning adults(1.5)*	

*Fisherman Satisfaction Units

Dolly Varden in the lake

Data on recent harvest of Dolly Varden in the lake are meager. Robbins' (1966) data for year 1962-63 and the summer of 1963 reported a harvest of 12,000 fish in the full year and 3,850 for the summer of 1963. This relates to limited observations that the major Dolly Varden lake fishery is from October through March.

Westslope cutthroat in the river

The westslope cutthroat catch totaled 15,557 caught in the main Flathead River or 37,886 for the upper tributaries plus the main river, according to Hanzel (1977). Data indicates 56 percent of these were actually kept and harvested or 8.711 fish for the main river with 21,216 estimated for the total upstream drainage.

Westslope cutthroat in Flathead Lake

Otis Robbins' 1966 creel data gave a lake harvest of 8,400 cutthroat for a full license year of angling from May 1, 1962 to April 30, 1963.

Kokanee salmon in the river

Kokanee spawning in the main Flathead River and McDonald Creek, a tributary to the Middle Fork at West Glacier, are believed to be responsible for more than 90 percent of the total Flathead kokanee population. Some limited spawning occurs at eight known sites on lakeshores and a few hundred are known to spawn in the Whitefish and Stillwater Rivers. Hanzel's report (1977) showed 187,124 adult salmon caught by angling and snagging in 1975 in the main river. Ninety percent were caught from the late run through November by snagging and 10 percent caught in the early run mainly in August and September of the summer data season.

Kokanee salmon in the lake

Kokanee are highly sought after by lake anglers from June through September. The catch is mainly adults at Age III+ which would spawn that fall. Some years when there is an especially strong year-class of Age II, and when the Age III+ is weak, substantial numbers of immature Age II fish appear in the catch. The most recent creel census data are for 1962-63 license year and indicated 317,000 were creeled that year from the lake.

Mountain whitefish in the river

Hanzel (1977) indicated a harvest of 7,717 in the main Flathead River. This small number is not indicative of the river population, only that the whitefish is not sought after by many fishermen. We would hypothesize that whitefish comprise better than 60 percent of the biomass at any given time.

Mountain whitefish in the lake

Robbins (1966) showed a harvest of 5,460 for the 1962-63 license year. Both mountain whitefish and lake whitefish probably comprise a major portion of the lake biomass.

Economic assessment

A major problem in treating with economic evaluation is the attempt of pure economists to assign finite,tangible values to a resource that has tangible and intangible values of infinite worth. All such assignations are arbitrary to the extent they do not assign values to match individual fisherman's true benefits received. An angler fishing for Dolly Varden and hoping to catch one weighing 10-15 pounds would rank his catch much higher than he would in catching a two-pound cutthroat. A fly fisherman, however, would probably value a two-pound cutthroat taken on a light line much higher than a larger Dolly Varden caught on a boat rod with heavy line and large lure.

We have attempted to assign values, based on our judgement, starting with one whitefish having a Fishery Satisfaction Unit of 1.0 (1 FSU=1.0). Table 2 has assigned FSU's for the Flathead River and Lake based on our arbitrary judgement of how each species by size rates with local anglers. The FSU for each species has been derived by multiplying the assigned FSU by the number of fish harvested in specific sizes, totaled for each species and for the lower Flathead River and Lake in Table 3. According to our assigned values, there were 393,175 FSU derived from the river fishery in 1975 which was deemed to be an average year.

Lake fishery data are more difficult to extrapolate except lake-caught salmon have a higher FSU rating than stream-caught adults because they are caught in their prime condition rather than having experienced some spawning deterioration.

The fall of 1975 was believed to be an average year for salmon fishing; 1977 was ranked as better than average; 1976 was ranked as poorer and 1978 was ranked as equally poor. The fall of 1974 appeared to be average or about like 1975. The ranking of both 1976 and 1978 as poor needs explanation. Both years exhibited an almost complete failure of harvest of those salmon that spawn in October-November in the main Flathead River. The early run (September and early October) that moved through the main river to spawn in McDonald Creek was about average in 1976 and better than average in 1978. This may indicate the factor responsible for poor snagging likely occurred due to egg or fry losses in the river and not after the fry reached the lake. This assumption is based on the concept that "in lake" mortality would not have been a discriminatory mortality for main river fish only. Over the 13 years I have been Regional Fishery Manager at Kalispell, McDonald Creek has

Table 3. Accumulated Fishery Satisfaction Units[1] for the main Flathead River game fish with catch numbers from 1975 creel census [2] and from Flathead Lake 1962-63 season [3]

Dolly Varden	(3.0) less than 24"	(10.0) more than 24"		Est. fish kept	Sub-total FSU
River fish #	1,378	848		2,226	
River FSU	4,134	8,480			12,614
Lake Fish	3,960	8,040		12,000	
Lake FSU	11,880	80,400			92,292

Westslope cutthroat	(2.0) less than 9"	(3.0) less than 14"	(5.0) Over 14"	Est. fish Kept	Sub-total FSU
River fish #	4,512	5,912	1,245	11,669	
River FSU	9,024	17,734	6,225		32,985
Lake fish #		8,400		8,400	
Lake FSU		25,200			25,200

Rainbow	(1.0) less than 12"	(2.0) more than 12"		Est fish Kept	Sub-total FSU
River fish #	204	526		730	
River FSU	204	1,050			1,254
Lake fish #		500		500	
Lake FSU		1,000			1,000

Mountain Whitefish	(1.0) all sizes			Est.fish kept	Sub-total FSU
River fish #	6,327			6,327	
River FSU	6,327				6,327
Lake fish #	4,200			4,200	
Lake FSU	4,200				4,200

Kokanee	Prespawning adults (2.0)	Spawning adults (1.5)		Est.fish kept	Sub-total FSU
River fish #	17,776	169,438		187,214	
River FSU	35,552	254,157			289.709
Lake fish #	317,400			317,400	
Lake FSU	634,800				634,800
				Total river fish FSU	342,889
				Total lake fish FSU	757,492
				Grand Total FSU	1,100,380

[1] Fisherman Satisfaction Units per fish from Table 2

[2] Hanzel 1977 -- angling pressure and game fish harvest estimates for 1975 in the Flathead System above Flathead Lake

[3] Robbins 1966 -- Flathead Lake (Montana) fishery investigations 1961-64. Technical papers, Bureau of Sport Fisheries and Wildlife. U.S. Dept. Interior

always had a good run. This run is probably limited only by spawning space and bald eagle predation and to some variable extent by snaggers as the salmon pass through the lower river.

Flow fluctuations

Fluctuations in the main Flathead River have been plotted for several years from U.S.G.S. gauging station at Columbia Falls (Station No. 12-36300) which measures the combined flows from the North, Middle and South Fork. The South Fork discharges from Hungry Horse Dam (Station No. 12-362500) vary from a minimum flow of 150 cfs to approximately 11,450 cfs. Frequency of operation with one to four generators has been generally unpredictable being governed by discharge for power, discharge to provide reservoir flood storage and discharge rates to maintain a full pool reservoir from June 15 through August. Full generation discharge during the October-November spawning run adds to the winter flow of about 1,200 cfs from the upper main river causing vertical elevation changes of 5.11 feet at the Columbia Falls gauging station.

Stream width was scaled from photos flown at 3,110 cfs, 5,216 cfs, and 8,770 cfs (actual gauge readings). Site #1 was above the Columbia Falls Highway 40 bridge and site #2 was about two miles below the bridge in known kokanee spawning areas. Distances were not scaled in feet, but measured in image widths in millimeters. At Site #1 the wetted width increased 32 percent and 36 percent for the wetted width at 5,216 and 8,770 cfs respectively. At Site #2, 17 percent and 40 percent were added at 5,216 and 8,770 cfs respectively. Average unregulated flows in late fall and winter are between 1,200 and 2,250 cfs and regulated flows from the reservoir are generally added in 2,500 cfs increments for each of four generators. We have insufficient data to project reliable impact estimates of various flow levels on the major game fish populations that migrate through or are dependent on the main river for part of their life cycle. We will make estimates supported by meager data (Table 4).

Dolly Varden smolts (7" to 9") move out of the tributaries at Age II+ years and move at an unknown speed to the lake. They leave the tributaries sporatically and in low numbers most of the time from July through September. There is likely no significant impact on smolt-sized fish except that the macroinvertebrates and plankton are probably limited in that area by an unknown amount and must reduce the food availability for small fish considerably. Small fish are dominate forage items for Dolly Varden of this size (Armstrong 1970).[1/]

Dolly Varden were severely impacted by construction of Hungry Horse Dam and our past estimates were a loss of 60 percent of the spawning and rearing habitat for Dolly Varden which had inhabited Flathead Lake.

[1/] Armstrong, R.H. Age, food and migration of Dolly Varden smolts in far southeastern Alaska. J. Fish. Res. Bd. Canada 27:991-1004.

Table 4. Percent of wetted perimeter added with regulated discharge estimated from photo measurement -- Flathead River, 1979

	WIDTH OF WETTED SURFACE - Site 1 (low flow photo 21)		
Regulated flows	3,110 cfs	5,216 cfs	8,770 cfs
Image width (mm)	28 mm	37 mm	38 mm
% increase in wetted width		32 %	36 %
	WIDTH OF WETTED SURFACE - Site 2 (low flow photo 57)		
Regulated flows	3,110 cfs	5,216 cfs	8,770 cfs
Image width (mm)	42 mm	49 mm	59 mm
% increase in wetted width		17 %	40 %

Westslope cutthroat adults start their spawning migration from the lake in late March and April since Hungry Horse Dam was built and early movers spend a month or more near Kalispell. We hypothesize that 40°F reservoir discharge waters cause cutthroat trout to ascend into the river and then their movements alternately encouraged and interrupted by fluctuations in temperature and flows. We have no evidence that such cutthroat migration delays cause decreased egg furtility. We do know warmer temperatures increase the rate for egg development and eggs over-ripen when trout are held too long where they can not spawn. We hope to explore this aspect; however, it does require a sacrifice of numerous trout. Reservoir discharges impact macroinvertebrates and must reduce available food for migrating fish.

Emigrating Age II+ cutthroat smolts leave tributary streams in late July through September and spend weeks before arriving at the lake. They are likely not impacted by either flows or modified temperatures from reservoir flows, but again they feed heavily on macroinvertebrates. Impacted populations of food insects must limit availability to smolts.

Mountain whitefish migrate through or into the main river to feed and spawn. Little is known of their life history in the main river except they are both resident and migratory fish in this section. They are dependent on the same macroinvertebrate populations as the trout and probably offer heavy competition to the trout for feed. We estimate that 60 percent, or more, of the biomass in the river is whitefish at any one time. The combination of reduced macroinvertebrates and heavy competition with whitefish is likely an added impact on cutthroat adults and smolts.

The major spawning habitat for kokanee salmon is in the main river below the South Fork confluence. We have referred to the harvest of kokanee from the main river on Page three (kokanee in the river) and (kokanee in the lake) and in Table 3. We would guess that in a good year there could be 500,000 spawning adults enter the Flathead River. Perhaps ten percent occur as the early sun and migrate into McDonald Creek at West Glacier. An estimated ten percent spawn in the Whitefish and Stillwater Rivers leaving 400,000 to spawn in the main river. Flow fluctuations impact this main river run during spawning and incubation and eggs are exposed to below zero air temperatures and dessication. There is also the possibility of fry being stranded in the gravels as low flow discharges during April and early May likely prevent access to the water because the gravel redds are above the river flow elevations.

A kokanee study on Meadow Creek, a tributary to Kootenai Lakes, B.C., mortality of egg to fry stage was about 80 percent under stable flow conditions. Under the past reservoir discharge patterns from Hungry Horse Dam we believe mortality from eggs to fry may average 90 percent and range from 70 percent to 98 percent in the main river. In years similar to the fall of 1978 and 1976, we believe egg mortality exceeded 95 percent in the main river.

Our data on yearly production, harvest, and successful fry emergence is admittedly meager and preliminary. Attempts to detect correlation between reservoir discharge patterns and large populations of adults four years later using impact criteria as we now view them, defies logic and is dependent on speculative analyses.

here are a few observations which do establish patterns. One is that poor year's of fishing occur when the average individual size exceeds 13.0 inches total length or that low density populations in the lake cause growth to Age III to exceed 13 inches. A second observation is that in poor years there appears to be a rather constant but low recruitment. The reproduction from McDonald Creek is relatively constant and correlates with the observations that flow, temperature and habitat are really uniform year-to-year.

In regards to economic analysis with various power and regulation alternatives, it appears we can make a reasonable assessment of the difference between existing condition and estimated benefits with reregulation. The only real difference on the aquatic environment between rewinding generators, an additional powerhouse with reregulation, and the combination of rewind and additional powerhouse is the greater number of days, of more than three or five consecutive days without pattern of not generating on weekends.

Water discharge conditions for water year 1972 (October 1971 - September 1972) and angler's success in the lake fishery was 9.12 salmon per trip. Reservoir discharge was on full generation except for five days after October 12 and full generation 26 days in November. Full generation occurred 26 days in December. January was full generation except for two days. February was off 16 days and on 12 days. March was off one day with the last half of March and 29 days in April at full generation, as were the first eight days of May. In summary, flows were high during most spawning, there were no periods exceeding three days when discharge was dropped to minimum and discharges were high during fry emergence of March, April and May.

These conditions provided a good average spawning run in late 1975. This year-class was worth a salmon harvest yielding 634,800 FSU. These flows should have fostered a good total food supply of macroinvertebrates and periphyton but probably impacted an unknown wuantity of these insect species which key on cold (33° to 34°F) for certain instar moltings.

Recent years that produced notably poor late runs were spawning years 1972-72 and 1974-75. Water discharges were average or somewhat less and discharges during spawning appeared to be relatively good. River temperatures were considerably colder than average during December and January when there was no generation discharge for the last half of December and off continuously about ten days at intervals in January. The most serious impact may have been the long periods of no discharge for 16 consecutive days in March, 15 consecutive days in April and 10 consecutive days in early May. These low flows in March and April may have stranded emergingfry and alevins in redds above the river level. Many redds had already been impaired by dessication and exposure during the 17 days below zero in December and January. The 1974-75 year-class was an average water year but generators were almost completely off during late April and early May for fry emergence. It was extremely cold in January and February on redds spawned high due to full generation during mid-October and November.

BENEFITS WITH AND WITHOUT PROJECT

Status Quo

The present dam and generator capacity of 328 megawatts has modified the ecology of the stream from the historical role the stream played before Hungry Horse Dam was built. Kokanee salmon spawned primarily on Flathead Lake shores and in McDonald Creek before 1954 dur to the critical stream temperatures of 37°F causing mortality on kokanee eggs in their first month of embryomic development. Following 1954 increasingly larger segments of the total population successfully spawned in the main Flathead as the hypolimnial reservoir discharge of 40°F water provided time for embryos to develop past the critical temperature sensitive stage to where they could withstand water temperatures of 32°F to 37°F of flows from the unregulated stream tributaries. In this regard, the existing plan and operation enhanced the total kokanee population as much as twice that of lakeshore spawners.

The construction of Hungry Horse Dam likely had an adverse effect on Flathead Lakeshore spawners by providing guaranteed storage to Montana Power to fill Flathead Lake to full pool (2,893 feet MSL) allowing additional lake drawdown and also delayed time of full drawdown. This had been further complicated and impacted by a Corps of Engineers, Montana Power and Flathead Lakers Agreement to delay reaching full pool until June 15 to allow subsoil drainage of agriculture land at the head of the lake. We believe the current operation of Hungry Horse Dam varies impact on the total kokanee population of the lake from 100 percent in a good year to 33 percent of the population by damage to the main river spawning success. This assumption is based on angler success in the lake and the observation that McDonald Creek spawning success is relatively constant.

Existing generation with reregulation

There should be the greatest biological benefit to the main river with this alternative for the following reasons.

1. Reregulation will not require more water to be discharged each day of full generation.
2. There will be fewer days between October 1 and May 1 in which the main river will be reduced to North and Middle Fork flows.
3. There will be less probability of three or more consecutive days of "no generation discharge."
4. Vast areas of kokanee spawning habitat no longer dewatered each night will be added.

Most benefits will accrue five out of seven days throughout the spawning and incubation. One condition should be avoided; full generation discharge and maximum rereg discharge should not be for more than eight (day) hours any day and occur mostly from 7 a.m. to 5 p.m. Full discharge at night during October and November would still cause eggs to be deposited at high bank elevations that would be out of the water a large part of the time of the incubation and emergence year. This alternative should provide better than average year for salmon reproduction which should yield more than 634,800 FSU for salmon (Table 5).

Existing with rewind and reregulation dam

Average discharge during days of generation will be slightly higher. Eggs will be deposited at slightly higher elevations and there will be a few more periods of three or more days in succession when there will be no discharge. This condition might reduce the total FSU to 600,000 or about a five percent reproduction.

Existing with power at outlet works and reregulation

The average and maximum discharge will be only slightly higher than Existing with Rewind. The number of consecutive days without discharge would be increased slightly also. We believe the FSU prediction would still be about 600,000. Our main concern with this alternative is that once the added generators and powerhouse are on line, the existing generators will require rewinding as a maintenance necessity, due to insulation aging, deterioration, and resulting reduced efficiency. At this point, anticipated power needs would likely result in rewinding existing generators to 383 and impacts to the fishery at that would be the same as under the following alternative.

Rewind to 383 megawatts plus power at outlet of 55 megawatts and reregulation

This alternative would require an additional 153,000 acre-feet of water for 20 days of discharge every four weeks. For three months it would take approximately 0.5 million acre-feet of 18 percent of the average annual discharge. It appears existing storage and generating capacity necessitate about two of the nine months with no generation between September and May. This means 22 percent of that time added to 18 percent could bring the "off generation" time to over three months of that fall-winter-spring period. We would expect the total FSU value for salmon to be reduced by 50 percent or 317,000 FSU.

Table 5. Fisherman Satisfaction Units (FSU) expected for salmon under variables*

Variables	FSU expected	FSU gained or lost on good year
Existing	634,800*	-----
Existing + Rereg	793,500	+ 158,700
Rewind + Rereg	753,825	+ 119,025
Existing + powerhouse + Rereg	643,920	+ 9,120
Rewind + powerhouse + Rereg	317,400	- 317,400

* 634,800 is FSU on good years which have occurred about five out of nine years (1969-1978). Four out of nine years expected FSU estimated at 211,388 or about 1/3 of an existing good year.

Local fishermen indicate that a trip would be worth repeating if FSU = 2.0. Several of our state waters have gone from a ten-fish limit to two-fish and some for catch and release only without substantially reducing the fishing effort.

CONCLUSIONS

There is not sufficient data to speculate on the impact of various power alternatives on Dolly Varden, cutthroat, or mountain whitefish. Macroinvertebrate studies and mountain whitefish spawning habitat and success would have to be quantified first. We will assume impacts under various alternatives are similar for these species.

1. The very preliminary analysis would lead us to estimate that installation of the rereg without added power would increase the average FSU for salmon by 25 percent or 158,700 units for a total of 793,500.

2. Benefits from reregulation plus rewinding existing generators would not alter benefits noted in #1 by adding 119,025 or 753,825 total FSU.

3. Benefits from added power at the outlet and reregulation would probably decrease the added FSU by one-quarter of 158,700 minus 39,675 FSU equalling 753,825 FSU.

4. Benefits from rewind plus power and outlet and reregulation are estimated to be provided an FSU comparable to 50 percent of the 1975 census evaluation or about 317,400 FSU. This is due to the 18 percent added days of no generation during incubation.

Sincerely,

Thomas R.Hay
Regional Supervisor

By:__________________
Robert E. Schumacher
Regional Fisheries Manager

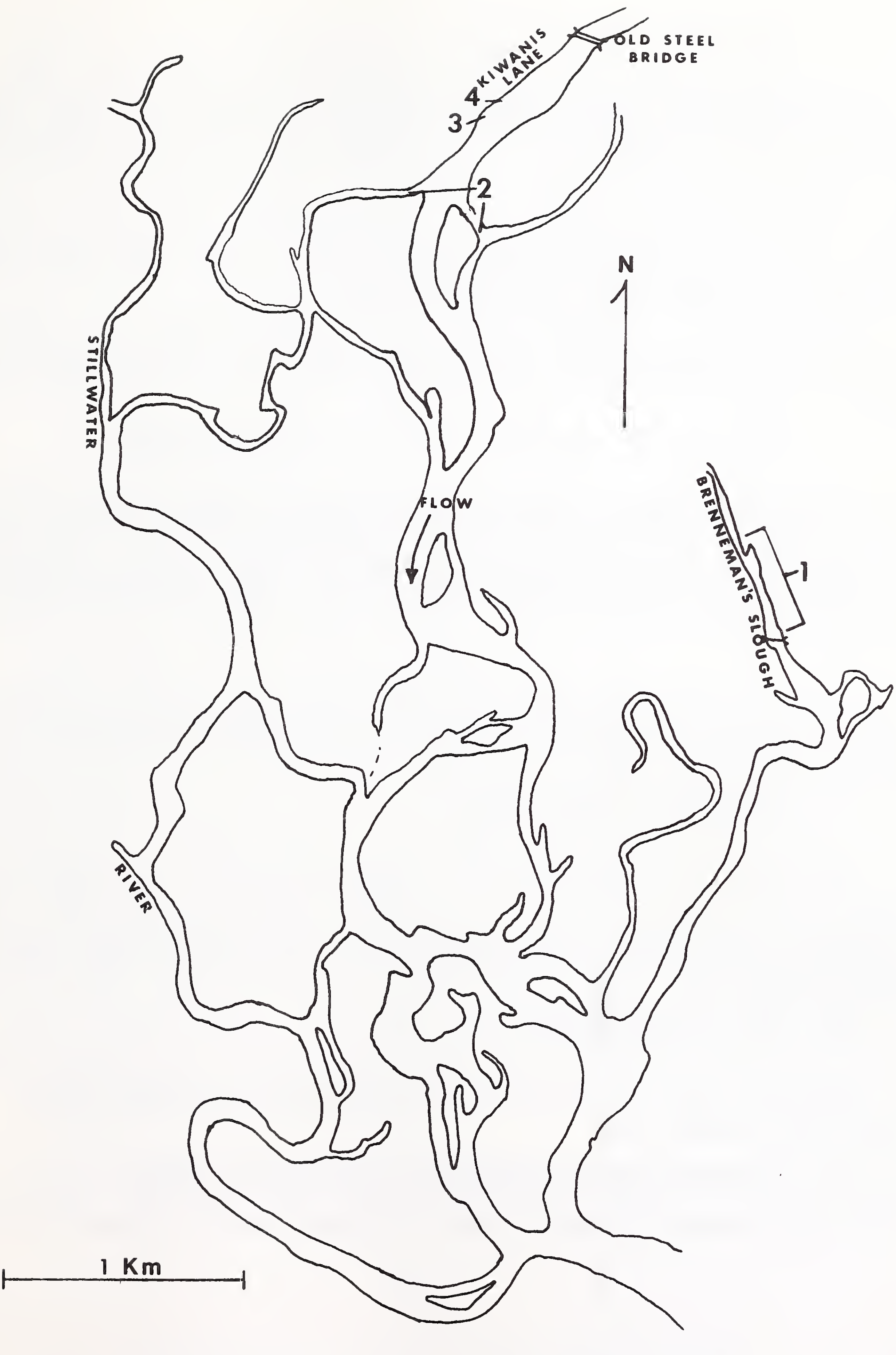
TRH:RES:ns

References: Hanzel, Delano A. 1977. Angler pressure and game fish harvest estimates for 1975 in the Flathead River system above Flathead Lake. Fisheries Investigational Report. Mont. Dept. Fish and Game. 23pp.

Robbins, Otis, Jr. 1966. Flathead Lake (Montana) Fisheries Investigation 1961-64. Technical Paper #4. Bureau Sport Fish and Wildl. 26pp.

APPENDIX B

Observed and potential kokanee spawning areas in the main stem Flathead River from its confluence with the Stillwater River to its confluence with the South Fork Flathead River.



Kokanee spawning areas main stem Flathead River

1. Brenneman's Slouth (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 R21W T28N 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. On November 8, 1979, there were an estimated 200 redds in this area. On December 28, 1979, there were 400 to 500 redds present. with many late spawners still working the area.

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. One redd was seen in this area.

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. One redd was seen in the area on November 27, 1979.

The east channel also contains a number of pockets of spawning gravel, but only 10 percent of it remains wet during low flow. On November 27, 1979, two redds were found in the back of the channel and two more were found where it returns to the main river.

3. Kiwanis Lane Log Jam (RK42.0)

Just downstream from Kiwanis Lane along the west bank is a large log jam. Just upstream from this at the base of a steep cut bank is a small amount of spawning gravel consisting of some good gravel mixed with larger cobble. On November 27, 1979, there were seven redds here. During low flow approximately one-half the usable gravel was dry and most of these redds were dry or only partially wetted.

4. Kiwanis Lane (RK42.0)

Along the west bank below the Kiwanis Lane picnic area, two redds were found on November 27, 1979. These were both located above the low water level. Substrate was considered poor.

5. Gravel Bar Between Steel Bridge and Highway 2 (RK42.6)

A large expanse of spawning gravel is located along the southeast end of this bar. During low flow, approximately 80 percent of this gravel is dry. Approximately 20 percent of the spawning gravels are in some small channels with flowing water and would probably be good incubation habitat. During high flow, the velocity may be too fast over most of this area to be good spawning habitat. No redds were found in this area in 1979.

6. U.S. Highway 2 Bridge (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. Approximately 60 redds were present when checked on November 26, 1979 during low flow. Sixty to 70 percent of the redds were completely wet; 20 to 30 percent were located near the water's edge and 10 percent were dry. More redds were dewatered after extensive periods of low flow.

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. No redds were seen in this area during 1979.

8. East Channel below Lybeck Dike (RK46.7)

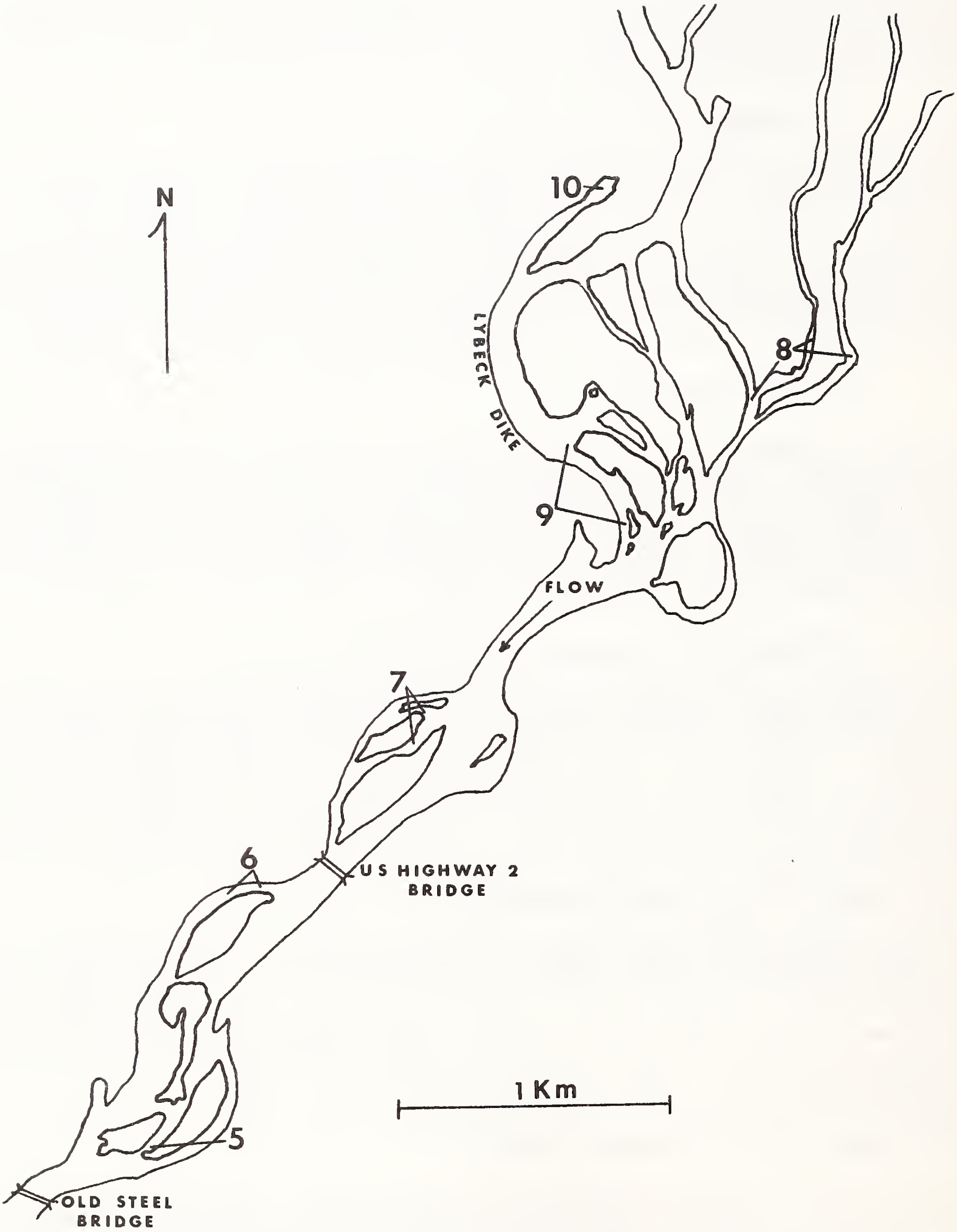
At the big bend just downstream from Reserve Drive along the west side of Section 35 T21W T29N, a channel branches off the east side. Approximately 1km up this channel are two small sloughs that extend back through the islands to the east. Each of these sloughs have some patches of spawning gravel in them. There is also some spawning gravel where these two sloughs enter the east channel. All or most of this gravel is dry during low flow. No redds were seen here during 1979.

9. Lybeck Dike - South End (RK47.3)

Directly across from the lower end of Lybeck Dike at Reserve Drive, the river splits into a number of small channels around a series of islands. There is a large area of small, loose gravel in this area. Water depths range from 30 to 60cm with mild velocities during low discharge. Good spawning habitat is available at low flows. During periods of high flow velocities would probably be too fast for a good spawning site. No redds were found here in 1979.

10. 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



Kokanee spawning areas main stem Flathead River

is dry during low discharge. Three redds were seen on November 13, 1979 and 20 to 25 on November 16, 1979. Approximately 50 percent of these redds were dry at low flow. Much of the substrate is silt-covered.

11. Spring Area Above Reserve Drive (Fairview Area) (RK49.4)

Approximately 1km 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. Approximately 110 redds were seen in this area on November 29, 1979. Of these redds, 10 to 15 percent were dry during low flow.

There is also good spawning gravel in some of the other channels and backwaters in this area. Eight to 10 redds were found in one backwater near the outflow of the above metnioned spring slough. These were all dewatered during low flow and none of it contained redds. Most of this gravel area would probably have current velocities too fast for spawning during high discharge.

12. East Fairview Area (near old shack) (RK49.9)

One km up the above mentioned east channel is a large spawning area. This area is in the northwest corner of Section 30 R20W T29N. Just downstream of where this channel makes a bend to the north there is a large, deep hole with a log jam along the east bank. Just upstream from this log jam above a cut bank on the east side is an old shack. On November 27, 1979, there was an estimated 200 to 500 redds in this deep hole. They extended from the shallow gravel bar along the west bank to the bottom of the hole at depths of up to 6m. During low flow, 5 to 10 percent of the redds along the west bank were dewatered. There were an additional 9 to 10 redds along the west shore directly below the old shack on November 27, 1979.

13. East Fairview Area (riffle above the shack) (RK50.4)

Approximately 0.3km above the previously mentioned hole, at the head end of an island is a large riffle across the channel. There is good gravel throughout this riffle but the water velocity is probably too fast for spawning. Directly upstream from this riffle there is a large expanse of gravel. It is slightly larger than most spawning gravel but is loose and could be worked. Part of this area should remain watered even during low flows. No redds were found in this area during 1979.

14. Mouth Gooderich Bayou (RK50.5)

Gooderich Bayou enters the westernmost channel above Reserve Drive in the southeast corner of Section 23, R20W R29N. 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. Three redds were present below the steep cut west bank on November 7, 1979. On November 28, 1979, 10 redds were found scattered along the gravel area. All of these redds remained wetted during low flow.

15. Pumphouse hole at Head of Easternmost Channel Above Reserve (RK52.2)

Where the east and middle channels of the splits above Reserve Drive diverge south of center in Section 18 R20W T29N, another small channel enters from the east. Near the mouth of this small channel along the east riverbank there is a large pool with a pumphouse on the south side. The pool contains good spawning gravel and had 50 to 60 redds in it on November 27, 1979. Some of these redds would be dewatered at low flow.

16. Small East Channel Between Reserve and Pressentine (RK52.2)

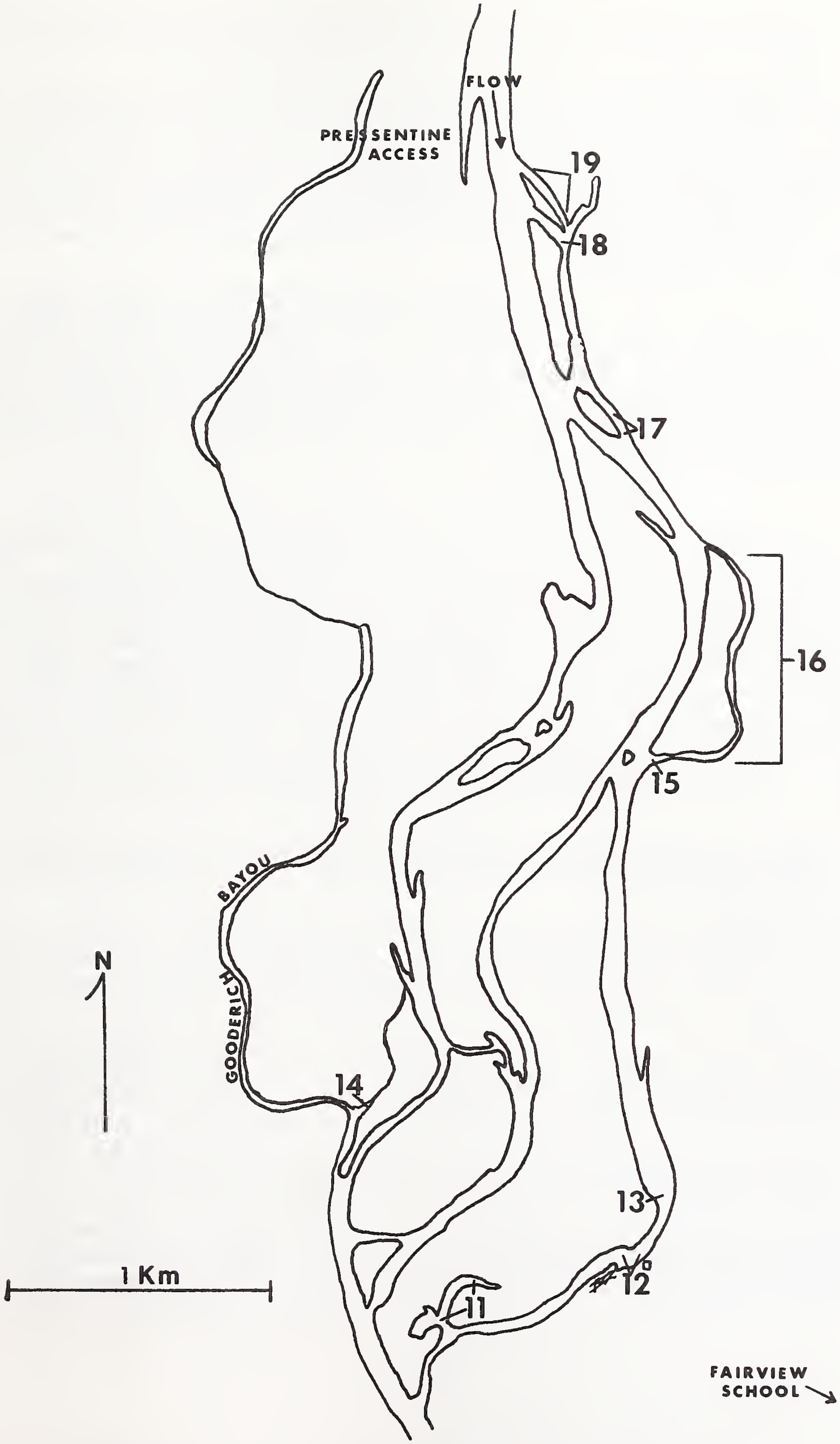
The small east channel mentioned above leaves the main channel approximately 2.4km below Pressentine access on a bend with a high bank on the east side. There is a house visible on top of this high bank. The channel runs for approximately 1km to the above mentioned pumphouse. There are stretches of spawning gravel along the center the full length of this channel. Most of the spawning gravel should remain wetted at low flow. No redds were found here in 1979.

17. Lower Pressentine Area (below the island) (RK54.4)

At the first major channel split below Pressentine access in the northwest corner of Section 18, R20W T29N, there is a small island along the east side. A large spawning area is located in the backwater east of this island. This area has good spawning gravel interspersed with some fines. Water velocities are barely detectable at high flow. During low flow, most of this area is dry. Forty to 50 redds were present in this area on November 6, 1979 and approximately 100 on November 28, 1979. Most of the redds were dewatered at low flow.

18. Upper Pressentine 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 0.8km 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 pond 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. Redds were first seen in this area on November 7, 1979, and an estimated 50 to 100 were present on November 28, 1979. These redds extended from water's edge down to 2 to 3m in depth. During low flow, nearly all of the good spawning gravel in this area is dewatered.



Kokanee spawning areas main stem Flathead River

19. Highwater Channel Across From Pressentine (RK55.5)

A small highwater channel is located on the east side of the main river channel approximately 200m upstream from the large island mentioned above. It converges with the east channel that runs behind this island. The entire channel has good spawning gravel and during high flows, water velocities are excellent for spawning. Fifty redds were present in this area on November 7, 1979 and approximately 200 on November 28, 1979. When river discharge dropped to low flow, this area was completely dewatered.

20. Small West Side Channels Between Pressentine and Buck's (RK57.9)

Between Pressentine access and Buck's Garden in the north center of Section 6 R20W T29N, there is a series of small side channels on the west side of the river. Several patches of good gravel are located in these channels. Most of the spawning gravel is deposited in shallow flats and would be dry during low flow. No redds were found in this area during 1979.

21. Convergence of Channels Along South Side of Buck's Island (RK59.5)

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. On November 8, 1979, there were 150 to 200 redds on this flat and extending part way up the western channel. There were 200 to 250 redds in this area on November 29, 1979, with more of them scattered along the west channel up to where the east channel diverges. There were also approximately 30 redds along the cut west bank of the east channel just above the convergence. During low flows this area is dewatered.

22. Buck's Gardens Just Upstream From Divergence of Channels and From Pumphouse (RK59.8)

One-half 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. There were 40 to 50 redds here when checked on both November 8 and November 29, 1979. The current velocity is low here during high flow because of a small rock dam that increases head for the pump. This area is dewatered during low flow although there is some ground water coming in along the west bank. This ground water may be enough to maintain a few redds during a moderate winter.

23. 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. There were 35 to 45 redds on this flat on November 8, 1979, and approximately 150 on November 29, 1979.

This area has moderately fast current velcoties during high flow but is completely dewatered at low flow.

24. 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 high flow, but is dry during low flow. No redds were seen in this area in 1979.

25. West Side of Eleanor Island (RK60.8).

Approximately one-half the distance up the west channel around Eleanor Island along the east bank is an area of spawning gravel. This area has good velocities at high flow, but is dewatered at low flow. No redds were seen here in 1979.

26. Kokanee Bend -- Large Bend Below Access (RK60.8)

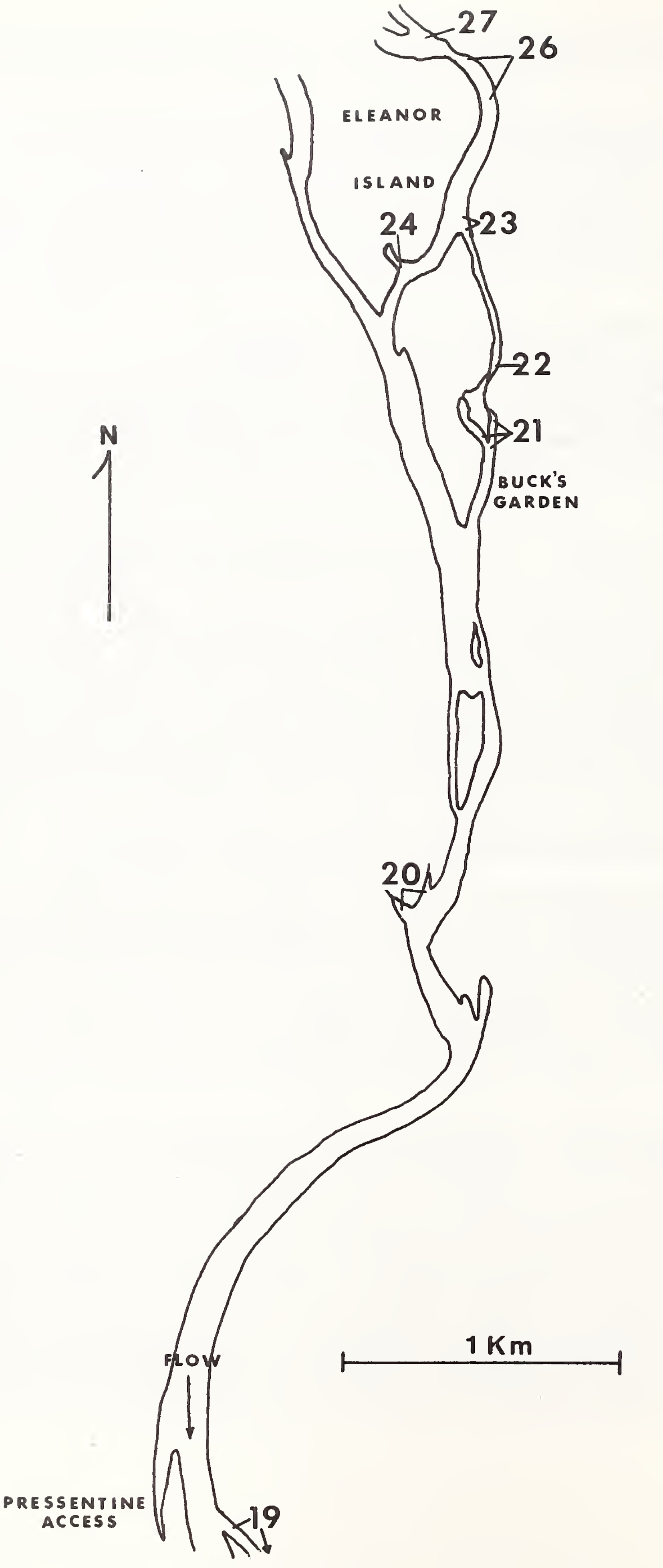
Between Buck's Island and Kokanee Bend access, the east channel makes a big bend with a steep cut east bank. From the large rock field at the lower end of the bend up part way around the bend, is good gravel along the east bank. Seventy-five to 100 redds were present here on October 23, 1979 and 200 to 300 on November 23, 1979. 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 dewatered at low flow, but there is ground water coming in along the bank that can maintain some eggs.

27. Kokanee Bend Backwater at End of Road (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 were 20 redds in this backwater on October 23, 1979 and 25 on November 23, 1979. Water backs in here from the river during periods of high flow, i.e., there is no current over the redds. This area is dewatered at low flow.

28. Kokanee Bend -- Lower End of Survey Site and 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. On November 23, 1979, there were 25 redds upstream of the divergence of this side channel and a few more along the east bank of the side channel just below the riffle at the head end. The redds were in the main river channel, but were in a back eddy area where velocities were moderate. All of the upper gravel area is dewatered at low



Kokanee spawning areas main stem Flathead River

flow as well as most of the side channel. There is a little flow through the center of this side channel at low flow which could maintain some redds.

29. Kokanee Bend Backwater Along East Bank at Head of Eleanor Island (RK61.8)

Along the east bank just downstream of where the river splits around Eleanor Island and upstream of the northernmost Kokanee Bend access road, a backwater extends north from the east bank. Approximately 100 meters upstream of the mouth of this backwater, the bottom cobble decreases in size and there are several pockets of good spawning gravel. There is some flow through this channel at high river flow, but the area is dewatered at low flow. No redds were seen in this area in 1979.

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

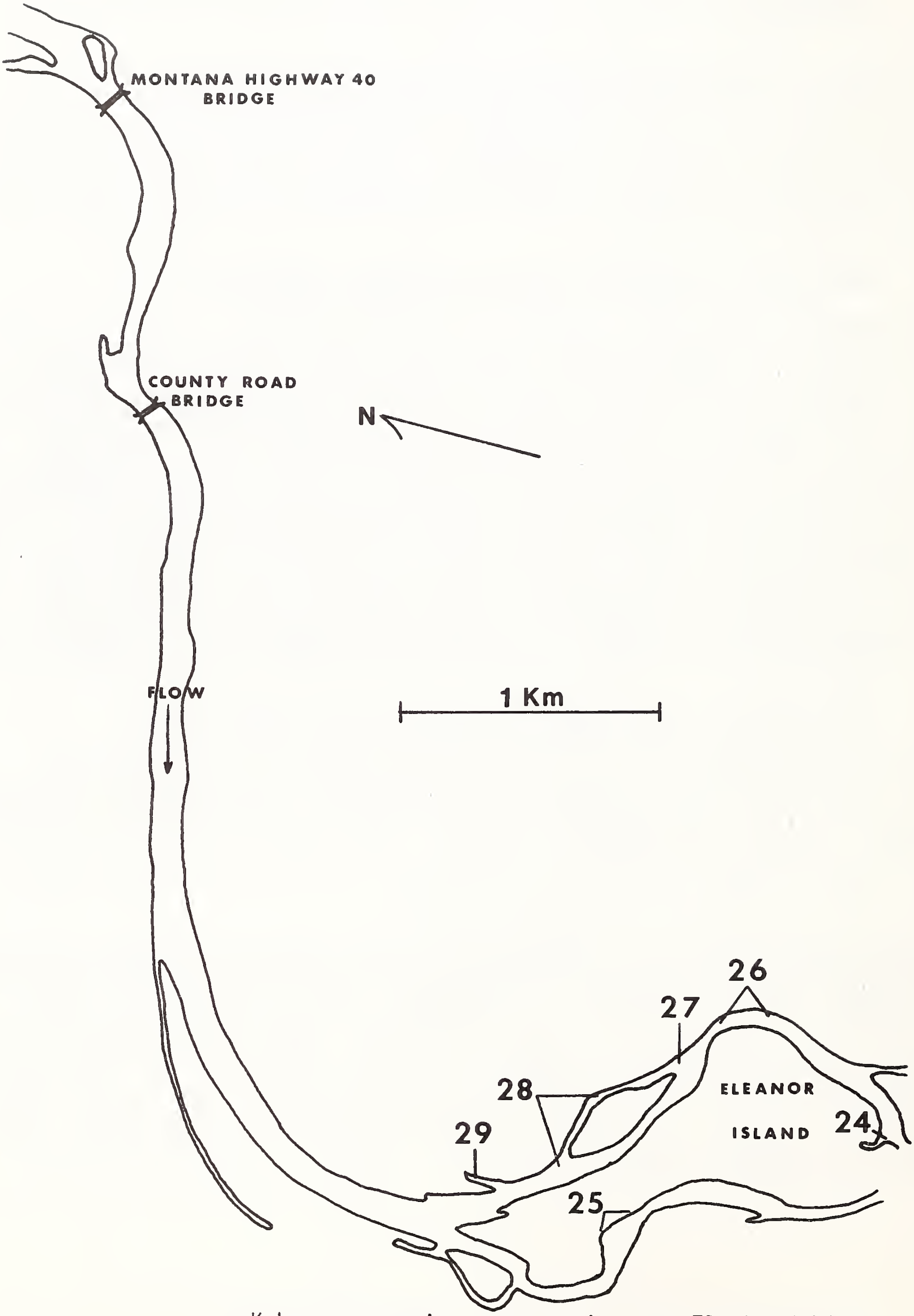
Approximately 0.8km above the Montana Highway 40 Bridge at Columbia Falls is a large gravel bar along the east side of the river. During high flow, water runs behind it creating an island. There is some good gravel along the outside of the point at the downstream end of this bar just above the steep cut east bank. This gravel is at the edge of the high water line. There were approximately 10 redds along this bar on November 9, 1979 and 25 on November 30, 1979. This area is in the main channel where the current is fast, but most of the redds were along the edge where the current broke on the gravel bar. This area is dewatered at low flow. There is also a large area of good gravel at the lower end of the channel that runs behind this gravel bar and another large area of gravel at the head of this channel. Both of these areas have good water velocities for spawning at high flow, but would be dewatered at low flows. Some water is trapped in the upper area. No redds were found in these areas in 1979.

31. Area Between Columbia Falls Gravel Bar and Slough (RK67.3)

Just upstream from the gravel bar mentioned above the along the east shoreline is a large area of marginal spawning gravel. The current is moderate over most of this area during high and medium flows, but the area is dewatered at low flow. No redds were present in 1979.

32. Mouth Columbia Falls Slough (RK67.6)

A spring slough converges with the main river on the east side approximately 200m upstream from the above mentioned gravel bar. The mouth of this slough is in the northeast corner of Section 9, R20 T30N. There is some good gravel at the mouth of this slough along the south shoreline. There were approximately 50 redds in this area on December 1, 1979 near several downed trees. 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. Most of this area is dewatered at low flow, although the flow from the slough does wet some of the gravel.



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33. Upper Columbia Falls Slough (RK68.5)

The slough mentioned above extends approximately 1km 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.

34. Head of Columbia Falls Shocking Section (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 deep hole by a boulder along the south bank. On December 1, 1979, there were approximately 100 redds in this hole. Water velocities are slow, but most redds are watered even during low flow periods.

35. Upper End of East Channel Above Columbia Falls Shocking Section (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. There were approximately 100 redds in this area on December 1, 1979. 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 dwatered.

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

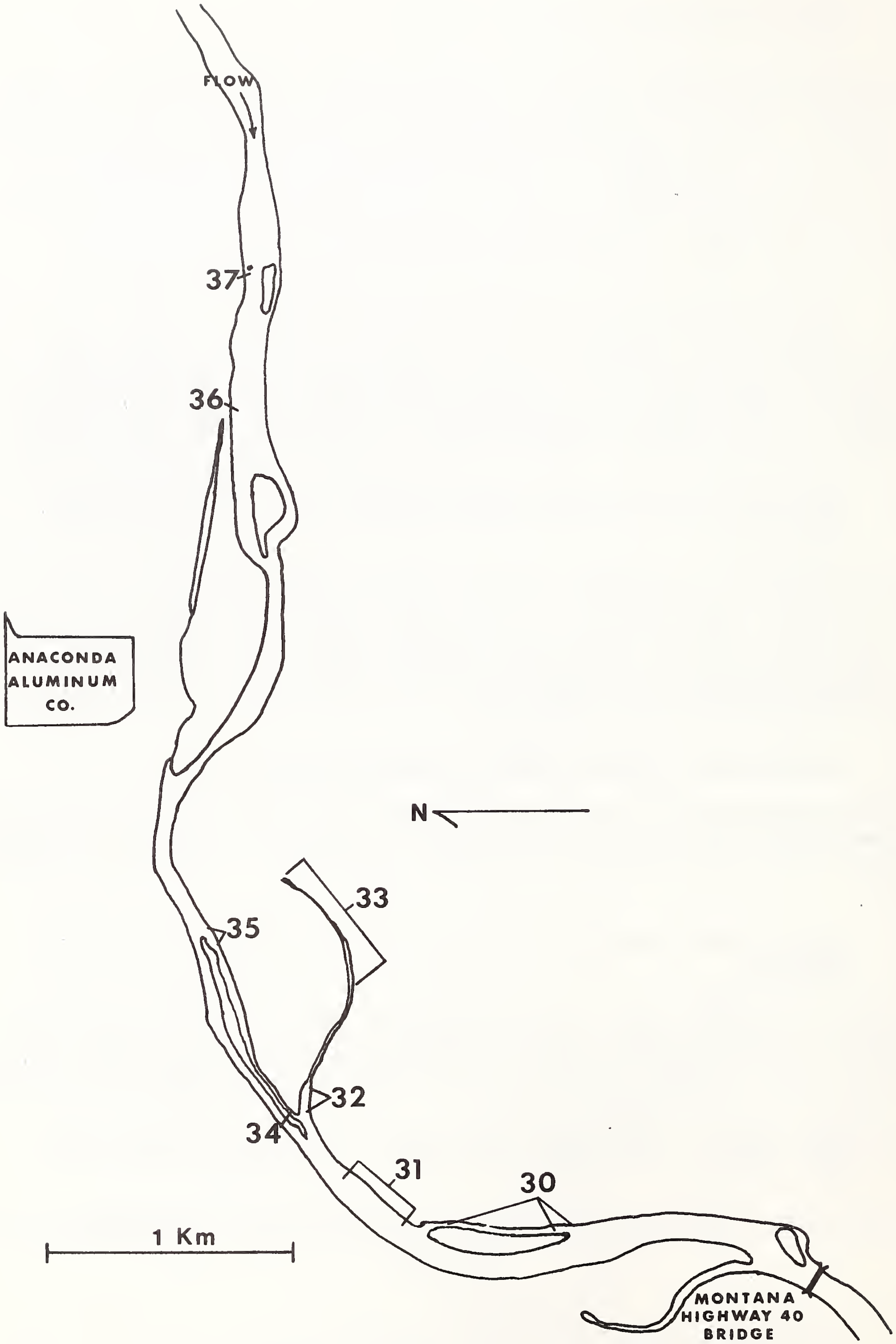
At the upstream end of the gravel bar below the Anaconda Aluminum Company is a large gravel flat along the north bank. This area is in a large back eddy with little current over it and is dewatered at low flow. No redds were present in 1979.

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

A large boulder lies near the north bank approximately 200m upstream of the Anaconda Bar and just blow the Cedar Creek overflow outlet. A small pocket of good gravel has collected behind this rock. This area has moderate velocities at high flow, but is mostly dewatered at low flow. No redds were present in 1979.

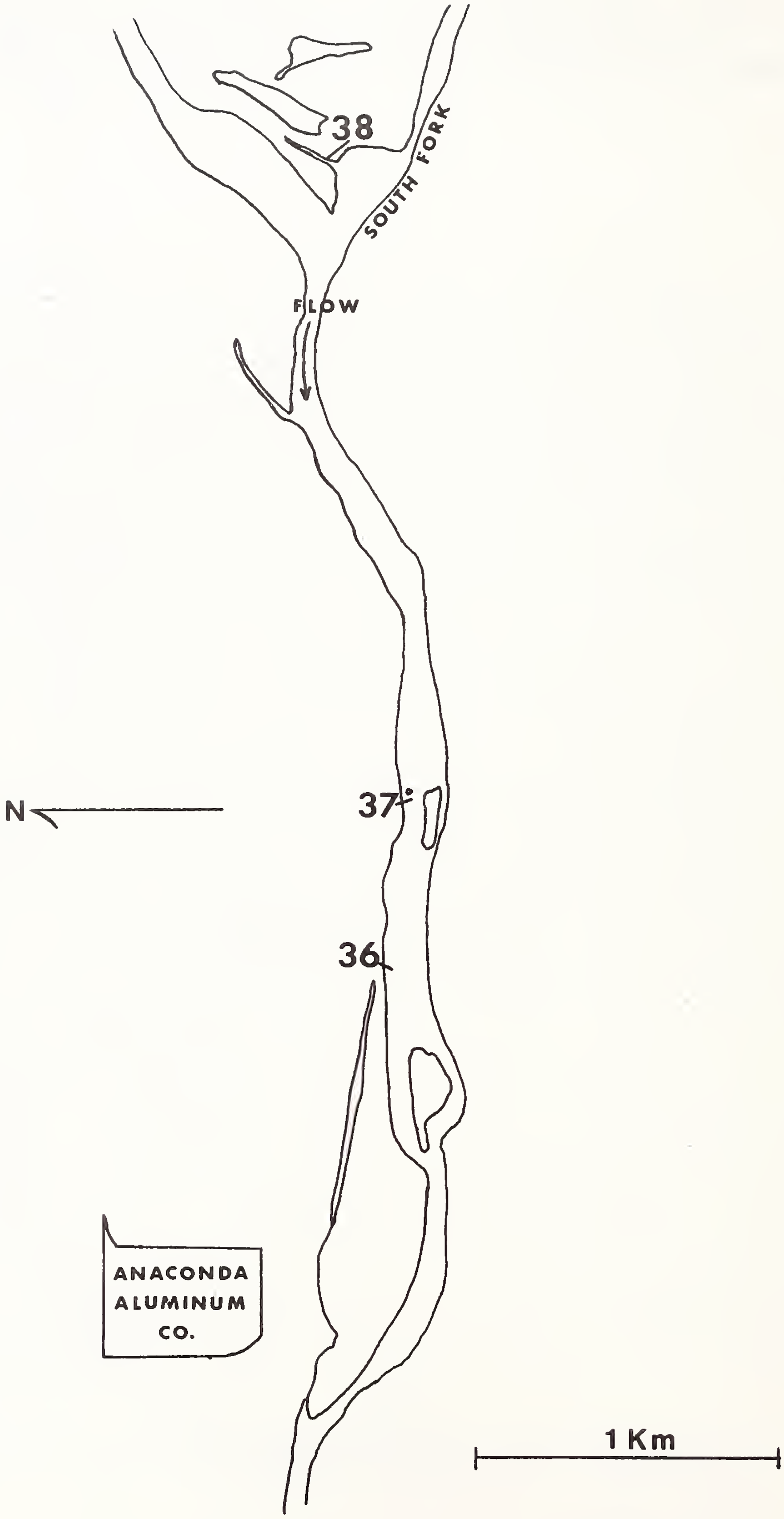
38. Side Channel From Monegan Hole Toward Flathead River Ranch Boat Ramp (RK73.7)

A small side channel extends upstream to the northeast from Monegan's Hole



Kokanee spawning areas main stem Flathead River

(mouth of the South Fork) towards the Flathead River Ranch boat ramp along the south river bank. Some good gravel is present along the center of this channel. Most of this is backup water from the river so there is little current. This area is dewatered at low flow. No redds were present in 1979.



Kokanee spawning areas main stem Flathead River

APPENDIX C

Fawn Creek - September, 1979

EPHEMEROPTERA
- Siphlonuridae
  - Ameletus similor
  - Small Siphlonuridae
- Baetidae
  - Baetis tricaudatus
  - Baetis bicaudatus
- Heptageniidae
  - Rhithrogena robusta
  - Rhithrogena hageni
  - Epeorus grandis
  - Epeorus deceptivus
  - Cinygmula sp. C
  - Small Heptageniidae
- Ephemerellidae
  - Ephemerella doddsi
  - Small Ephemerellidae

DIPTERA
- Tipulidae
  - Hexatoma sp.
  - Tipula sp.
- Chironomidae

PLECOPTERA
- Peltoperlidae
  - Yoroperla brevis
- Nemouridae
  - Zapada columbiana
  - Zapada cinctipes
  - Small Nemouridae
- Leuctridae
  - Despaxia augusta
  - Small Leuctridae
- Capniidae
  - Small Capniidae
- Perlidae
  - Doroneuria theodora
- Perlodidae
  - Megarcys watertoni
  - Setvena bradleyi
  - Small Perlodidae
- Chloroperlidae
  - Sweltsa sp.
  - Kathroperla perdita
  - Small Chloroperlidae

LEPIDOPTERA

TRICHOPTERA
- Hydropsychidae
  - Parapsyche elsis
  - Small Hydropsychidae
- Rhyacophilidae
  - Rhyacophila vepulsa
  - Rhyacophila vaccua
- Glossosomatidae
  - Glossosoma sp.
- Limnephilidae
  - Ecclisomyia sp.

OTHER INVERTEBRATES
- Turbellaria
- Nematoda
- Oligochaeta
  - Lumbriculidae
- Gastropoda
  - Gyraulus sp.

APPENDIX D

Mean number of individuals per meter^2. Mean = $\bar{x}$. Standard deviation = (s.d.).

July, 1979

	Bible Camp Kick(x=5) $\bar{x}$(s.d.)	Kokanee Bend Kick(x=8) $\bar{x}$(s.d.)
EPHEMEROPTERA		
Baetidae		
Baetis tricaudatus	688.2(612.0)	72.0(49.5)
Baetis bicaudatus	5.4(4.5)	0.3(1.2)
Baetis hageni	55.8(61.2)	10.2(12.9
Pseudocleon sp.	99.0(83.7)	41.7(21.9)
Heptageniidae		
Rhithrogena hageni	328.2(364.2)	90.9(38.7)
Epeorus albertae	78.0(31.5)	18.3(14.7)
Cinygmula sp.	45.6(39.3)	36.9(27.0)
Stenonoma sp.	0 (0)	0 (0)
Small Heptageniidae	0 (0)	9.3(12.3)
Ephemerellidae		
Ephemerella doddsi	36.0(24.6)	13.8(15.0)
Ephemerella inermis	0.6(1.5)	7.2(6.6)
Ephemerella tibialis	90.6(60.6)	12.3(10.8)
Ephemerella flavilinea	18.6(15.6)	6.9(5.7)
Ephemerella heterocaudata	0 (0)	1.2(1.5)
Leptophlebiidae		
Paraleptophlebia heteronea	4.2(5.1)	1.8(2.1)
PLECOPTERA		
Pteronarcidae		
Pteronarcella badia	49.8(57.3)	34.8(19.8)
Perlidae		
Classenia sabulosa	6.0(10.2)	2.1(3.6)
Hesperaperla pacifica	4.8(4.5)	2.1(5.1)

July, 1979 Cont.

	Bible Camp	Kokanee Bend
	Kick(x=5)	Kick(x=8)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Perlodidae		
Kogotus modestus	0.6(1.5)	0 (0)
Small Perlodidae	38.4(30.6)	83.7(106.2)
Chloroperlidae		
Suwallia sp.	62.4(40.5)	48.0(12.9)
Sweltsa coloradensis	0 (0)	0 (0)
Small Chloroperlidae	1.2(2.7)	0 (0)
Nemouridae		
Zapada columbiana	0 (0)	0 (0)
TRICHOPTERA		
Hydropsychidae		
Arctopsyche grandis	74.4(45.6)	0 (0)
Symphitopsyche oslari	82.2(62.4)	6.3(6.6)
Parapsyche elsis	0 (0)	0 (0)
Hydropsychidae pupae	4.8(7.5)	0 (0)
Rhyacophilidae		
Rhyacophila angelita	9.0(9.0)	3.0(1.2)
Rhyacophila vaccua	0.6(1.5)	0 (0)
Rhyacophila verrula	0 (0)	0 (0)
Small Rhyacophila sp.	0 (0)	0 (0)
Brachycentridae		
Brachycentrus americanus	9.0(7.5)	1.8(3.3)
COLEOPTERA		
Elmidae		
Optioservus quadrimaculatus	0.6(1.5)	0.3(1.2)

July, 1979 Cont.

	Bible Camp Kick(x=5) $\bar{x}$(s.d.)	Kokanee Bend Kick(x=8) $\bar{x}$(s.d.)
DIPTERA		
Deuterophlebiidae		
Deuterophlebia sp.	0 (0)	1.5(1.5)
Blephariceridae	0 (0)	0.9(2.1)
Tipulidae		
Hexatoma sp.	7.2(7.5)	0.9(2.1)
Tanyderidae		
Protanyderus sp.	0 (0)	1.5(2.4)
Simuliidae		
Simulium sp.	606.6(798.9)	135.3(218.7)
Chironomidae		
larvae	463.2(183.9)	326.7(213.9)
pupae	10.2(12.9)	6.3(6.0)
adults	0 (0)	3.9(5.1)
Athericidae		
Atherix variegata	0 (0)	0.3(1.2)
Empididae		
Chelifera sp.	1.2(1.8)	2.4(3.6)
Hemerodromia pupae	0.6(1.5)	1.2(2.1)
OTHER INVERTEBRATES		
Turbellaria	0 (0)	0 (0)
Nematoda	0 (0)	1.2(2.1)
Oligochaeta	1.2(1.8)	0.3(1.2)
Hydrocarina	8.4(14.1)	2.7(4.5)

August, 1979

	Bible Camp		Kokanee Bend	
	Kick(x=4)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{X}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
EPHEMEROPTERA				
Baetidae				
Baetis tricaudatus	238.5(345.3)	153.0(104.5)	234.9(130.2)	236.4(207.6)
Baetis bicaudatus	0 (0)	0 (0)	0 (0)	0 (0)
Baetis hageni	30.0(40.2)	0 (0)	2.1(4.5)	0 (0)
Pseudocleon sp.	3.9(5.7)	4.8(5.4)	0.9(1.5)	1.2(1.5)
Siphlonuridae				
Siphlonurus sp.	2.4(4.5)	1.2(2.7)	0 (0)	0 (0)
Ameletus connectus	1.5(3.0)	0 (0)	0 (0)	0 (0)
Ameletus oregonensis	2.4(4.5)	0 (0)	0 (0)	0 (0)
Heptageniidae				
Rhithrogena hageni	271.5(388.5)	189.6(55.8)	121.5(57.9)	73.2(48.9)
Rhithrogena robusta	7.5(15.0)	2.4(3.9)	0 (0)	0.6(1.2)
Epeorus albertae	1.5(1.8)	0 (0)	2.4(2.7)	4.8(3.3)
Cinygmula sp.	0 (0)	0 (0)	2.1(4.5)	1.2(2.7)
Small Heptageniidae	519.9(691.8)	290.4(305.4)	40.5(43.5)	58.5(57.0)
Ephemerellidae				
Ephemerella doddsi	36.9(43.2)	49.2(19.8)	31.5(43.8)	22.2(21.3)
Ephemerella inermis	2.4(4.5)	1.2(2.7)	0 (0)	1.2(1.5)
Ephemerella tibialis	11.4(9.0)	7.2(8.1)	40.5(37.5)	34.8(22.2)
Ephemerella hystrix	0.9(1.5)	0.6(1.5)	0 (0)	0 (0)
Ephemerella flavilinea	0 (0)	0 (0)	1.5(3.0)	3.0(3.0)
Leptophlebiidae				
Paraleptophlebia bicornuta	5.1(10.5)	0 (0)	0 (0)	0 (0)
Paraleptophlebia heteronea	0 (0)	2.4(5.4)	0 (0)	0.6(1.2)

August, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=4)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
PLECOPTERA				
Pteronarcidae				
Pteronarcys californica	0 (0)	0 (0)	0 (0)	0.6(1.2)
Pteronarcella badia	13.5(18.3)	7.8(6.6)	67.5(43.2)	21.6(14.7)
Perlidae				
Classenia sabulosa	14.1(22.5)	10.8(6.6)	8.1(10.8)	1.8(2.7)
Hesperaperla pacifica	5.1(6.3)	2.4(3.9)	1.5(1.8)	3.6(3.9)
Doroneuria theodora	0 (0)	0 (0)	0 (0)	0 (0)
Small Perlidae	0.9(1.5)	13.8(15.3)	2.1(2.7)	3.6(2.4)
Perlodidae				
Skwala parallela	0 (0)	0 (0)	3.9(5.7)	3.6(4.8)
Isogenoides colubrinus	7.5(15.0)	0.6(1.5)	4.5(7.2)	0 (0)
Small Perlodidae	20.1(21.0)	4.8(7.8)	13.5(9.9)	122.4(162.6)
Chloroperlidae				
Suwallia sp.	26.4(36.6)	3.6(4.8)	29.1(12.6)	7.2(33.0)
Sweltsa coloradensis	3.9(5.7)	0.6(1.5)	0.9(1.5)	1.8(1.5)
Small Chloroperlidae	1.5(3.0)	7.8(9.9)	8.1(10.8)	17.4(29.1)
Nemouridae				
Zapada cinctipes	1.5(3.0)	0.6(1.5)	0 (0)	0 (0)
Zapada columbiana	0 (0)	0 (0)	0 (0)	0 (0)
Capniidae				
Small Capniidae	51.9(55.5)	4.8(7.5)	4.5(5.1)	21.0(3.9)
TRICHOPTERA				
Hydropsychidae				
Arctopsyche grandis	34.5(37.2)	11.4(7.2)	17.1(7.8)	33.0(25.5)
Symphitopsyche oslari	47.4(43.2)	26.4(17.4)	4.5(3.9)	8.4(5.7)
Symphitopsyche cockerelli	142.5(115.2)	59.4(26.4)	11.1(22.5)	20.4(32.4)

August, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=4)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Small Hydropsychidae	44.4(86.4)	82.2(65.1)	13.5(23.1)	12.0(23.7)
Hydropsychid pupae	0 (0)	0 (0)	0.9(1.5)	0.6(1.2)
Rhyacophilidae				
Rhyacophila angelita	0.9(1.5)	0 (0)	0 (0)	3.0(2.1)
Rhyacophila verrula	0 (0)	0 (0)	0 (0)	0 (0)
Small Rhyacophila sp.	0 (0)	0.6(1.5)	0 (0)	0.6(1.2)
Glossosomatidae				
Glossosoma sp.	4.5(7.2)	6.6(9.9)	15.9(11.4)	31.2(25.2)
Brachycentridae				
Brachycentrus americanus	2.4(2.7)	0.6(1.5)	0 (0)	2.4(1.5)
Limnephilidae				
Neophylax rickeri	0 (0)	0 (0)	0 (0)	0.6(1.2)
DIPTERA				
Tipulidae				
Hexatoma sp.	6.0(4.2)	1.8(2.7)	0 (0)	0.6(1.2)
Tanyderidae				
Protanyderus sp.	0 (0)	0 (0)	2.1(4.5)	0 (0)
Simuliidae				
Simulium sp.	905.4(1638.9)	78.6(134.7)	461.1(318.9)	1003.2(1242.9)
Simulium arcticum pupae	9.9(19.5)	0.6(1.5)	0 (0)	0 (0)
Chironomidae				
larvae	58.5(48.0)	43.2(52.8)	94.5(102.3)	159.0(224.4)
pupae	0 (0)	0 (0)	0 (0)	0 (0)
adults	0 (0)	1.2(2.7)	0 (0)	0.6(1.2)
Athericidae				
Atherix variegata	3.0(2.4)	1.2(1.5)	6.0(6.9)	3.6(3.3)

August, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=4)	Circular(x=5)	Kick(x=4)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
OTHER INVERTEBRATES				
Turbellaria	7.5(15.0)	0.6(1.5)	0 (0)	0 (0)
Oligochaeta	0 (0)	0 (0)	0 (0)	0 (0)
Hydrocarina	0 (0)	0.6(1.5)	2.1(3.0)	0.6(1.2)

September, 1979

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=5)	Kick(x=4)	Circular(x=4)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
EPHEMEROPTERA				
Baetidae				
Baetis tricaudatus	172.8(88.8)	71.4(35.7)	169.8(95.4)	117.9(87.9)
Baetis bicaudatus	0 (0)	0 (0)	0 (0)	0 (0)
Baetis hageni	9.6(13.2)	28.2(58.2)	0 (0)	0 (0)
Pseudocleon sp.	24.0(29.4)	6.0(8.7)	5.4(10.5)	6.0(12.0)
Heptageniidae				
Rhithrogena hageni	1152.6(645.6)	262.2(113.4)	262.2(101.1)	243.0(133.8)
Rhithrogena robusta	4.8(10.8)	0 (0)	4.8(10.8)	0 (0)
Epeorus albertae	0 (0)	0 (0)	3.0(3.6)	7.5(11.4)
Epeorus sp.	0 (0)	0 (0)	0 (0)	0 (0)
Small Heptageniidae	216.0(161.1)	108.6(96.3)	93.6(149.7)	91.5(71.1)
Ephemerellidae				
Ephemerella doddsi	211.2(171.6)	25.8(15.9)	41.4(21.0)	54.9(44.7)
Ephemerella inermis	33.6(27.3)	8.4(10.2)	20.4(24.6)	18.0(36.0)
Ephemerella tibialis	0 (0)	0 (0)	9.0(3.6)	13.5(23.1)
Ephemerella spinifera	0 (0)	0 (0)	4.8(10.8)	0 (0)
Leptophlebiidae				
Paraleptophlebia heteronea	19.2(20.1)	3.0(3.0)	0 (0)	6.0(12.0)
PLECOPTERA				
Pteronarcidae				
Pteronarcys californica	1.2(1.5)	0 (0)	0.6(1.5)	0 (0)
Pteronarcella badia	67.2(46.2)	42.0(60.3)	180.0(117.3)	130.0(182.1)
Perlidae				
Classenia sabulosa	37.8(36.3)	7.8(6.3)	6.6(5.4)	12.9(12.9)
Hesperaperla pacifica	12.6(12.6)	1.2(2.7)	14.4(12.0)	1.5(3.0)
Small Perlidae	14.4(13.2)	0.6(1.5)	6.0(13.5)	6.9(11.7)

September, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=5)	Kick(x=4)	Circular(x=4)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Perlodidae				
Skwala parallela	0 (0)	0.6(1.5)	6.6(9.6)	0 (0)
Isogenoides colubrinus	4.8(10.8)	0 (0)	15.6(12.3)	7.5(11.4)
Isoperla fulva	6.0(10.5)	1.8(3.9)	0 (0)	0 (0)
Small Perlodidae and Taeniopterygidae	100.8(186.3)	47.4(47.7)	645.6(876.3)	691.5(1159.2)
Chloroperlidae				
Suwallia sp.	0 (0)	0 (0)	7.2(8.4)	0 (0)
Sweltsa coloradensis	9.6(13.2)	1.8(1.5)	25.8(30.9)	1.5(3.0)
Small Chloroperlidae	0 (0)	1.8(3.9)	69.6(81.0)	77.1(70.5)
Nemouridae				
Zapada cinctipes	14.4(21.6)	1.2(2.7)	0.6(1.5)	0.9(1.5)
Zapada columbiana	0 (0)	0 (0)	0 (0)	0 (0)
Capniidae				
Small Capniidae	9.6(21.6)	2.4(5.4)	63.6(107.4)	23.1(46.5)
TRICHOPTERA				
Hydropsychidae				
Arctopsyche grandis	34.8(48.0)	10.2(11.7)	198.0(10.2)	145.5(84.9)
Symphitopsyche oslari	201.0(162.3)	46.2(27.0)	5.4(5.7)	6.0(12.0)
Symphitopsyche cockerelli	293.4(177.9)	93.6(84.9)	24.0(13.8)	20.4(27.9)
Small Hydropsychidae	374.4(348.0)	114.6(144.0)	47.4(29.4)	21.0(42.0)
Hydropsychid pupae	0 (0)	0 (0)	0 (0)	0.9(1.5)
Rhyacophilidae				
Rhyacophila angelita	0 (0)	0 (0)	1.8(1.5)	0 (0)
Rhyacophila coloradensis	9.6(13.2)	0 (0)	0 (0)	0 (0)
Rhyacophila vepulsa	0 (0)	0 (0)	0 (0)	0 (0)

September, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=5)	Kick(x=4)	Circular(x=4)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Glossosomatidae				
Glossosoma sp.	14.4(21.6)	1.8(1.5)	286.2(276.0)	117.0(103.8)
Brachycentridae				
Brachycentrus americanus	0.6(1.5)	0 (0)	10.2(3.3)	5.4(10.5)
DIPTERA				
Tipulidae				
Hexatoma sp.	25.8(23.4)	1.2(1.5)	5.4(10.5)	0 (0)
Tanyderidae				
Protanyderus sp.	0 (0)	0 (0)	0.6(1.5)	0 (0)
Blephariceridae				
Blephariceras sp.	0 (0)	0 (0)	0.6(1.5)	0 (0)
Simuliidae				
Simulium sp.	4.8(10.8)	6.6(14.7)	452.4(311.1)	270.0(330.0)
Simulium arcticum pupae	0 (0)	0 (0)	123.6(90.0)	21.9(43.5)
Chironomidae				
larvae	225.6(134.4)	11.4(20.7)	177.6(222.9)	119.1(238.5)
pupae	0.6(1.5)	67.2(65.4)	111.0(162.0)	12.9(23.7)
adults	0 (0)	0 (0)	0 (0)	0 (0)
Athericidae				
Atherix variegata	4.8(10.8)	1.8(3.9)	3.0(3.0)	12.0(13.8)
OTHER INVERTEBRATES				
Turbellaria	4.8(10.8)	1.8(1.5)	0 (0)	0 (0)
Nematoda	0 (0)	0 (0)	0 (0)	0 (0)
Oligochaeta	0 (0)	0 (0)	0 (0)	0 (0)
Lumbriculidae	4.8(10.8)	1.8(1.5)	1.8(3.9)	0 (0)
Naididae	0 (0)	0 (0)	0 (0)	0 (0)
Hydrocarina	0.6(1.5)	0 (0)	0.6(1.5)	6.0(12.0)

October, 1979

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=4)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
EPHEMEROPTERA				
Siphlonuridae				
Ameletus cooki	0.6(1.5)	0.9(1.5)	0 (0)	0 (0)
Baetidae				
Baetis tricaudatus	1575.6(674.4)	968.1(294.0)	748.2(602.4)	793.2(490.5)
Baetis hageni	427.2(168.6)	416.4(303.6)	51.0(81.0)	70.2(81.0)
Pseudocleon sp.	0 (0)	0 (0)	0 (0)	4.8(10.8)
Heptageniidae				
Rhithrogena hageni	1758.6(732.3)	542.4(323.4)	563.4(282.3)	145.8(92.4)
Rhithrogena robusta	3.0(4.2)	0 (0)	0.6(1.5)	0 (0)
Epeorus albertae	214.8(222.6)	105.0(122.7)	3.6(6.6)	6.0(7.2)
Epeorus deceptivus	0 (0)	0 (0)	0 (0)	0 (0)
Cinygmula sp.	36.0(61.2)	30.0(36.9)	89.4(189.9)	48.0(66.6)
Small Heptageniidae	2278.2(918.0)	851.4(601.2)	1445.4(1117.5)	1794.6(840.0)
Ephemerellidae				
Ephemerella doddsi	121.2(75.9)	21.0(18.0)	125.4(84.6)	51.6(36.0)
Ephemerella inermis	627.0(222.6)	237.0(162.0)	383.4(247.5)	464.4(504.0)
Ephemerella spinifera	0 (0)	0 (0)	7.8(7.2)	3.6(6.6)
Leptophlebiidae				
Paraleptophlebia heteronea	114.6(91.2)	24.9(18.3)	1.8(2.7)	1.8(2.7)
PLECOPTERA				
Pteronarcidae				
Pteronarcys californica	1.8(2.7)	0.9(1.5)	3.0(5.1)	0.6(1.5)
Pteronarcella badia	9.6(6.9)	16.5(27.0)	218.4(132.3)	81.0(75.6)
Perlidae				
Classenia sabulosa	49.8(40.2)	10.5(5.1)	10.2(8.7)	5.4(9.0)
Hesperaperla pacifica	18.0(19.2)	2.4(3.0)	9.6(13.2)	12.0(17.4)
Calineuria californica	0 (0)	0 (0)	0 (0)	0 (0)
Small Perlidae	15.6(20.4)	0 (0)	12.0(12.0)	34.2(42.3)

October, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=4)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Perlodidae				
Isoperla fulva	130.8(127.8)	24.9(20.7)	19.8(19.5)	40.8(32.1)
Isogenoides colubrinus	0 (0)	0 (0)	11.4(8.7)	6.6(7.5)
Cultus aestivalis	0 (0)	0 (0)	1.2(1.8)	0.6(1.5)
Megarcys watertoni	0 (0)	0 (0)	0 (0)	0 (0)
Small Perlodidae	0 (0)	0 (0)	5.4(7.5)	7.2(12.9)
Chloroperlidae				
Suwalliapallidula adult	0.6(1.5)	0 (0)	0 (0)	0 (0)
Suwallia sp.	0 (0)	0 (0)	1.2(1.8)	0 (0)
Sweltsa coloradensis	3.6(3.9)	3.0(0)	21.6(21.9)	14.4(13.5)
Small Chloroperlidae	47.4(83.4)	22.5(27.0)	279.6(191.4)	209.4(105.3)
Nemouridae				
Zapada cinctipes	2.4(3.3)	0 (0)	12.6(9.0)	13.8(13.5)
Zapada columbiana	0 (0)	0 (0)	0 (0)	0 (0)
Amphinemura sp.	0.6(1.5)	0 (0)	0 (0)	0 (0)
Capniidae				
Small Capniidae	178.2(123.9)	134.4(43.5)	828.6(738.9)	1168.8(827.1)
Taeniopterygidae				
Small Taeniopterygidae	3640.2(1218.0)	1153.5(920.1)	3370.2(1490.1)	3177.0(1999.8)
TRICHOPTERA				
Hydropsychidae				
Arctopsyche grandis	27.0(29.7)	3.9(4.5)	286.2(234.9)	301.2(198.6)
Symphitopsyche oslari	655.8(378.9)	140.4(61.8)	30.6(33.0)	9.0(11.1)
Symphitopsyche cockerelli	129.6(109.5)	31.5(14.4)	46.8(42.3)	10.2(10.5)
Hydropsyche placoda	49.8(43.2)	14.1(28.5)	0.6(1.5)	0 (0)
Small Hydropsychidae	681.0(410.4)	51.9(45.6)	246.6(227.1)	103.8(125.4)
Hydropsychid pupae	0 (0)	0 (0)	0.6(1.5)	0 (0)

October, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=4)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Rhyacophilidae				
Rhyacophila coloradensis	4.8(10.8)	0 (0)	5.4(6.3)	0 (0)
Small Rhyacophila sp.	4.8(10.8)	0 (0)	0 (0)	5.4(10.5)
Rhyacophila pupae	0 (0)	0 (0)	0.6(1.5)	0 (0)
Glossosomatidae				
Glossosoma sp.	6.0(10.5)	38.4(74.4)	1159.2(495.3)	458.4(333.6)
Hydroplilidae				
Ochrotrichia sp.	4.8(10.8)	0 (0)	0 (0)	0 (0)
Brachycentridae				
Brachycentrus americanus	1.8(2.7)	0 (0)	6.0(6.9)	25.2(33.6)
COLEOPTERA				
Elmidae				
Zaitzevia parvula	4.8(10.8)	0 (0)	0 (0)	2.4(3.3)
Optioservus quadrimaculatus	0 (0)	0 (0)	0.6(1.5)	3.6(6.6)
DIPTERA				
Tipulidae				
Hexatoma sp.	30.0(42.3)	13.5(12.3)	12.0(18.0)	3.6(5.4)
Antocha sp.	0 (0)	0 (0)	2.4(5.4)	2.4(5.4)
Tanyderidae				
Protanyderus sp.	0.6(1.5)	0 (0)	1.8(3.9)	0.6(1.5)
Simuliidae				
Simulium sp.	1.2(2.7)	0 (0)	24.6(36.3)	6.0(11.7)
Simulium arcticum pupae	0 (0)	0 (0)	28.8(64.5)	0 (0)

October, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=4)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Chironomidae				
larvae	278.4(321.0)	230.4(187.8)	0 (0)	642.0(212.1)
pupae	15.0(21.3)	3.0(6.0)	0 (0)	2.4(3.9)
adults	3.0(6.6)	0 (0)	0 (0)	0 (0)
Athericidae				
Atherix variegata	19.2(24.6)	8.4(5.7)	25.2(15.6)	13.8(13.8)
Empididae				
Chelifera sp.	0 (0)	0 (0)	2.4(5.4)	0 (0)
OTHER INVERTEBRATES				
Turbellaria	13.8(30.9)	6.9(13.5)	0 (0)	2.4(5.4)
Nematoda	6.0(10.2)	2.4(4.5)	13.8(18.6)	33.0(49.5)
Oligochaeta				
Lumbriculidae	21.0(47.1)	6.9(13.5)	26.4(18.3)	10.8(20.7)
Naididae	4.8(10.8)	0 (0)	1025.4(1971.9)	230.4(228.9)
Hydrocarina	26.4(30.0)	179.4(319.2)	0 (0)	211.2(224.4)

November, 1979

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
EPHEMEROPTERA				
Siphlonuridae				
Ameletus sparsatus	0.6(1.2)	0 (0)	0.6(1.2)	2.4(5.4)
Ameletus cooki	0.6(1.2)	0 (0)	0 (0)	0 (0)
Small Ameletus sp.	9.6(21.6)	19.2(31.2)	0 (0)	0 (0)
Baetidae				
Baetis tricaudatus	1535.4(727.8)	988.2(768.6)	1053.6(1120.5)	400.2(325.5)
Baetis hageni	1124.4(513.0)	453.0(380.1)	91.2(167.7)	15.0(22.5)
Heptageniidae				
Rhithrogena hageni	3082.8(1060.2)	651.6(575.1)	335.4(223.8)	157.8(135.0)
Rhithrogena robusta	0 (0)	0 (0)	0.6(1.2)	0 (0)
Epeorus albertae	218.4(133.8)	172.8(181.5)	12.0(25.2)	5.4(12.0)
Epeorus grandis	0 (0)	0 (0)	0 (0)	0 (0)
Cinygmula sp.	186.6(155.7)	51.0(41.1)	970.8(1227.3)	88.8(124.5)
Small Heptageniidae	3379.2(917.4)	1974.6(1783.8)	1221.6(3034.8)	496.8(324.0)
Ephemerellidae				
Ephemerella doddsi	73.2(21.9)	19.8(18.9)	34.2(9.6)	46.8(34.5)
Ephemerella inermis	471.0(37.5)	184.8(162.6)	339.6(509.4)	86.4(107.4)
Ephemerella spinifera	0 (0)	0 (0)	4.8(10.8)	1.2(1.5)
Leptophlebiidae				
Paraleptophlebia heteronea	99.0(80.7)	33.6(34.8)	10.8(14.4)	14.4(21.6)
PLECOPTERA				
Pteronarcidae				
Pteronarcys californica	1.2(1.5)	0 (0)	8.4(15.6)	1.2(1.5)
Pteronarcella badia	17.4(19.5)	1.2(1.5)	81.6(31.8)	52.2(16.5)
Perlidae				
Classenia sabulosa	34.8(14.4)	7.2(8.1)	27.0(21.6)	9.0(6.6)
Hesperaperla pacifica	19.8(15.3)	4.2(4.5)	22.8(26.4)	3.0(5.1)
Small Perlidae	0 (0)	0 (0)	14.4(84.9)	0.6(1.5)

November, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Perlodidae				
Isoperla fulva	57.6(22.8)	9.6(7.5)	153.6(163.8)	51.0(47.1)
Isoperla patricia	0 (0)	0 (0)	1.2(1.5)	2.4(3.9)
Isogenoides colubrinus	1.2(1.5)	0 (0)	4.8(9.0)	0.6(1.2)
Megarcys watertoni	0 (0)	0 (0)	0 (0)	0 (0)
Small Perlodidae	0 (0)	0 (0)	1.8(2.7)	0.6(1.5)
Chloroperlidae				
Sweltsa coloradensis	10.2(5.4)	1.8(2.7)	16.8(26.4)	1.8(1.5)
Chloroperlid sp. A	2.4(3.3)	1.2(2.7)	61.8(60.9)	34.2(41.7)
Small Chloroperlidae	99.6(66.3)	44.4(50.4)	124.8(63.0)	102.6(73.2)
Nemouridae				
Zapada cinctipes	10.2(22.8)	0 (0)	46.2(95.1)	0.6(1.2)
Zapada columbiana	0 (0)	0 (0)	0 (0)	0 (0)
Leuctridae				
Despaxia augusta	0 (0)	0 (0)	0 (0)	0 (0)
Capniidae				
Utacapnia sp.	32.4(35.4)	2.4) 2.4)	50.4(56.7)	11.4(12.0)
Small Capniidae	436.8(81.0)	223.2(201.3)	1013.4(1202.7)	190.2(150.00
Taeniopterygidae				
Taenionema pacificum	703.5(435.3)	271.8(282.0)	2447.4(1474.8)	963.0(668.4)
Small Taeniopterygidae	2393.4(1080.6)	679.2(460.2)	1677.0(1844.1)	863.4(712.2)
TRICHOPTERA				
Hydropsychidae				
Arctopsyche grandis	15.0(8.4)	9.0(9.0)	8424.0(1283.1)	144.6(168.0)
Symphitopsyche cockerelli	96.0(33.3)	25.8(19.2)	40.8(57.0)	23.4(42.3)
Symphitopsyche oslari	490.2(359.4)	200.4(154.5)	152.4(294.0)	52.8(109.8)
Hydropsyche placoda	183.0(168.9)	40.2(45.6)	8.4(14.4)	3.6(8.1)
Small Hydropsychidae	437.4(159.9)	150.6(143.1)	386.4(699.9)	117.0(196.5)

November, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Rhyacophilidae				
Rhyacophila bifila	4.8(10.8)	0.6(1.2)	1.8(2.7)	0 (0)
Rhyacophila vepulsa	0 (0)	0 (0)	0 (0)	6.0(12.0)
Small Rhyacophila sp.	0 (0)	0 (0)	0 (0)	0.6(1.2)
Glossosomatidae				
Glossosoma sp.	27.0(25.2)	3.6(4.8)	268.2(281.7)	1308.0(113.4)
Brachycentridae				
Brachycentrus americanus	1.2(1.5)	4.2(6.3)	18.0(22.2)	1.8(2.7)
COLEOPTERA				
Elmidae				
Zaitzevia parvula	1.2(2.7)	2.4(5.4)	0 (0)	0 (0)
Optioservus quadrimaculatus	5.4(12.0)	0 (0)	0 (0)	0 (0)
Haliplidae				
Brychius sp.	0.6(1.2)	0 (0)	0 (0)	0 (0)
Dytiscidae	0 (0)	0 (0)	0.6(1.2)	0 (0)
DIPTERA				
Blephariceridae	0 (0)	0 (0)	0 (0)	0.6(1.2)
Tipulidae				
Hexatoma sp.	19.2(10.8)	2.4(3.9)	2.4(2.4)	2.4(2.4)
Simuliidae				
Simulium sp.	73.2(127.2)	7.8(15.9)	9.6(14.1)	19.2(21.6)
Chironomidae				
larvae	3078.6(2213.7)	1341.0(1296.0)	6229.2(9309.0)	1818.6(1961.1)
adults	1.2(2.7)	0 (0)	3.0(5.1)	0.6(1.2)

November, 1979 Cont.

	Bible Camp		Kokanee Bend	
	Kick(x=5)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Athericidae				
Atherix variegata	13.8(22.8)	1.2(1.5)	34.8(47.4)	4.2(2.7)
OTHER INVERTEBRATES				
Turbellaria	19.8(23.4)	18.0(25.8)	0.6(1.2)	0 (0)
Nematoda	61.2(36.3)	4.8(10.8)	16.2(24.0)	9.0(11.1)
Oligochaeta				
Lumbriculidae	18.6(18.3)	4.2(9.3)	12.0(12.9)	0 (0)
Naididae	0 (0)	4.8(10.8)	8.4(15.6)	7.2(10.8)
Hirudinia				
Piscicola sp.	0 (0)	0 (0)	0.6(1.2)	0 (0)
Hydracarina	84.0(70.5)	39.6(31.5)	124.2(253.2)	16.8(20.1)

South Fork

	July, 1979	August, 1979	
	Kick(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
EPHEMEROPTERA			
Baetidae			
Baetis tricaudatus	21.6(12.3)	0.6(1.2)	0 (0)
Baetis bicaudatus	82.2(67.8)	9.6(9.9)	9.6(13.2)
Baetis hageni	0 (0)	0 (0)	0 (0)
Pseudocleon sp.	0 (0)	0 (0)	0 (0)
Siphlonuridae			
Siphlonurus sp.		0 (0)	0 (0)
Ameletus connectus		0 (0)	0 (0)
Ameletus oregonensis		0 (0)	0 (0)
Heptageniidae			
Rhithrogena hageni	2.4(5.4)	0 (0)	0 (0)
Rhithrogena robusta		0 (0)	0 (0)
Epeorus albertae	0 (0)	0 (0)	0 (0)
Cinygmula sp.	1.2(2.7)	0 (0)	0 (0)
Stenonoma sp.	2.4(5.4)		
Small Heptageniidae	0 (0)	0 (0)	0 (0)
Ephemerellidae			
Ephemerella doddsi	7.2(10.8)	0 (0)	0 (0)
Ephemerella inermis	0 (0)	0 (0)	0 (0)
Ephemerella tibialis	0 (0)	0 (0)	0 (0)
Ephemerella hystrix		0 (0)	0 (0)
Ephemerella flavilinea	1.2(2.7)	0 (0)	0 (0)
Ephemerella heterocaudata	1.2(1.5)		
Leptophlebiidae			
Paraleptophlebia bicornuta		0 (0)	0 (0)
Paraleptophlebia heteronea	0 (0)	0 (0)	0 (0)

South Fork Cont.

	July, 1979	August, 1979	
	Kick(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
PLECOPTERA			
Pteronarcidae			
Pteronarcys californica		0 (0)	0 (0)
Pteronarcella badia	0 (0)	0 (0)	0 (0)
Perlidae			
Classenia sabulosa	0 (0)	0 (0)	0 (0)
Hesperaperla pacifica	0 (0)	0 (0)	0 (0)
Doroneuria theodora		1.2 (1.5)	0 (0)
Small Perlidae		0 (0)	0 (0)
Perlodidae			
Kogotus modestus	3.6 (2.4)		
Skwala parallela		0 (0)	0 (0)
Isogenoides colubrinus		0 (0)	0 (0)
Small Perlodidae	0.6 (1.5)	0.6 (1.2)	0 (0)
Chloroperlidae			
Suwallia sp.	3.0 (5.1)	0 (0)	0 (0)
Sweltsa coloradensis	0 (0)	0 (0)	0 (0)
Small Chloroperlidae	0 (0)	0 (0)	0 (0)
Nemouridae			
Zapada cinctipes		0 (0)	0 (0)
Zapada columbiana	9.0 (13.5)	4.8 (10.8)	4.8 (10.8)
Capniidae			
Small Capniidae		0 (0)	0 (0)
TRICHOPTERA			
Hydropsychidae			
Arctopsyche grandis	0 (0)	0 (0)	0 (0)
Symphitopsyche oslari	0 (0)	0 (0)	0 (0)
Symphitopsyche cockerelli		0 (0)	0 (0)

South Fork Cont.

	July, 1979	August, 1979	
	Kick(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Hydropsychidae Cont.			
Parapsyche elsis	0.6(1.5)		
Small Hydropsychidae		0 (0)	0 (0)
Hydropsychidae pupae	0 (0)	0 (0)	0 (0)
Rhyacophilidae			
Rhyacophila angelita	0 (0)	0 (0)	0 (0)
Rhyacophila vaccua	0 (0)		
Rhyacophila verrula	5.4(3.9)	1.2(1.5)	0 (0)
Small Rhyacophila sp.	4.8(6.6)	0 (0)	0 (0)
Glossosomatidae			
Glossosoma sp.		0 (0)	0 (0)
Brachycentridae			
Brachycentrus americanus	0 (0)	0 (0)	0 (0)
Limnephilidae			
Neophylax rickeri		0 (0)	0 (0)
COLEOPTERA			
Elmidae			
Optioservus quadrimaculatus	0 (0)		
DIPTERA			
Deuterophlebiidae			
Deuterophlebia sp.	0 (0)		
Blephariceridae	0 (0)		
Tipulidae			
Hexatoma sp.	0 (0)	0 (0)	0 (0)
Tanyderidae			
Protanyderus sp.	0 (0)	0 (0)	0 (0)

South Fork Cont.

	July, 1979	August, 1979	
	Kick(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Simuliidae			
Simulium sp.	0 (0)	0 (0)	0 (0)
Simulium arcticum pupae		0 (0)	0 (0)
Chironomidae			
larvae	9580.2(3309.6)	5509.8(1702.2)	3620.4(2335.2)
pupae	15.0(25.5)	0 (0)	0 (0)
adults	0 (0)	0 (0)	0 (0)
Athericidae			
Atherix variegata	0 (0)	0 (0)	0 (0)
Empididae			
Chelifera sp.	0 (0)		
Hemerodromia pupae	0 (0)		
OTHER INVERTEBRATES			
Turbellaria	108.0(25.8)	171.0(81.6)	57.6(62.7)
Nematoda	0 (0)		
Oligochaeta	209.4(221.1)	133.2(131.7)	25.2(21.0)
Hydrocarina	36.0(55.5)	0 (0)	0 (0)

South Fork Cont.

	September, 1979		October, 1979	
	Kick(x=5)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{X}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
EPHEMEROPTERA				
Siphlonuridae				
Ameletus cooki			0 (0)	0 (0)
Baetidae				
Baetis tricaudatus	0 (0)	0 (0)	4.2(5.1)	1.8(2.7)
Baetis bicaudatus	0 (0)	9.6(21.6)		
Baetis hageni	0 (0)	0 (0)	0 (0)	0 (0)
Pseudocleon sp.	0 (0)	0 (0)	0 (0)	0 (0)
Heptageniidae				
Rhithrogena hageni	0 (0)	0 (0)	0.6(1.5)	0.6(1.5)
Rhithrogena robusta	0 (0)	0 (0)	0 (0)	0 (0)
Epeorus albertae	0 (0)	0 (0)	0 (0)	0 (0)
Epeorus deceptivus			2.4(3.9)	0.6(1.5)
Epeorus sp.	0 (0)	7.2(10.8)		
Cinygmula sp.			0.6(1.5)	0 (0)
Small Heptageniidae	0 (0)	0 (0)	0.6(1.5)	0 (0)
Ephemerellidae				
Ephemerella doddsi	0 (0)	0 (0)	0 (0)	0 (0)
Ephemerella inermis	0 (0)	0 (0)	0 (0)	0 (0)
Ephemerella tibialis	0 (0)	0 (0)		
Ephemerella spinifera	0 (0)	0 (0)	0 (0)	0 (0)
Leptophlebiidae				
Paraleptophlebia heteronea	0 (0)	0 (0)	0 (0)	0 (0)
PLECOPTERA				
Pteronarcidae				
Pteronarcys californica	0 (0)	0 (0)	0 (0)	0 (0)
Pteronarcella badia	0 (0)	0 (0)	0 (0)	0 (0)

South Fork Cont.

	September, 1979		October, 1979	
	Kick(x=5)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Perlidae				
Classenia sabulosa	0 (0)	0 (0)	0 (0)	0 (0)
Hesperaperla pacifica	0 (0)	0 (0)	0 (0)	0 (0)
Calineuria californica			0.6(1.5)	0 (0)
Small Perlidae	0 (0)	0 (0)	0 (0)	0 (0)
Perlodidae				
Skwala parallela	0 (0)	0 (0)		
Isoperla fulva	0 (0)	0 (0)	0 (0)	0 (0)
Isogenoides colubrinus	0 (0)	0 (0)	0 (0)	0 (0)
Cultus aestivalis			0 (0)	0 (0)
Megarcys watertoni			0.6(1.5)	0 (0)
Small Perlodidae and Taeniopterygidae	0 (0)	0 (0)	0 (0)	0 (0)
Chloroperlidae				
Suwalliapallidula adult			0 (0)	0 (0)
Suwallia sp.	0 (0)	0 (0)	0 (0)	0 (0)
Sweltsa coloradensis	4.8(10.8)	4.8(10.8)	0.6(1.5)	0 (0)
Small Chloroperlidae	0 (0)	0 (0)	0 (0)	0 (0)
Nemouridae				
Zapada cinctipes	0 (0)	0 (0)	0 (0)	0 (0)
Zapada columbiana	4.8(10.8)	0 (0)	13.2(8.7)	12.6(12.6)
Amphinemura sp.			0 (0)	0 (0)
Capniidae				
Small Capniidae	0 (0)	0 (0)	0 (0)	0 (0)
Taeniopterygidae				
Small Taeniopterygidae			0.6(1.5)	0 (0)
TRICHOPTERA				
Hydropsychidae				
Arctopsyche grandis	0 (0)	0 (0)	0 (0)	0 (0)

South Fork Cont.

	September, 1979		October, 1979	
	Kick(x=5)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$9s.d.)
Hydropsychidae Cont.				
Symphitopsyche oslari	0 (0)	0 (0)	0 (0)	0 (0)
Symphitopsyche cockerelli	0 (0)	0 (0)	0 (0)	0 (0)
Hydropsyche placoda			0 (0)	0 (0)
Small Hydropsychidae	0 (0)	0 (0)	0 (0)	0 (0)
Hydropsychid pupae	0 (0)	0 (0)	0 (0)	0 (0)
Rhyacophilidae				
Rhyacophila angelita	0 (0)	0 (0)		
Rhyacophila coloradensis	4.8(10.8)	0 (0)	0.6(1.5)	0 (0)
Rhyacophila vepulsa	4.8(10.8)	0 (0)		
Small Rhyacophila sp.			0 (0)	0 (0)
Rhyacophila pupae			0 (0)	0 (0)
Glossosomatidae				
Glossosoma sp.	0 (0)	0 (0)	0 (0)	0 (0)
Hydroplilidae				
Ochrotrichia sp.			0 (0)	0 (0)
Brachycentridae				
Brachycentrus americanus	0 (0)	0 (0)	0 (0)	0 (0)
COLEOPTERA				
Elmidae				
Zaitzevia parvula			0 (0)	0 (0)
Optioservus quadrimaculatus			0 (0)	0 (0)

South Fork Cont.

	September, 1979		October, 1979	
	Kick(x=5)	Circular(x=5)	Kick(x=5)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
DIPTERA				
Tipulidae				
Hexatoma sp.	0 (0)	0 (0)	0 (0)	0 (0)
Antocha sp.			0 (0)	0 (0)
Tanyderidae				
Protanyderus sp.	0 (0)	0 (0)	0 (0)	0 (0)
Blephariceridae				
Blephariceros sp.	0 (0)	0 (0)		
Simuliidae				
Simulium sp.	0 (0)	0 (0)	0 (0)	0 (0)
Simulium arcticum pupae	0 (0)	0 (0)	0 (0)	0 (0)
Chironomidae				
larvae	4334.4(3120.6)	6000.0(2023.8)	2819.4(1887.9)	1361.4(859.5)
pupae	6.6(6.3)	67.2(93.6)	6.6(14.7)	7.2(12.9)
adults	3.0(2.1)	0 (0)	9.0(20.1)	0 (0)
Athericidae				
Atherix variegata	0 (0)	0 (0)	0 (0)	0 (0)
Empididae				
Chelifera sp.			0 (0)	0 (0)
OTHER INVERTEBRATES				
Turbellaria	62.4(62.7)	60.0(79.5)	2.4(5.4)	0.6(1.5)
Nematoda	0 (0)	0 (0)	0 (0)	0 (0)
Oligochaeta	0 (0)	117.6(99.9)		
Lumbriculidae	19.2(31.2)	0 (0)	46.8(27.9)	11.4(4.5)
Naididae	0 (0)	0 (0)	0 (0)	0 (0)
Hydrocarina	0 (0)	0 (0)	0 (0)	0 (0)

South Fork Cont.

	November, 1979	
	Kick(x=4)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
EPHEMEROPTERA		
Siphlonuridae		
Ameletus sparsatus	0 (0)	0 (0)
Ameletus cooki	0 (0)	0 (0)
Small Ameletus sp.	0 (0)	0 (0)
Baetidae		
Baetis tricaudatus	111.9(75.9)	0 (0)
Baetis hageni	0 (0)	0 (0)
Heptageniidae		
Rhithrogena hageni	0 (0)	0 (0)
Rhithrogena robusta	0.9(1.5)	1.2(1.5)
Epeorus albertae	0 (0)	0 (0)
Epeorus grandis	15.9(15.3)	3.0(3.0)
Cinygmula sp.	0.9(1.5)	0 (0)
Small Heptageniidae	12.0(24.0)	73.2(49.2)
Ephemerellidae		
Ephemerella doddsi	0 (0)	0 (0)
Ephemerella inermis	0 (0)	0 (0)
Ephemerella spinifera	0 (0)	0 (0)
Leptophlebiidae		
Paraleptophlebia heteronea	0 (0)	0 (0)
PLECOPTERA		
Pteronarcidae		
Pteronarcys californica	27.9(27.6)	0 (0)
Pteronarcella badia	0 (0)	0 (0)
Perlidae		
Classenia sabulosa	0 (0)	0 (0)
Hesperaperla pacifica	0 (0)	0 (0)
Small Perlidae	0 (0)	0 (0)

South Fork Cont.

	November, 1979	
	Kick(x=4)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Perlodidae		
Isoperla fulva	0 (0)	0 (0)
Isoperla patricia	0 (0)	0 (0)
Isogenoides colubrinus	0 (0)	0 (0)
Megarcys watertoni	0.9(1.5)	0 (0)
Small Perlodidae	1.5(3.0)	68.4(40.5)
Chloroperlidae		
Sweltsa coloradensis	0.9(1.5)	0 (0)
Chloroperlid sp. A	0 (0)	0.6(1.2)
Small Chloroperlidae	18.0(23.1)	0 (0)
Nemouridae		
Zapada cinctipes	19.5(35.1)	4.8(7.5)
Zapada columbiana	27.9(27.6)	19.5(19.5)
Leuctridae		
Despaxia augusta	0.9(1.5)	0 (0)
Capniidae		
Utacapnia sp.	0.9(1.5)	1.2(2.7)
Small Capniidae	13.5(14.1)	21.6(21.0)
Taeniopterygidae		
Taenionema pacificum	34.5(46.8)	8.4(13.2)
Small Taeniopterygidae	0 (0)	0 (0)
TRICHOPTERA		
Hydropsychidae		
Arctopsyche grandis	0 (0)	0 (0)
Symphitopsyche cockerelli	0 (0)	0 (0)
Symphitopsyche oslari	0.9(1.5)	1.2(1.5)
Hydropsyche placoda	0 (0)	0.6(1.2)
Small Hydropsychidae	0 (0)	0 (0)

South Fork Cont.

	November, 1979	
	Kick(x=4)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
Rhyacophilidae		
Rhyacophila bifila	0 (0)	0.6(1.2)
Rhyacophila vepulsa	6.0(12.0)	0 (0)
Small Rhyacophila sp.	0 (0)	0 (0)
Glossosomatidae		
Glossosoma sp.	0 (0)	0 (0)
Brachycentridae		
Brachycentus americanus	0 (0)	0 (0)
COLEOPTERA		
Elmidae		
Zaitzevia parvula	0 (0)	0 (0)
Optioservus quadrimaculatus	0 (0)	0 (0)
Haliplidae		
Brychius sp.	0 (0)	0 (0)
Dytiscidae	0 (0)	0 (0)
DIPTERA		
Blephariceridae	0 (0)	0 (0)
Tipulidae		
Hexatoma sp.	0 (0)	0 (0)
Simuliidae		
Simulium sp.	0 (0)	0 (0)
Chironomidae		
larvae	9572.4(3690.3)	7270.2(4347.6)
adults	0 (0)	0 (0)
Athericidae		
Atherix variegata	0 (0)	0 (0)

South Fork Cont.

	November, 1979	
	Kick(x=4)	Circular(x=5)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
OTHER INVERTEBRATES		
Turbellaria	203.4(108.3)	103.2(63.3)
Nematoda	18.0(23.1)	0 (0)
Oligochaeta		
Lumbriculidae	235.5(251.4)	91.8(112.2)
Naididae	84.0(104.7)	91.8(112.2)
Hirudinia		
Piscicola sp.	0 (0)	0 (0)
Hydracarina	42.0(84.0)	15.0(13.8)

South Fork Cont.

	December, 1979		January, 1980
	Kick(x=4)	Circular(x=4)	Kick(x=8)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
EPHEMEROPTERA			
Baetidae			
Baetis tricaudatus	162.9(50.7)	105.0(77.4)	378.0(391.5)
Heptageniidae			
Rhithrogena robusta	7.5(15.0)		0.3(0.9)
Epeorus grandis	0.9(1.5)	1.5(3.0)	
Cinygmula sp.		6.0(12.0)	
Small Heptageniidae	42.9(52.8)	6.0(12.0)	12.9(18.9)
Ephemerellidae			
Ephemerella doddsi		0.9(1.5)	
Ephemerella inermis		0.9(1.5)	
PLECOPTERA			
Perlidae			
Doroneuria theodora	0.9(1.5)		
Perlodidae			
Setvena bradleyi	0.9(1.5)		
Kogotus modestus			0.3(0.9)
Small Perlodidae	12.0(24.0)	13.5(23.1)	27.0(27.9)
Chloroperlidae			
Suwallia sp.	0.9(1.5)		
Sweltsa coloradensis	0.9(1.5)		1.2(2.1)
Chloroperlid sp. A.	7.5(15.0)	1.5(1.8)	
Nemouridae			
Zapada columbiana	22.5(23.7)	6.0(5.4)	3.9(3.9)
Zapada cinctipes	13.5(14.1)	8.4(14.7)	4.5(9.0)
Taeniopterygidae			
Taenionema pacificum	43.5(22.8)	25.5(27.9)	6.9(7.2)
Capniidae			
Small Capniidae	54.9(35.1)	8.4(10.8)	30.0(33.3)

South Fork Cont.

	December, 1979		January, 1980
	Kick(x=4)	Circular(x=4)	Kick(x=8)
	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)	$\bar{x}$(s.d.)
TRICHOPTERA			
Rhyacophilidae			
Rhyacophila bifila	0.9(1.5)		
Rhyacophila vepulsa	0.9(1.5)		
Small Rhyacophila sp.			0 (0)
Glossosomatidae			
Glossosoma sp.			0 (0)
DIPTERA			
Chironomidae			
larvae	17,310.0(6069.0)	13,029.0(4215.0)	1197.6(1430.1)
OTHER INVERTEBRATES			
Turbellaria	312.9(284.1)	0.9(1.5)	330.0(206.4)
Nematoda		6.9(11.7)	12.0(12.9)
Oligochaeta			
Lumbriculidae	409.5(126.3)	65.4(39.3)	445.8(381.9)
Naididae	30.9(37.2)	24.0(48.0)	58.8(69.3)
Hydracarina	85.5(91.8)	18.0(12.0)	183.0(264.0)

LITERATURE CITED

Allen, J.L. and P.D. Harman. 1970. Control of pH in MS-222 anesthetic solutions. Prog. Fish Cult., 32:100

Allen, W.M. 1964. Fishery Management Program. Kintla Lake. USDI Wildl. Serv. Prog. Rep. 4p.

Behnke, R.J. 1979. Monograph of the native trouts of the genus *Salmo* of western North America. 215p.

Bjornn, T.C. 1957. A survey of the fishery resources of Priest and Upper Priest Lakes and their tributaries, Idaho, Idaho Dept. Fish, Game, Compl. Rep. 176p.

Block, D.G. 1955. Trout migration and spawning studies on the North Fork drainage of the Flathead River. M.S. Thesis, Montana State Univ. Bozeman, MT 68p.

Bovee, K.D. and J. Cochnauer. 1977. Development and Evaluation of Weighted Criteria, Probability of Use Curves for Instream Flow Assessment. Fisheries. Instream Flow Information Paper No.3. Cooperative Instream Flow Service Group. Fort Collins, Colorado. 39pp.

Brinck, P. 1949. Studies on Swedish Stoneflies (Plecoptera), Opusc Entomol (Lund) 11: 1-250.

Brusven, M.A., C. MacPhee and R. Biggam. 1974. Effects of water fluctuations on benthic insects. pp.67-79. In: Anatomy of a River, Ch.5. Pacific Northwest River Basin Comm. Report. Vancouver, Washington

Carle, F.L. 1976. An evaluation of the removal method for estimating benthic populations and diversity. MS.Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 108pp.

Cavender, T.M. 1978. Taxonomy and distribution of the bull trout (Salvelinus confluentus) (Suckley), from the American Northwest. Calif. Fish Game, 64(3):139-174.

Coon, J.C., R.R. Ringe and T.C. Bjornn. 1977. Abundance, growth, distribution and movements of white sturgeon in the mid-Snake River. Idaho Water Resources Research Inst. Job Compl. Rep. 63p.

Cummins, K.W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. Am. Mid. Nat. 67: 477-504.

Cushman, R.M., H.H. Shugart, Jr., S.G. Hildebrand, and J.W. Elwood, 1978. The effect of growth curve and sampling regime on instantaneous growth, removal - summation and Hynes/Hamilton estimates of aquatic insect production: a computer simulation, Limnology. Oceanogr. 23:184-189.

Domrose, R.J. 1968. Kokanee redd exposure and hatching success in relation to receding Flathead Lake levels. Unpublished. 2p.

Domrose, R.J. 1975. Notes on kokanee redd examination and fry emergence in relation to Hungry Horse Reservoir discharge. Unpublished. 4p.

Elliott, J.M. 1972. Effects of temperature on the time of hatching in *Baetis rhodani* (Ephemeroptera Baetidae). Oecologia 9:47-51.

Fahy, E. 1973. Observations on the growth of Ephemeroptera in fluctuating and constant temperature conditions. Proc. Roy. Irish. Acad. 73:133-149.

Fisher, S.G. and A. LaVoy. 1972. Differences in littoral fauna due to fluctuating water levels below a hydroelectric dam. J. Fish. Res. Bd. Canada 29:1472-1476.

Foerster, R.E. 1944. The relation of lake population density to size of young sockeye salmon (*Oncorhynchus herka*) J. Fish. Res. Bd. Canada, 6(3):267-280.

Fried, S.M., J.D. McCleave and K.A. Stred. 1976. Buoyancy compensation by Atlantic salmon (*Salmo salar*) tagged internally with dummy telemetry transmitters. J. Fish. Res. Bd. Canada, 33:1377-1380.

Graham, P.J., D. Read, S. Leathe, J. Miller and K. Pratt. 1980. Flathead River Basin Fisheries Study - 1980. Montana Dept. Fish, Wildl. Parks. Kalispell, Mt. 118p + App.

Groot, C., K. Simpson, I. Todd, P.S. Murray and G.A. Buxton. 1975. Movements of sockeye salmon (*Oncorhynchus nerka*) in the Skeena River estuary as revealed by ultrasonic tracking. J. Fish. Res. Bd. Canada, 32:233-242.

Hanzel, D.A. 1964. Evaluation of kokanee spawning and population density in Flathead Lake and tributaries. Mont. Dept. Fish Game, 10p.

LITERATURE CITED CONT.

Hanzel, D.A. 1977. Angler pressure and game fish harvest estimates for 1975 in the Flathead River System above Flathead Lake. Mont. Dept. Fish Game. 23p.

Harshbarger, T.J. and P.E. Porter. 1979. Survival of brown trout eggs: two planting techniques compared. Prog. Fish. Cult., 41(4):206-209.

Hart, L.G. and R.C. Summerfelt. 1975. Surgical procedures for implanting ultrasonic transmitters into Flathead catfish (*Pylodictis olivaris*) Trans. Am. Fish. Soc., 104 (1):56-59.

Hasler, A.D., E.S. Gardella, R.M. Harrall and H.F. Henderson. 1969. Open water orientation of white bass (*Roccus chrysops*) as determined by ultrasonic tracking methods. J. Fish. Res. Bd. Canada, 26:2173-2192.

Henricson, J. and K. Muller. 1979. Stream regulation in Sweden with some examples from central Europe. pp183-199. In: The Ecology of Regulated Streams. Ward, J.V. and J.A. Stanford, Eds. Plenum Press. New York.

Hilsenhoff, W.L. 1971. Changes in the downstream insect and amphipod fauna caused by an impoundment with a hypolimnion drain. Ann. Entomol. Soc. Amer. 64:743-746.

Hoffman, C.E. and R.V. Kilambi. 1970. Environmental changes produced by cold water outlets from three Arkansas reservoirs. Water Resources Research Center Publ. No.5 Univ. of Arkansas, Fayetteville, Ark.

Hunter, J.W. 1973. A discussion of game fish in the state of Washington as related to water requirements. Wash. Dept. Game, 66p.

Huston, J.E. and R.E. Schumacher. 1978. Report on fish migration studies in Flathead River between Flathead Lake and the confluence of the South Fork with the main stem. Mont. Dept. Fish and Game. Job. Compl. Rep., 16p.

Hynes, H.B.N. 1970. The ecology of running waters. University of Toronto Press Toronto. 555pp.

Isom, B.G. 1971. Effects of storage and main stream reservoirs on benthic macroinvertebrates in the Tennessee Valley. pp.179-191. In: G.E. Hall (ed) Reservoir Fisheries and LImnology. Special publ. No.8 Am. Fish. Soc. Wash. D.C.

LITERATURE CITED CONT.

Johnson, H.E. 1963. Observations on the life history and movement of cutthroat trout (*Salmo clarki*) in Flathead River drainage Montana Proc. Acad. Sci., 23:96-110.

Johnson W.E. 1965. On mechanisms of self-regulation of population abundance in (*Oncorhynchus nerka*) Mitt. Internat. Verein. Limnol. 13:66-87.

Kelso, J.R.M. 1974. Influence of thermal effluent on movement of brown bullhead (*Italurus nebulosus*) as determined by ultrasonic tracking J. Fish. Res. Bd. Canada, 31:1507-1513.

Knight, A.E. and G. Marancik. 1977. Monitoring movements of juvenile anadromous fish by radiotelemetry. Prog. Fish. Cult., 39(3):148-150.

Lehmkuhl, D.M. 1972. Change in thermal regime as a cause of reduction of benthic fauna downstream of a reservoir. J. Fish. Res. Bd. Canada. 29:1329-2323.

McCleave, J.D. and R.M. Horrall. 1970. Ultrasonic tracking of homing cutthroat trout (*Salmo clarki*) in Yellowstone Lake. J. Fish. Res. Bd. Canada. 27:715-730.

McCleave, J.D. and K.A. Stred. 1975. Effect of dummy telemetry transmitters on stamina of Atlantic salmon (*Salmo salar*) smolts. J. Fish. Res. Bd. Canada. 32:559-563.

McMaster, K.M., R.G. White, R.R. Ringe and T.C. Bjornn. 1977. Effects of reduced nighttime flows on upstream migration of adult chinook salmon and steelhead trout in the lower Snake River. U.S. Army Corps of Engineers, Job. Compl. Rep.m 64p.

McMullin, S.L. 1979. The food habits and distribution of rainbow and cutthroat trout in Lake Koocanusa, Montana. M.S. Thesis. Univ. of Idaho. Moscow, Idaho 80p.

McNeil, W.J. 1964. A method of measuring mortality of pink salmon eggs and larva. U.S. Fish. Wildl. Serv. Fish. Bull., 66(3):575-588.

McNeil, W.J. 1968. Survival of pink and chum salmon eggs and alevins. Pages 101-117 in: T.G. Northcote, Editor. Symposium on salmon and trout in streams. Univ. British Columbia, Vancouver, B.C.

Morton, W.M. 1968. A review of all fishery data obtained from waters of the North Fork fishery management unit for the fifty-year period from 1916 through 1966. USDI Fish. Wild. Serv. Glacier Ntl. Park. 163p.

Nebeker, A.V. 1971. Effect of high winter water temperatures on adult emergence of aquatic insects. Water Res. 5:777-783.

Nebeker, A.V. and A.R. Gaufin. 1967. Factors affecting wing length and emergence in the winter stonefly, *Capnia nana* Entomol. News 78:85-92.

Newell, R.L. 1976. Yellowstone River Study. Mont. Dept. of Fish and Game and Intake Water Co., Final Report 259pp.

Pearson, W.D., R.H. Kramer and D.R. Franklin. 1968. Macroinvertebrates in the Green River below Flaming Gorge Dam. 1964-1965 and 1967. Proc. Utah Acad. Sci. Arts. Lett 45:148-167.

Primm, S.L. 1979. Complexity and stability: another look at MacArthur's original hypothesis Oikos 33:351-357.

Prince, E.D. and O.E. Maughan. 1978. Ultrasonic telemetry technique for monitoring bluegill movement. Prog. Fish. Cult., 40(3):90-93.

Rogers, D.E. 1978. Fertilization of Little Togiak Lake. Fish. Res. Inst., Univer. Wash. Seattle, Wash. 41p.

Schreck, C.B., R.A. Whaley, M.L. Bass, O.E. Maughan and M. Solozzi. 1976. Physiological responses of rainbow trout (*Salmo gairdneri*) to electroshock. J. Fish. Res. Bd. Canada. 33(1):76-84.

Shepherd, B. 1973. Transmitter attachment and fish behavior. Underwater Telemetry Newsletter. 3(1):8-11.

Smith, A.K. 1973. Fish and Wildlife Resources of the Umatilla Basin. Oregon and their water requirements. Ore. Game. Comm. Job. Compl. Rep. 70p.

Smith, S.D. 1968. The Rhyacophida of the Salmon River drainage of Idaho with special reference to larvae (Trichoptera-Rhyacophilidae) Ann. Ent. Soc. Amer. 61:655-674.

Spencer, J.A. and H.B.N. Hynes. 1971. Differences in benthos upstream and downstream of an impoundment. J. Fish. Res. Bd. Canada 28:35-43.

Stanford, J.A. 1975. Ecological studies of Plecoptera in the upper Flathead Rivers, Montana. PhD. dissertation, Univ. of Utah. Salt Lake City. 241p.

Stanford, J.A. and A.R. Gaufin. 1974. Hyporheic communities of two Montana Rivers. Science 185:700-702.

Stanford, J.A. and F.R. Hauer. 1979. Preliminary Observations on the Ecological Effects of Flow Regulation in the Flathead River, Montana. Flathead Research Group University of Montana. Biological Station for U.S. Bureau of Reclamation. Boise, Idaho. 27pp.

Stanford, J.A., F.R. Hauer., T.J. Stuart, 1979. Annual Report of Work Completed during 1978-79 on Limnology of Flathead Lake-River Ecosystem, Montana. Flathead Research Group. Univ. of Montana Biological Station. Submitted to Environmental Protection Agency Denver, Colorado. 155pp.

Stefanich, F.A. 1953. Natural reproduction of kokanee in Flathead Lake and tributaries. Montana Dept. Fish Game. Job Compl. Rep. 6p.

Stefanich, F.A. 1954. Natural reproduction of kokanee in Flathead Lake and tributaries. Montana Dept. Fish Game. Job Compl. Rep. 10p.

Stober, Q.J., R.E. Marita and A.H. Hamalainen. 1978. Instream flow and the reproductive efficiency of sockeye salmon. Fish Res. Inst., Univ. Wash., Seattle, Wash. 124p.

Sweeney, B.W. 1978. Bioenergetics and developmental response of a mayfly to thermal variations. Limnol. Oceanogr. 23:461-477.

Thorup, J. and C. Lindegaard. 1977. Studies on Danish springs. Folia Limnol. Sound. 17:7-15.

Wade, D.T., R.G. White, and S. Mate 1978. A Study of Fish and Aquatic Macroninvertebrate Fauna in the South Fork Boise River below Anderson Ranch Dam. Annual Progress Report. Idaho Coop. Fishery Research Unit. Univ. of Idaho 117pp.

Wallace J.B., J.R. Webster, and W.R. Woodall. 1977. The role of filter feeders in flowing waters. Arch. Hydrobiol. 79(4):506-532.

Wallace, R.L. 1979. Review of cutthroat trout: taxonomy evolution and distribution. Summary of paper presented to Amer. Fish Soc. West Yellowstone, Mt.

Ward, J.V. 1974. A temperature stressed stream ecosystem below a hypolimnial release mountain reservoir. Arch. Hydrobiol. 74:247-275.

LITERATURE CITED CONT.

WARD, J.V. 1976a Comparative limnology of differentially regulated sections of a Colorado mountain river. Arch. Hydrobiol. 78(3): 319-342.

Ward, J.V. 1976b. Effects of thermal constancy and seasonal temperature displacement of community structure of stream macroinvertebrates. pp 302-307. In. Thermal Ecology II. G.W. Esch and R.W. McFarlane (ed) ERDA Symposium Series (CONF-750425).

Ward, J.V. and R.A. Short. 1978. Macroinvertebrate community structure of from special lotic habitats in Colorado U.S.A. Verh. Int. Verein. Limnol. 20:1382-1387.

Ward, J.V. and J.A. Stanford. 1979. Ecological factors controlling stream zoobenthos with emphasis on thermal modification of regulated streams. pp.35-55: In: The Ecology of Regulated Streams. Ward, J.V. and J.A. Stanford (eds) Plenum Publishing Corp. New York.

Waters, T.F. and G.W. Crawford. 1973. Annual production of a stream mayfly population. A comparison of methods. Limnol. Oceanogr. 18: 286-296.

Young, W.C., D.H. Kent, and B.G. Whiteside. 1976. The influence of a deep storage reservoir on the species diversty of benthic macroinvertebrate communities of the Guadaloupe River. Texas. Texas. J. Sci. 27: 213-224.

Ziebell, C.D. 1973. Ultrasonic transmitters for tracking channel catfish. Prog. Fish. Cult., 35(1): 28-32.