The Impact of Hungry Horse Dam on the Kokanee Fishery of the Flathead River

by

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EXECUTIVE SUMMARY

This study is part of an effort to evaluate the feasibility of increasing power production at Hungry Horse Dam and constructing a reregulating dam downstream. Of particular concern is the impact of the operation of Hungry Horse Dam on the kokanee fishery in the Flathead River. This report includes results from our second field season.

Spawning migration of kokanee into the Flathead River was two weeks later in 1980 than 1979. Kokanee moved upstream at a faster rate in 1980. The estimated number of kokanee in McDonald Creek, a major spawning area, was 45,400 by late October. This was approximately 20-30 percent fewer than in 1979. The number of redds observed in the main stem Flathead River was 467, over 80 percent fewer than in 1979. Only 77 redds were observed in areas not influenced by springs.

Controlled flows provided during the peak spawning period (November) at Columbia Falls between 1700 hours and 2300 hours were not to exceed 5,000 cfs. Although spawning was limited, controlled flows appeared to be successful in forcing fish to spawn below water levels that would be dewatered during the winter. Estimated mortality of eggs due to dewatering was less than five percent during 1980-81 season, compared to more than 60 percent in 1979-80.

Egg dewatering experiments were conducted on green and eyed eggs to assess the impact of flow fluctuations on reproductive success. Kokanee eggs survived overnight (12 hours) dewatering until air temperatures approached -10° C. During cold weather, complete mortality can occur in less than 12 hours. During mild weather, excessive egg mortality was observed in 16 hours for green eggs and approximately 40 hours for eyed eggs.

Repeated dewatering can result in significant cumulative egg mortality. Eggs subjected to overnight dewatering seven days per week suffered 98.6 percent mortality to emergence compared to 44 percent for the control. Emergence was delayed about one month in the seven day peaking channel compared to the control.

Analysis of stream flow and kokanee year class strength indicates that operation of Hungry Horse Dam ~~operation~~ affects Flathead kokanee populations. We correlated kokanee length with the difference between mean incubation and spawning river gauge heights. A logarithmic plot of the relationship resulted in a good fit ($r^2 = .853$). Natural log of kokanee length correlated well with mean hours per day of incubation flows more than 0.37 m lower than spawning flows ($r^2 = .855$). Frequency of egg dewatering was highly correlated with kokanee length ($r^2 = .899$).

The feasibility of developing a flow regime for successful kokanee reproduction out of Hungry Horse Dam and a reregulating dam are contingent on the availability of water from the project and the capacity of the proposed reregulating dam. Sound management also requires planning for

low water years. Surplus storage would be available in an eightieth percentile flow year at spawning flows ranging from 3,500 to 6,000 cfs. The proposed reregulating dam would be ineffective at reducing egg mortality due to dewatering if spawning flows exceeded 4,000 cfs (with a 145 cfs minimum flow from Hungry Horse) or 4,500 cfs (with a 500 cfs minimum flow from Hungry Horse). This will also require Hungry Horse to develop a more consistent cyclic and seasonal operating regime.

Data is presented on relative abundance, movement and age and growth of westslope cutthroat trout, rainbow trout, bull trout and mountain whitefish in the main Flathead River during the study period.

A minimum flow of 2,500 cfs at Columbia Falls between July 1 and April 30 was recommended. This would provide a more stable base for fish and fish food habitat. The recommended minimum flow is less than the mean monthly flow over the period of record during every month.

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Cathy Turley typed the manuscript.

TABLE OF CONTENTS

TABLE OF CONTENTS CONT.

TABLE OF CONTENTS CONT.

LIST OF TABLES

LIST OF TABLES CONT.

LIST OF FIGURES

LIST OF FIGURES CONT.

LIST OF FIGURES CONT.

LIST OF FIGURES CONT.

INTRODUCTION

Impoundment of the South Fork Flathead River began in 1948 and was completed in 1952 with the construction of Hungry Horse Dam. At that time, Hungry Horse was the fourth largest concrete dam in the world. Located eight km upstream from the mouth of the South Fork, Hungry Horse created a reservoir approximately 66 km long with a storage capacity of 3,461,000 acre feet (af). The dam is operated primarily for flood control and hydroelectric energy production. The crest of the dam is 172 m high (1,087 m above mean sea level). Penstocks are located 75 m below the crest. At present peak capacity, the powerhouse produces 328 Mw.

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

Present minimum flow from Hungry Horse is approximately 145 cfs. Rated capacity is 11,417 cfs. All of the aquatic biota in the main stem Flathead is affected to some degree by Hungry Horse Dam. Among those organisms most directly affected are kokanee salmon (*Oncorhynchus nerka*), westslope cutthroat trout (*Salmo clarki lewisi*), mountain whitefish (*Prosopium williamsoni*) and all aquatic invertebrates. This report will deal only with effects on fish populations.

The Hungry Horse project is part of the Bonneville Power Administration electrical energy grid. Operation of Hungry Horse is determined in concert with the complex network of electrical energy producing systems, consumption needs and flood control requirements throughout the Pacific Northwest. Water leaving Hungry Horse passes through 19 dams before reaching the Pacific Ocean.

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

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

Hungry Horse alternatives are being evaluated both with and without a reregulating dam. The proposed reregulating dam would be located on the South Fork and have a storage capacity of 1,950 af. Increased peaking power at Hungry Horse could result in as much as a ten percent increase in total annual power production.

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

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

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

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

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

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

a. Determining the relative contributions of various spawning areas in the Flathead Drainage.

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

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

In its present operational mode, variations in Hungry Horse's annual, monthly and daily flows can be extreme and unpredictable. Operation ranges from full generation 24 hours per day for many days to no generation for long periods due to the many constraints under which the project now operates. Uprate of existing generators or adding generators would increase peak discharges and river fluctuations. The reregulating dam could moderate daily fluctuations; however, its small storage capacity would make it ineffective in maintaining constant flows after two or more days of either peak discharge or minimum discharge.

Balancing the needs of the Flathead's aquatic biota with electrical energy production would be difficult even with a predictable flow regime.

Under the present Hungry Horse operation, aquatic resource management options are extremely limited. Unless a predictable operational mode is effected, no improvement in the kokanee fishery can be expected and its productivity will continue to decline.

DESCRIPTION OF STUDY AREA

The Flathead River drains 21,876 km² of southeast British Columbia and Northwest Montana (Figure 1). 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 out of British Columbia forming the western boundary of Glacier National Park. From the Canadian border to Camas Creek, a distance of 68 km, the North Fork is classified a scenic river under the National Wild and Scenic Rivers Act. The lower 24 km 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 southwestern 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 2.5 m daily due to peak hydroelectric energy production (Figure 2).

The main stem Flathead River is classified a recreational river from the confluence of the North and Middle Forks to the confluence of the South Fork. Downstream of the South Fork, flows in the main stem are partially 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). During fall and winter, the main stem hydrograph mirrors that of the South Fork. Daily vertical water level fluctuations in the main stem, due to Hungry Horse operation, can vary as much as 1.4 m (Figure 2).

Water temperature in the main stem is 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 River.

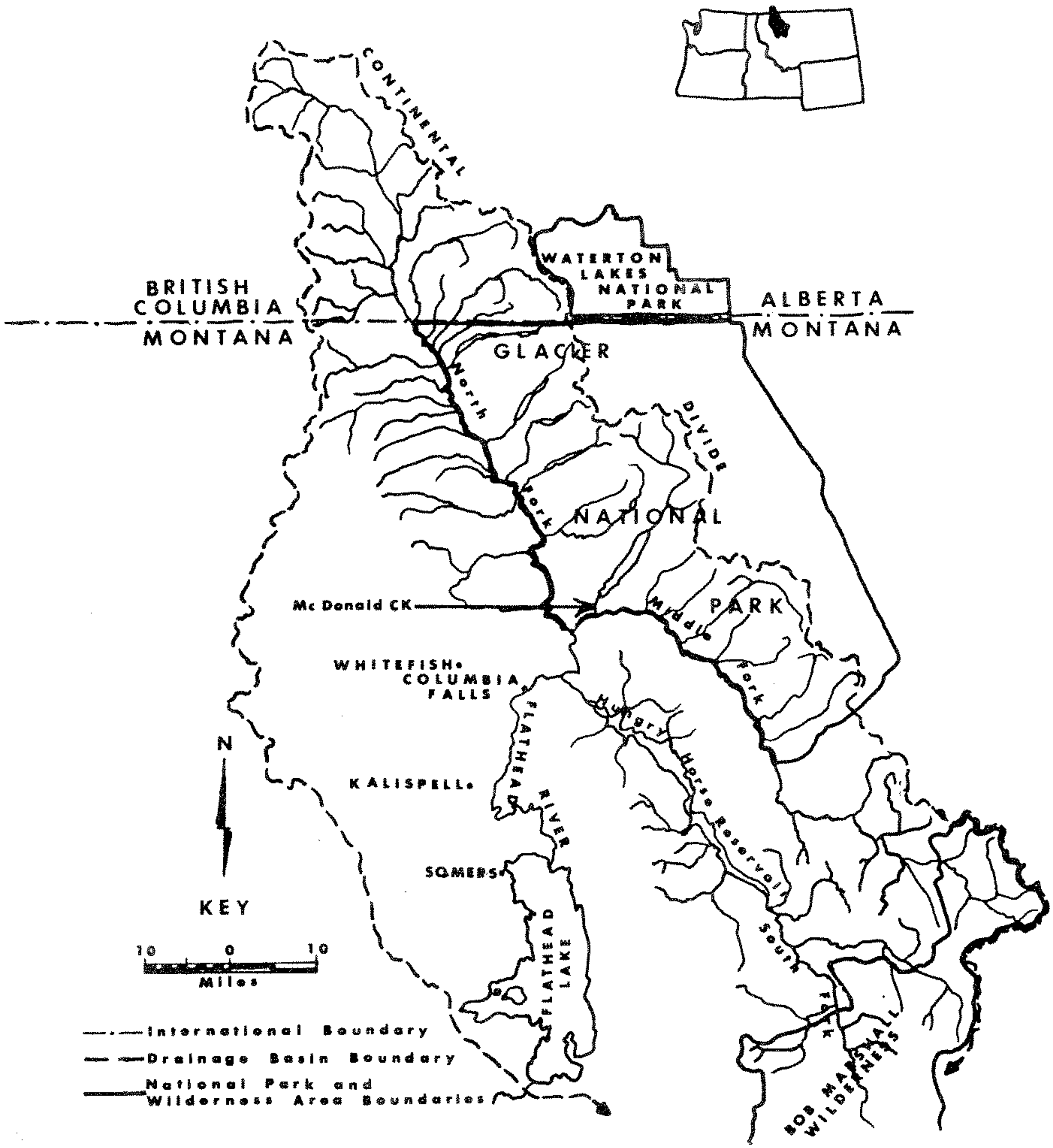

Figure 1. The upper Flathead drainage.

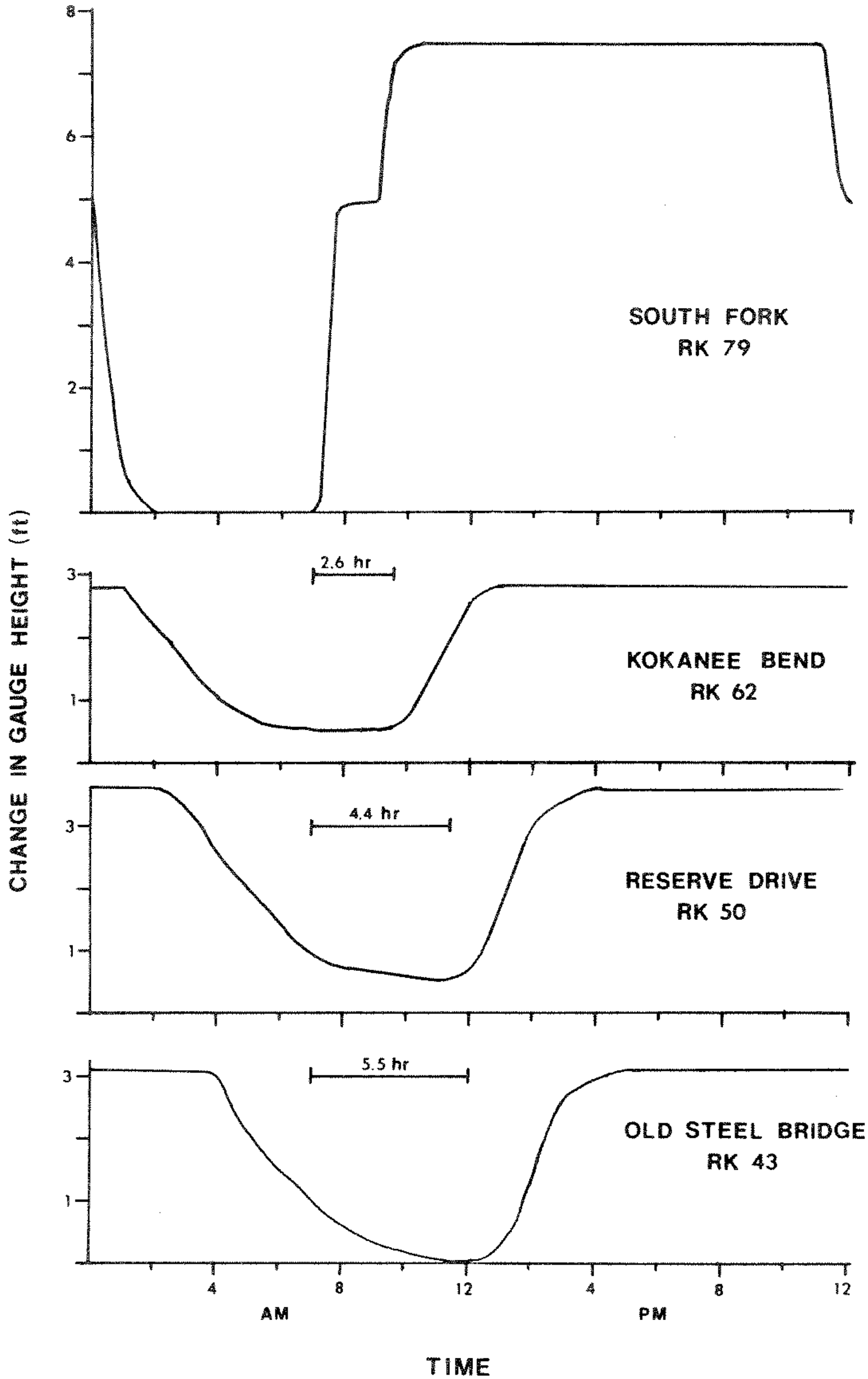

Figure 2. Vertical water level changes in the South Fork and three areas of the main stem Flathead River as a result of generation at Hungry Horse Dam, August 2, 1979. Range of flows is 164 cfs to 9,100 cfs in the South Fork and 3,210 cfs to 12,100 cfs in the main stem.

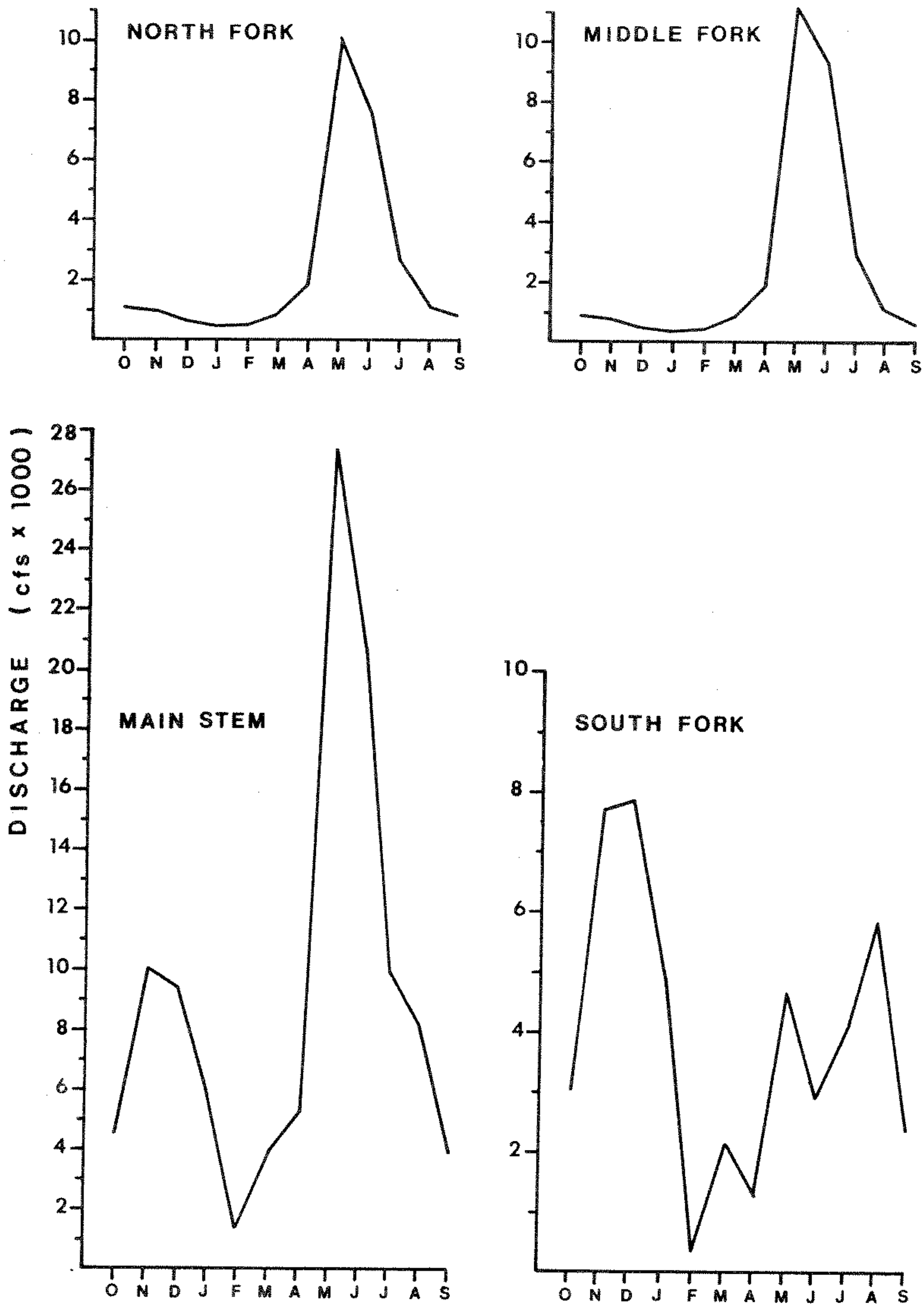

Figure 3. 1979 hydrographs for the North Fork near Canyon Creek, Middle Fork near West Glacier, South Fork near Hungry Horse and Flathead River at Columbia Falls.

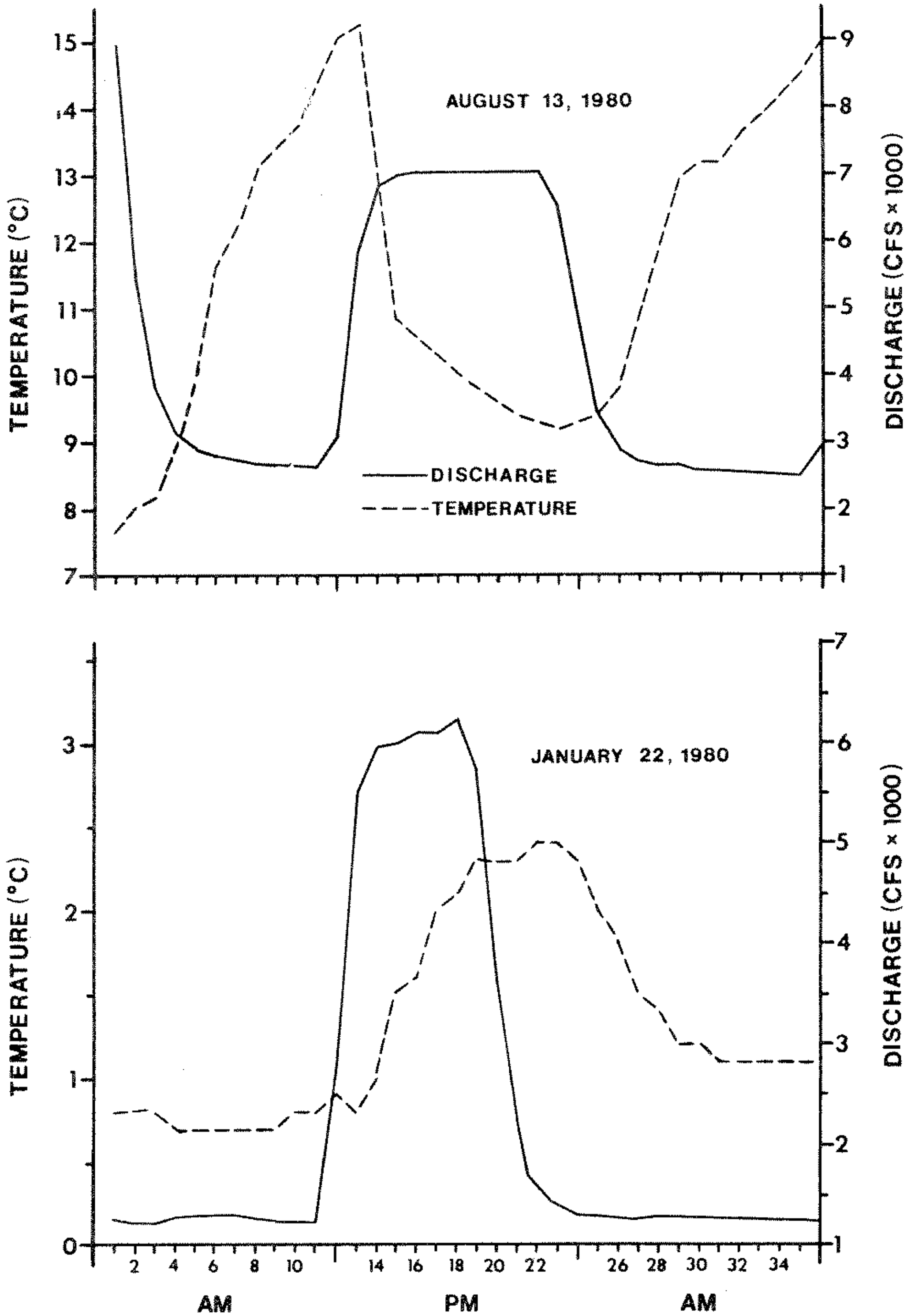

Figure 4. Flow-related temperature fluctuations in the main stem Flathead River at Columbia Falls on a winter day and a summer day.

Westslope cutthroat, bull trout (*Salvelinus confluentis*) and kokanee provide most of the sport fishing in the Flathead River (Hanzel 1977). Cutthroat and bull trout are native to the Flathead, but kokanee is an introduced species.

Cutthroat migrate up the Flathead River from Flathead Lake in winter and early spring. Exact timing of migration may be affected by operation of Hungry Horse powerhouse (Huston and Schumacher 1978). Spawning occurs in May and June in tributaries of the North and Middle Forks.

Three distinct life history patterns of westslope cutthroat commonly occur throughout their native range (Behnke 1979). Adfluvial cutthroat reside in small streams for one to three years before emigrating to a lake. Growth is generally more rapid in lakes than in streams. After a period of one to three years in a lake, adfluvial cutthroat mature and ascend tributary streams to spawn. Westslope cutthroat probably evolved as adfluvial fish in Glacial Lake Missoula (Wallace 1979). Fluvial westslope cutthroat follow a life history pattern similar to adfluvial fish except maturation occurs in a large river. Spawning typically occurs in smaller tributaries. Resident westslope cutthroat spend their entire lives in small headwater streams.

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

Bull trout begin migrating up the Flathead River in spring. Spawning occurs in North and Middle Fork tributaries during September and October. Bull trout support an important trophy fishery in the main stem, North Fork and Middle Fork from May through September, and year around in Flathead Lake. Regulations forbid taking of bull trout less than 457 mm (18 inches) in length. Anglers commonly harvest bull trout weighing two to five kilograms and occasionally up to 10 kilograms.

In terms of total harvest only, kokanee is easily the most important game fish in the Flathead drainage. Anglers troll Flathead Lake year around for kokanee. A regionally important snagging fishery centers around fall kokanee spawning migrations. Spawning occurs from late September through December in several areas of the drainage including the Middle Fork, McDonald Creek, the main stem Flathead, Whitefish River, Swan River and Flathead Lake. Main stem spawners are directly affected by fluctuating water levels caused by operation of Hungry Horse powerhouse.

Other fish species are probably affected by Hungry Horse operations during at least a portion of their life histories. Other species commonly found in the Flathead include rainbow trout (*Salmo gairdneri*), mountain whitefish and largescale sucker (*Catostomus macrocheilus*). Several other species are encountered less frequently, including brook trout (*Salvelinus fontinalis*), Yellowstone cutthroat trout (*Salmo clarki bouvieri*), lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), 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.

Resident fish population and cutthroat trout sampling was confined to six electrofishing sections (Figure 5). Main stem kokanee spawning areas we sampled are described by Graham et al. (1980a, Appendix B).

KOKANEE MIGRATION, SPAWNING AND INCUBATION

INTRODUCTION

Kokanee were probably introduced to Flathead Lake in 1916. After a period of colonization, a thriving kokanee fishery developed by the early 1930's. Kokanee has become the dominant game fish in the Flathead drainage, supporting a trolling fishery in Flathead Lake throughout the summer and a short-lived but intense snagging fishery during fall in the Flathead River. Kokanee comprised over 80 percent of the harvest in the Flathead River in 1975 (Hanzel 1977).

Flathead's kokanee fishery has developed into one of regional importance. Summer home owners and tourists from all over western North America fish for kokanee in Flathead Lake during summer. Anglers from most of the western states, British Columbia and Alberta converge on the Flathead in September and October to snag salmon on their spawning migration. High catch rates and liberal bag limits have combined to make the fishery extremely popular.

Historically, most kokanee spawning in the Flathead drainage occurred along the shores of Flathead Lake, in McDonald Creek, and the Whitefish River (Stefanich 1953, 1954). Following impoundment of the South Fork by Hungry Horse Dam in 1952, a shift towards increased river spawning and decreased lake spawning was noted (Hanzel 1964). Reasons for the shift were not documented, but it was probably related to habitat changes in the Flathead River caused by regulation of the South Fork. Hypolimnial releases from Hungry Horse Dam increased late fall and winter water temperatures in the Flathead River over historical averages. Prior to construction of Hungry Horse, cold river temperatures probably limited reproductive success in the main stem river.

At the present, the amount of spawning in Flathead Lake is unknown. Of those spawning areas in the drainage that have been investigated during this study, McDonald Creek is by far the most important. Depending on

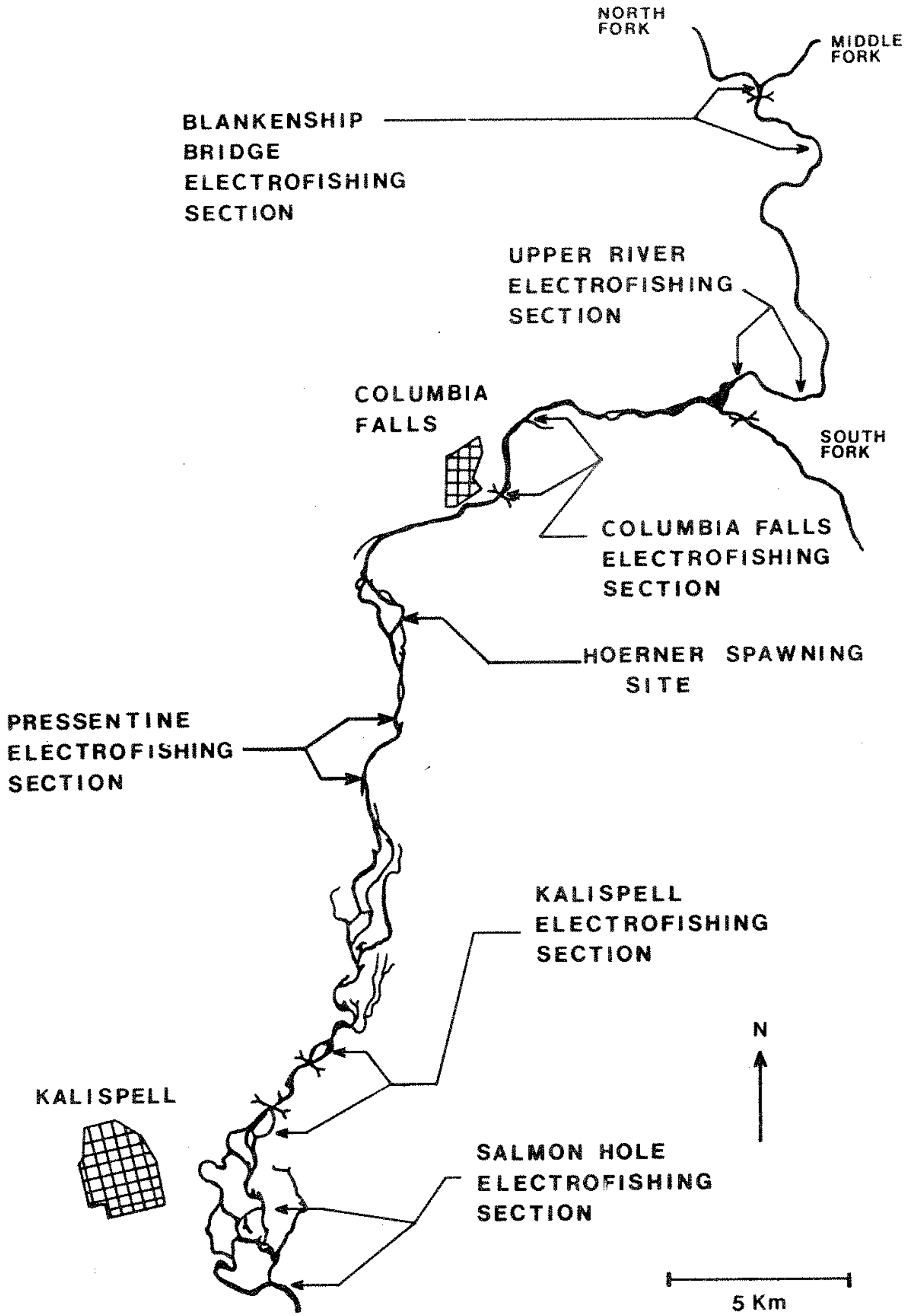

Figure 5. Sample sites in the Flathead River, 1980-81.

the strength of respective spawning runs, other areas that can make substantial contributions include the Nyack Flats area of the Middle Fork, the lower Middle Fork below McDonald Creek, main stem Flathead River below its confluence with the South Fork and the Whitefish River. A few kokanee spawn in the South Fork below Hungry Horse Dam and in the North Fork drainage.

South Fork and main stem spawners are directly affected by operation of Hungry Horse Dam. Kokanee prefer shallow areas with moderate water velocities for spawning. In large rivers like the Flathead, those preferences limit spawning to areas near the banks and in side channels. Vertical water level fluctuations of over two meters in the South Fork and up to 1.4 m in the main stem can result in alternate wetting and dewatering of eggs if flows are high during spawning. Since eggs incubate in the stream gravels over winter, dewatering can quickly cause death due to freezing.

McNeil (1968) determined that incubation mortality was the most important factor governing year class strength of pink salmon (*Oncorhynchus gorbuscha*) in southeast Alaska streams. Stober et al. (1978) obtained similar results with sockeye salmon in the Cedar River, Washington.

Incubation mortality is probably the most important factor governing year class strength of Flathead kokanee. Eggs deposited in the South Fork, main stem, and Flathead Lake are all subject to water level fluctuations. Incubation mortality can vary greatly from year to year, depending on water level fluctuations.

Information on year class strength is important to managers of a kokanee fishery because in a given year, a single year class supports most of the fishing pressure. A weak year class of age III+ kokanee usually results in poor fishing, even if succeeding year classes are strong.

METHODS

Migration

Migration of kokanee spawners was monitored by direct underwater observation (snorkeling) and mark and recapture. We snorkeled throughout the drainage in an effort to assess the distribution of successive waves of migrating kokanee. Mark and recapture methods were used to help identify destinations of kokanee that migrated through the lower main stem at various times. Tag return information was also used to determine migration rates. No creel census information was gathered in 1980.

We spot-checked the North and Middle Forks in late September by snorkeling near 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 Moose, Coal, Camas and Canyon creeks. The Middle

Fork was snorkeled near Ole, Paola, Crystal and Deerlick creeks. Snorkel surveys of the North and Middle Forks were repeated in mid-October.

We snorkeled the entire length of lower McDonald Creek (from the outlet of Lake McDonald to the mouth of McDonald Creek) and all pools in the Middle Fork below McDonald Creek in late September. McDonald Creek was snorkeled a second time in late October. High turbidity in the Middle Fork prevented a second survey.

The main stem Flathead River was spot-checked from the confluence of the North and Middle Forks to the Kalispell electrofishing section. The survey was conducted during the last week of September.

We tagged 301 kokanee with blue dart tags on September 15, 1980 in the Kalispell electrofishing section. We planned to tag at least two more groups of kokanee, but were unable to do so for the remainder of the season. After the first wave of kokanee passed through the Kalispell area, too few kokanee were present to permit mass marking.

Spawning

The Bureau of Reclamation, Bonneville Power Administration and Montana Department of Fish, Wildlife and Parks agreed to test experimental kokanee spawning and incubation flows in the Flathead River in water year 1981. The experimental flow regime simulated operation of a reregulating dam and was designed to prevent kokanee from spawning in areas that would be subsequently dewatered. The cooperating agencies agreed to restrict generation at Hungry Horse Dam between 1500 hours and 2100 hours throughout the month of November, so that flows gauged in the main stem at Columbia Falls between 1700 hours and 2300 hours would not exceed 5,000 cfs. Minimum flow in November was estimated to be high enough to prevent excessive dewatering mortality during periods of no generation.

Kokanee redd counts in the main stem between the mouths of the Stillwater and South Fork Flathead Rivers were made during the first and last weeks of November, 1980. All areas that contained suitable gravels were carefully inspected on foot whenever possible. Deeper areas were checked from a boat.

Because of the high density of spawners in McDonald Creek, and resulting superimposition of redds, no attempt was made to count redds. We did not attempt to locate or count redds in the North or Middle Forks.

Redds in the Whitefish River were counted on October 16, 1980. Spawning in the Whitefish River was nearly complete at that time.

A portion of McDonald Creek and major spawning areas in the main stem were mapped. Qualitative observations were used to separate good and poor spawning gravels in each area. Gravels were separated primarily on the basis of size of predominant gravels. Gravels containing a large proportion of either large (>50 mm) substrate or small (sand, silt) substrate were considered poor.

Incubation

Experimental incubation flows were designed to minimize long-term dewatering of kokanee eggs in the main stem. A minimum flow constraint of 2,000 cfs at Columbia Falls was agreed upon by the cooperating agencies. Based on our observations of main stem spawning in November, 1980, we determined that few main stem redds would be dewatered at flows equal to or exceeding 2,000 cfs.

Due to the poor run of kokanee spawners into the main stem in 1980, sampling of eggs and alevins was extremely limited. Nearly all main stem spawning in 1980 was located in spring areas where impacts of Hungry Horse operations were minimal. Main stem redds in affected areas were sampled on February 23-24, 1981.

Density of egg deposition and live:dead ratio in McDonald Creek were estimated on December 12, 1980. Subsequent attempts to sample McDonald Creek were aborted due to high water. Mild winter weather and rain resulted in higher flows in McDonald Creek than in water year 1980. Increased depth limited the effectiveness of our hydraulic sampling apparatus.

Emergence

Limited sampling to determine timing of fry emergence was undertaken in spring 1981. Fry emigrating from McDonald Creek and Columbia Falls slough were netted once per week from April 1 to May 4. Other areas were spot-checked as water conditions allowed. Square nylon nets with an opening measuring 0.5 m^2 were used to catch fry. The nets were 1.6 m long and consisted of two mesh sizes. The throat of the net was made of 1.6 mm mesh while 3.2 mm mesh was used near the mouth.

Dewatering experiments

We conducted a series of experiments during the winter of 1980-81 to determine tolerance of kokanee eggs at various stages of development to dewatering. Simultaneous short-term experiments were conducted at the Hoerner spawning area in the Flathead River and in artificial stream channels located at Somers salmon hatchery (Figure 6). Long-term experiments were conducted in the artificial stream channels.

Short-term dewatering experiments with green eggs were conducted at both sites in early December. Sixty-four fiberglass screen bags containing gravel and 100 green eggs each were buried approximately 10 cm below the gravel surface at the Hoerner site (Figure 5). The bags were split into two groups, one buried below minimum flow elevation and one buried above minimum flow elevation. Rising water caused by generation at Hungry Horse wetted the upper group shortly after burial. Generation at Hungry Horse continued for several hours then ceased overnight. The same pattern was followed the next day. After generating for approximately eight

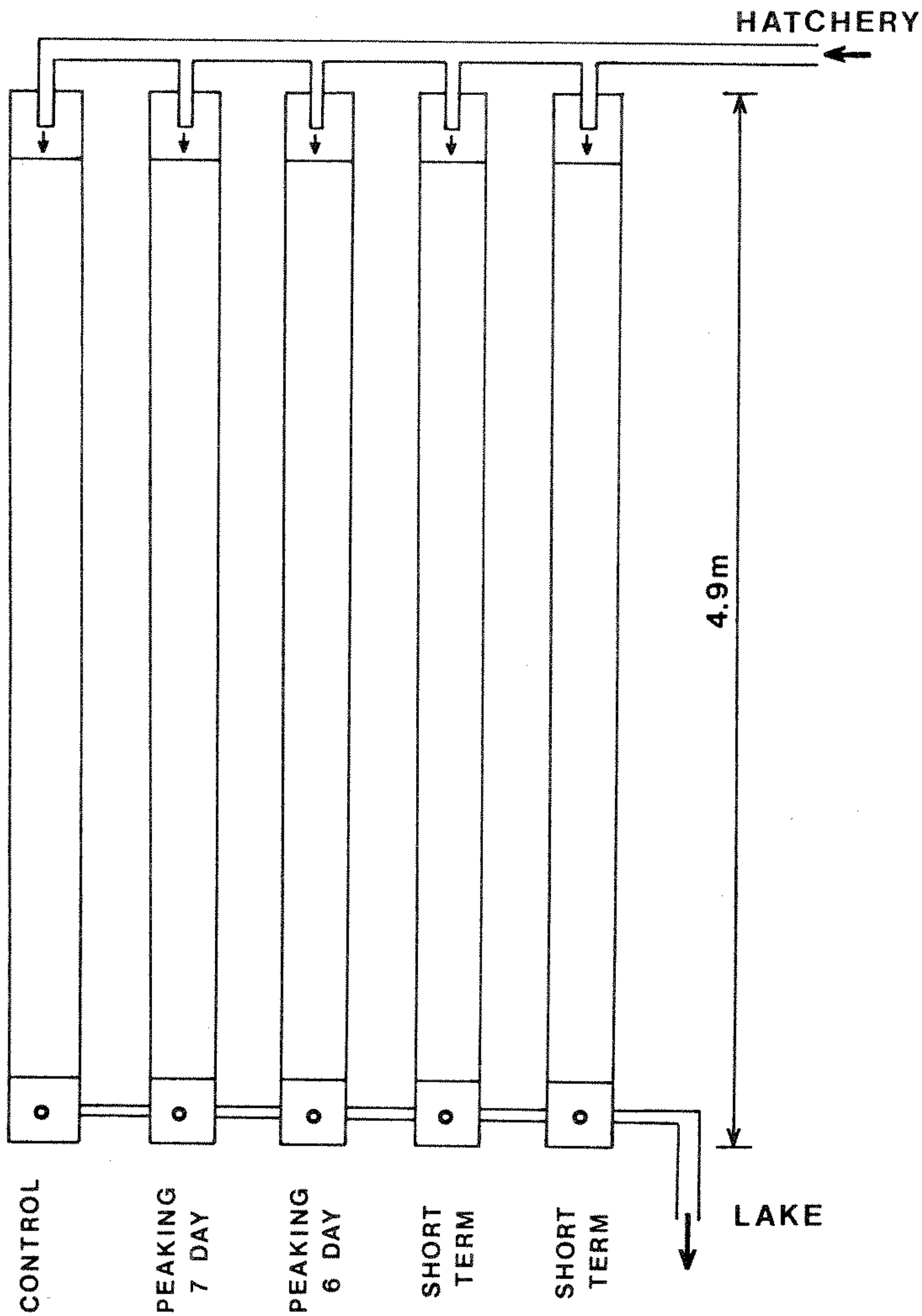

Figure 6. Schematic diagram of artificial stream channels at Somers hatchery. The channels were used to perform kokanee egg dewatering experiments under controlled conditions.

hours on the third day, operations at Hungry Horse ceased for the weekend. Eggs from the wetted and dewatered groups were excavated periodically throughout the period to assess mortality. Air and gravel temperatures were monitored throughout the experiment.

Twelve bags containing 100 green eggs each were buried approximately 10 cm below the gravel surface in each of two channels at Somers. Eggs in the Somers channels were not dewatered overnight. Weekend dewatering began approximately one hour earlier in the Somers channels than at the Hoerner site. Temperatures at Somers were monitored with a multiprobe thermograph. Eggs in both channels (one 15 cm deep, one 25 cm deep) were excavated on the same schedule as those at the Hoerner site.

A second set of simultaneous experiments was conducted with eyed eggs in early February. Procedures were identical to those described previously. Weather during the eyed egg experiment was similar to that experienced during the green egg experiment, but milder than mid-winter average. A cold front lowered temperatures significantly immediately after the eyed egg experiment was completed. A second experiment with eyed eggs was conducted at Somers only during the cold spell.

Long-term dewatering experiments were conducted in three artificial channels at Somers hatchery. Eggs were buried free in the gravel, approximately 10 cm below the surface. Eggs in one channel were wetted continuously. Eggs in the second channel were subjected to a seven-day peaking regime. Eggs were watered from 0800 hours until 1700 hours each day. Eggs in the third channel were subjected to a six-day peaking regime, identical to the second channel, except they were dewatered from 1700 hours Saturday until 0800 hours Monday (39 consecutive hours) each week. We buried a total of 1000 eggs each in the continuously wetted and seven-day peaking channels and 900 eggs in the six-day peaking channel.

Stream flow-year class strength relationships

We continued to investigate the relationships between Flathead River flows during the kokanee spawning and incubation seasons and year class strength of kokanee produced as a result of those flows. Length of kokanee spawners was used as an indicator of year class strength. We assumed that growth was inversely proportional to population size, an assumption backed up by several researchers (Bjornn 1957, Foerster 1944, Johnson 1965, Goodlad et al. 1974, Stober et al. 1978).

Interactions between as well as within year classes can affect kokanee growth. To account for year class interactions, we used a weighted three-year moving average of flow conditions when calculating independent variables. Interactions and an example of independent variable calculation are detailed in a previous report (Graham et al. 1980a).

Several new relationships were tested and refinements of the previously reported relationships were made. Data corresponding to the 1980 spawn year were incorporated.

Flow redistribution

Management of flows appears to be the best method of optimizing kokanee reproductive success in the main stem Flathead River. We made a series of calculations to determine the capacity of Hungry Horse Dam to provide optimum incubation conditions in the main stem at various spawning flows under fiftieth and eightieth percentile flow conditions. The calculations were made assuming existing power capacity with a reregulating dam. Unless otherwise stated, all flows refer to the U.S.G.S. gauging station on the main stem at Columbia Falls.

Calculations were made for spawning (November) flows ranging from 3,500 cfs to 6,000 cfs in 500 cfs increments. We estimated incubation flows could be 0.37 m lower than spawning flows (1.2 ft. stage at Columbia Falls) without causing significant egg mortality due to dewatering. Spawning flows and associated incubation flows are listed in Table 1.

Table 1. Incubation flows needed to wet most redds at a range of spawning flows from 3,500 to 6,000 cfs.

Spawning flow(cfs)	Incubation flow(cfs)
3,500	1,840
4,000	2,150
4,500	2,490
5,000	2,830
5,500	3,200
6,000	3,570

Hungry Horse outflows needed to meet spawning flow criteria were estimated by determining the flow, in excess of North and Middle Fork flows, needed to achieve the desired flow at Columbia Falls. We assumed the spawning flow would be provided six hours per day, seven days per week throughout November . We assumed Hungry Horse would provide enough water to achieve incubation flows at Columbia Falls the other 18 hours per day. A minimum Hungry Horse outflow of 145 cfs was assumed. Hungry Horse outflow during the incubation period was calculated as the discharge in excess of North and Middle Fork flows needed to achieve the desired flow at Columbia Falls continuously from December through March.

Fiftieth and eightieth percentile flows were drawn from data for water years 1929-1980 (Table 2). Data were provided by the Bureau of Reclamation, Boise District office.

We also estimated the capacity, in hours, of the proposed reregulating dam to provide flows designed to meet spawning and incubation flow criteria.

Calculations were based upon assumptions of a full rereg pool (1,950 af) and inflows of either 145 cfs or 500 cfs.

Table 2. Fiftieth and eightieth percentile flows in the combined North and Middle Forks and in the South Fork (Hungry Horse Reservoir inflow) during kokanee spawning and incubation periods. Data for water years 1929-1980 provided by Bureau of Reclamation.

	North and Middle Forks		South Fork	
Month	50% (cfs)	80% (cfs)	50% (cfs)	80% (cfs)
November	1,875	1,244	986	563
December	1,440	1,042	981	676
January	1,239	986	944	554
February	1,272	966	841	587
March	1,474	1,156	992	716

RESULTS AND DISCUSSION

Migration

Adult kokanee were caught periodically throughout the summer in our electrofishing sections. The first large concentration of kokanee appeared in the Kalispell area in mid-September, approximately two weeks later than in 1979. Rate of upstream movement was more rapid in 1980 than in 1979. Minimum migration rate of early run kokanee recaptured in 1980 was 2.9 km/day versus 1.5 km/day in 1979.

Anglers returned 29 (9.6 percent) kokanee tags in 1980. In 1979, 13.5 percent of the early run tags were returned. The lower harvest rate in 1980 is probably a result of more rapid movement. Kokanee spent less time holding in the Kalispell and West Glacier areas in 1980 than in 1979. A significant portion of the early run harvest occurred in those areas in 1979.

Anglers returned two tags from kokanee caught in the Middle Fork at the mouth of McDonald Creek. A third tagged kokanee was observed in McDonald Creek during our snorkel surveys.

We observed no kokanee during two snorkel surveys of the North Fork in 1980. No kokanee were observed in the Middle Fork above McDonald Creek in late September. Approximately 25 kokanee were seen in the Middle Fork at the mouth of Deerlick Creek on October 10. Approximately 500 kokanee were observed in Beaver Creek (tributary of Deerlick Creek) in November 1980 (Gordon Pouliot, West Glacier, Montana, personal communication).

We estimated 36,000 kokanee were present in McDonald Creek on September 25, 1980 (range = 29,000 - 43,000). The September, 1980 estimate was much higher than the September, 1979 estimate of approximately 1,500. Most McDonald Creek kokanee held in the Middle Fork below the mouth of McDonald Creek for two to three weeks in 1979, probably because of warm water temperatures in McDonald Creek. Late September temperatures in McDonald Creek ranged from 17° to 19° C in 1979 compared to 13° to 14° C during September 1980.

Few kokanee were observed in the Flathead drainage below McDonald Creek in late September, 1980. We saw approximately 450 kokanee in the lower Middle Fork, versus 7,000-12,000 in late September, 1979. Approximately 200-300 kokanee were seen in the main stem above the South Fork and less than 100 were seen below the South Fork.

A second snorkel survey of McDonald Creek on October 22 yielded 45,400 kokanee (range = 37,000 - 54,000). Approximately 4,000 kokanee had already spawned and died in McDonald Creek in 1980. Our 1979 estimate of 40,000-64,000 spawners in McDonald Creek was probably conservative compared with our 1980 estimate (which we considered to be more reliable). A total of 60,000-70,000 spawners in 1979 seems more likely.

Excessive turbidity prevented us from conducting a second snorkel survey of the lower Middle Fork. Because later migrations did not develop in 1980, we did not attempt a second survey of the lower drainage.

Spawning

A total of 467 kokanee redds were counted in the main stem below the South Fork in 1980, a reduction of over 80 percent compared to the 1979 redd count. Over 78 percent of the redds counted in 1980 were located in Columbia Falls and Brenneman spring sloughs (Table 3). Only 77 redds were counted in main stem areas not influenced by springs.

The poor main stem spawning run reduced our opportunity to assess the effects of experimental spawning flows; however, preliminary results were encouraging. Of redds located in the main stem and not affected by springs, 75 percent appeared to be located in areas that would not be dewatered at normal mid-winter low flows.

We counted 426 kokanee redds in the Whitefish River on October 16. Spawning was nearly complete on that date. Apparently, a temporal shift of kokanee spawning in the Whitefish River has occurred during the last 30 years. Stefanich (1952) reported catching 3,924 kokanee in a Whitefish River trap between November 19 and December 9, 1951.

Table 3. Kokanee redd counts by area of the main stem Flathead River in 1979 and 1980.

Landmark	River Kilometer	1979	1980
Columbia Falls slough	68.5	330	231
Main channel-east bank	68.2	100	0
Main channel-east bank	68.0	100	0
Columbia Falls slough-mouth	67.9	50	0
Main channel-east bank	66.8	20	0
Eleanor Island-west channel	61.8	0	1
Kokanee Bend	61.7	25	0
Kokanee Bend-end of road	61.6	25	0
Kokanee Bend-rockfield	61.2	250	0
Hoerner area	60.7	150	0
Buck's gardens	60.0	290	5
Pressentine-east bank side channel	56.2	200	1
Pressentine-east channel	56.1	100	7
Pressentine-east channel backwater	55.4	100	0
Pressentine-east channel	55.4	0	13
East channel	53.9	55	0
East channel	52.3	0	3
Gooderich Bayou	52.3	10	0
East channel-shack	51.8	9	0
East channel-log jam	51.7	350	0
Fairview Spring slough	51.5	119	12
Reserve Drive-slough	50.4	22	0
East channel-mouth	44.4	0	15
Spruce Park-side channel	44.3	0	6
Highway 2 bridge-side channel	43.8	60	11
Old Steel Bridge-west bank	42.8	0	25
Kiwanis Lane-west bank	41.8	7	1
East channel	41.0	1	0
East channel	40.9	2	0
East channel	40.7	2	0
Brenneman's Slough	38.6	425	136
TOTAL		2,802	467

Incubation

Approximately 90 percent of the eggs excavated in McDonald Creek control site on December 12, 1980 were alive. Survival was comparable to that in December, 1979. Spawning in the sample site was more dense than in most areas of McDonald Creek in 1980. Because of dense spawning activity, our estimate of egg deposition was much higher than estimated potential deposition (approximately 18.2 million eggs).

Sampling of main stem redds was limited due to the poor 1980 spawning run. Redds in the Spruce Park and Pressentine areas were sampled in late February, 1981. Survival in wetted redds was over 80 percent. Complete mortality was observed in most dewatered redds, although survival of less than 10 percent was found in some redds near the low water mark.

Based on our observation of the limited 1980 main stem spawning, experimental spawning flows had the desired effect of preventing most kokanee from spawning in areas dewatered during the winter. We estimate that mortality directly attributable to dewatering occurred in less than five percent of main stem redds during 1980-81 season. During the 1979-80 season, dewatering-caused mortality occurred in more than 60 percent of main stem redds.

Emergence

Emergence and smolting of juvenile kokanee in McDonald Creek occurred from late March through early May, 1981. Peak emigration of juveniles from McDonald Creek occurred during the third week of April (Figure 7). Peak emigration coincided with increasing flows and occurred approximately one month earlier than in 1978 (Montana Department of Fish, Wildlife and Parks, unpublished data).

Emergence and smolting in Columbia Falls slough occurred throughout the month of April, with a peak at mid-month (Figure 8). Peak spawning activity in Columbia Falls slough occurs approximately one month later than in McDonald Creek. However, warmer winter water temperatures in the Columbia Falls spring environment resulted in emergence at approximately the same time in 1981. During colder winters than that experienced in 1980-81, embryonic development of kokanee in McDonald Creek would be slower and emergence in Columbia Falls slough would probably occur as much as a month earlier than in McDonald Creek.

Catch of kokanee fry in the Middle Fork at the mouth of Deerlick Creek was declining by mid-April. Emergence of kokanee probably occurs earlier in Beaver Creek (a tributary of Deerlick Creek) than in any other kokanee spawning area in the drainage. Spawning in Beaver Creek normally peaks in October and the comparatively warm spring environment results in early emergence.

We were unable to sample fry from main channel spawning areas in the Flathead River. Nets cannot be used in main channel areas because

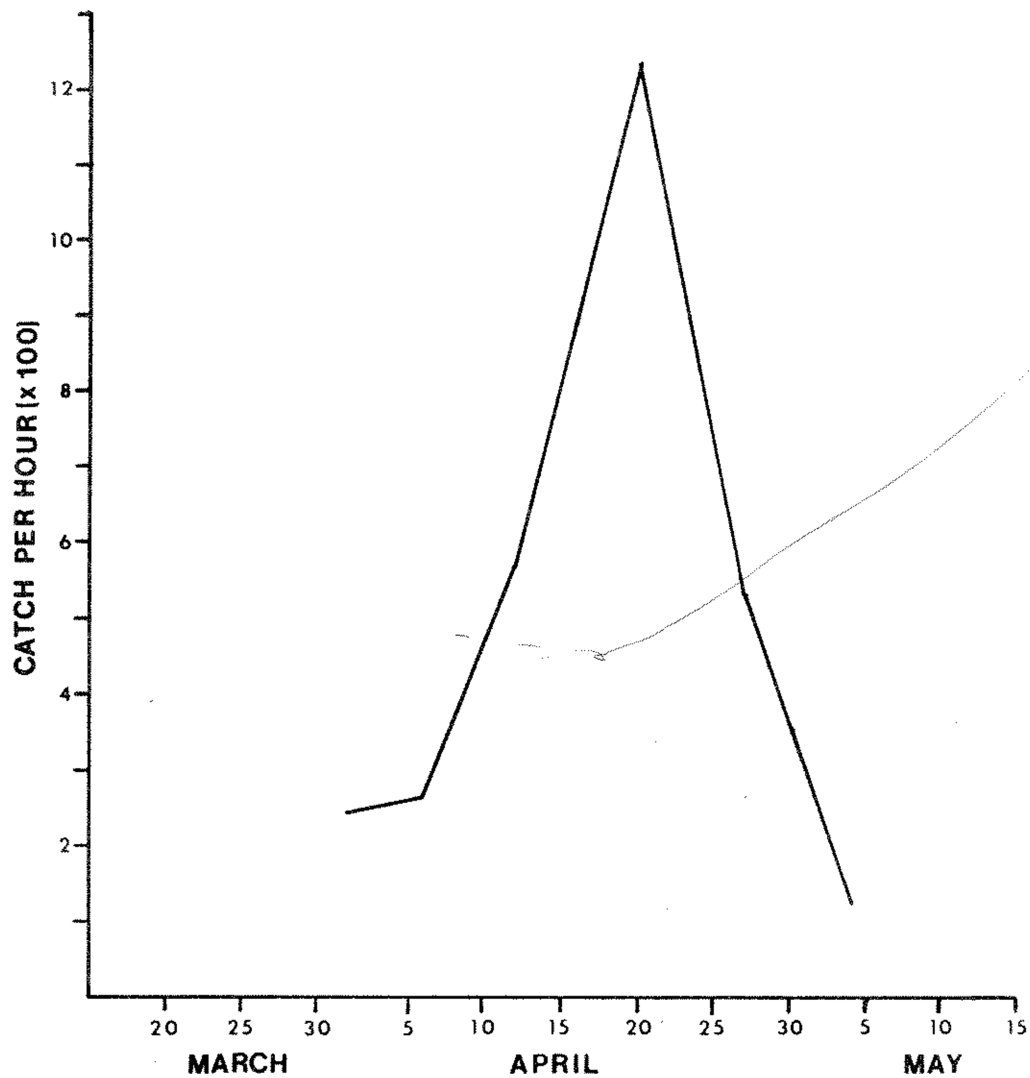

Figure 7. Relative abundance of kokanee fry emigrating from McDonald Creek, 1981, as determined by 0.5 m net catches at the mouth of the creek.

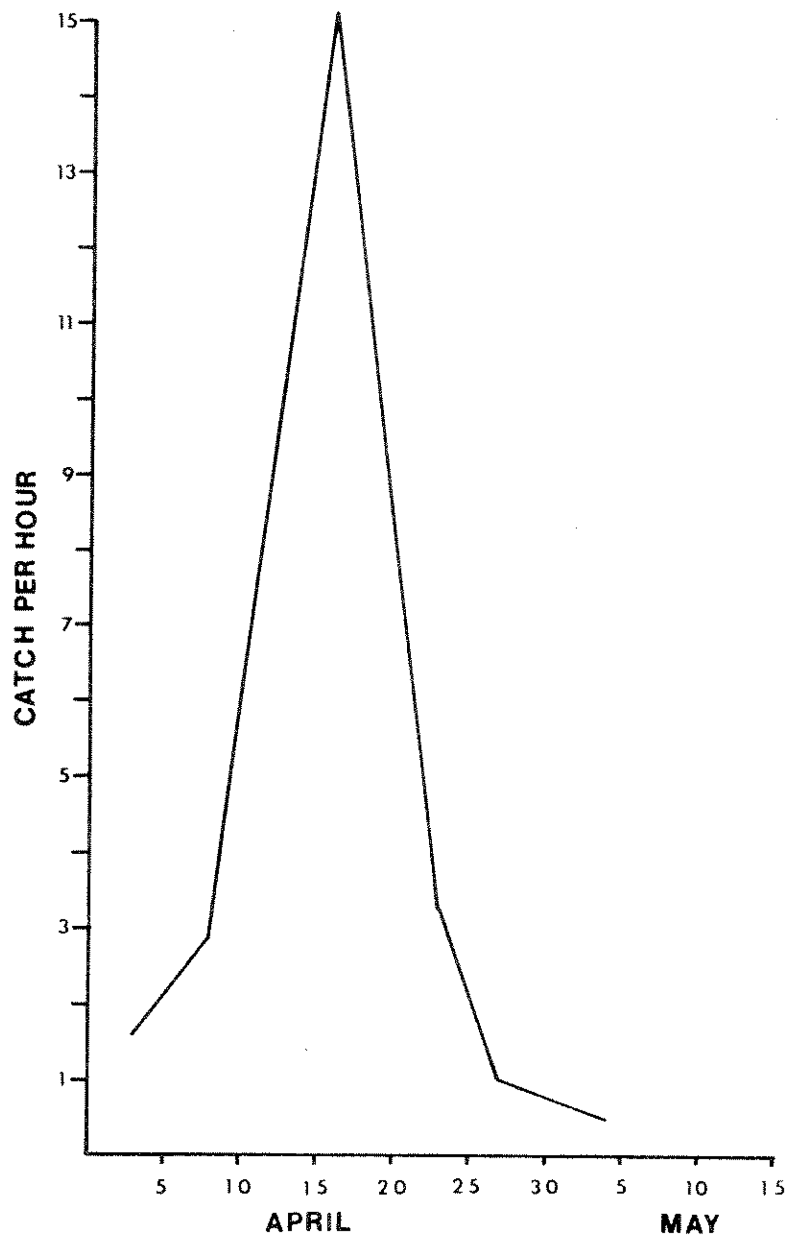

Figure 8. Relative abundance of kokanee fry emigrating from Columbia Falls slough, 1981, as determined by 0.5 m net catches.

the areas are not confined and water level fluctuations render fixed nets useless. Based on the spawning period of main stem spawners and incubation period water temperatures, we estimate most main channel emergence would occur in May.

Dewatering experiments

Green eggs - main stem

Overnight dewatering on December 3-4, 1980 had no effect on survival of green eggs buried above the minimum flow level at the Hoerner site. Survival of both wetted and dewatered eggs was nearly 100 percent after 13 hours. Unseasonably warm air temperatures (above freezing) prevailed throughout the night.

Mortality of dewatered eggs increased shortly after weekend dewatering began (Figure 9). Air temperatures dropped to below seasonal norms during the weekend. Mortality increased at a faster rate between 12 and 16 hours after weekend dewatering began and was complete at approximately 36 hours.

Survival of green eggs buried below the minimum flow level (control) remained near 100 percent throughout the weekend despite near-freezing water temperature and a significant build up of ice (Figure 10).

Green eggs - channels

Survival of dewatered green eggs in both artificial channels at Somers showed similar patterns. Eggs in the Somers channels were not subjected to overnight dewatering prior to the weekend dewatering experiment.

Survival in both channels was greater than 90 percent 16 hours after dewatering. However, survival dropped rapidly after 16 hours in the 15 cm-deep channel to zero at 36 hours (Figure 11). Survival in the 25 cm-deep channel was maintained at a high level for 24 hours before dropping to zero at 30 hours (Figure 12), although eggs were buried at the same depth in both channels.

Gravel temperatures did not reach freezing in either channel during the experiments; however, the temperature probes were buried slightly deeper than the eggs. It was not clear whether mortality occurred from dessication or freezing.

Eyed eggs - main stem

Eyed eggs withstood weekend dewatering better than green eggs but nevertheless experienced significant mortality. Eyed eggs buried at the Hoerner site displayed no ill effects from dewatering up to 40 hours, but survival dropped rapidly to 20 percent at 48 hours (Figure 13). Air temperatures during the weekend dewatering experiment with eyed eggs

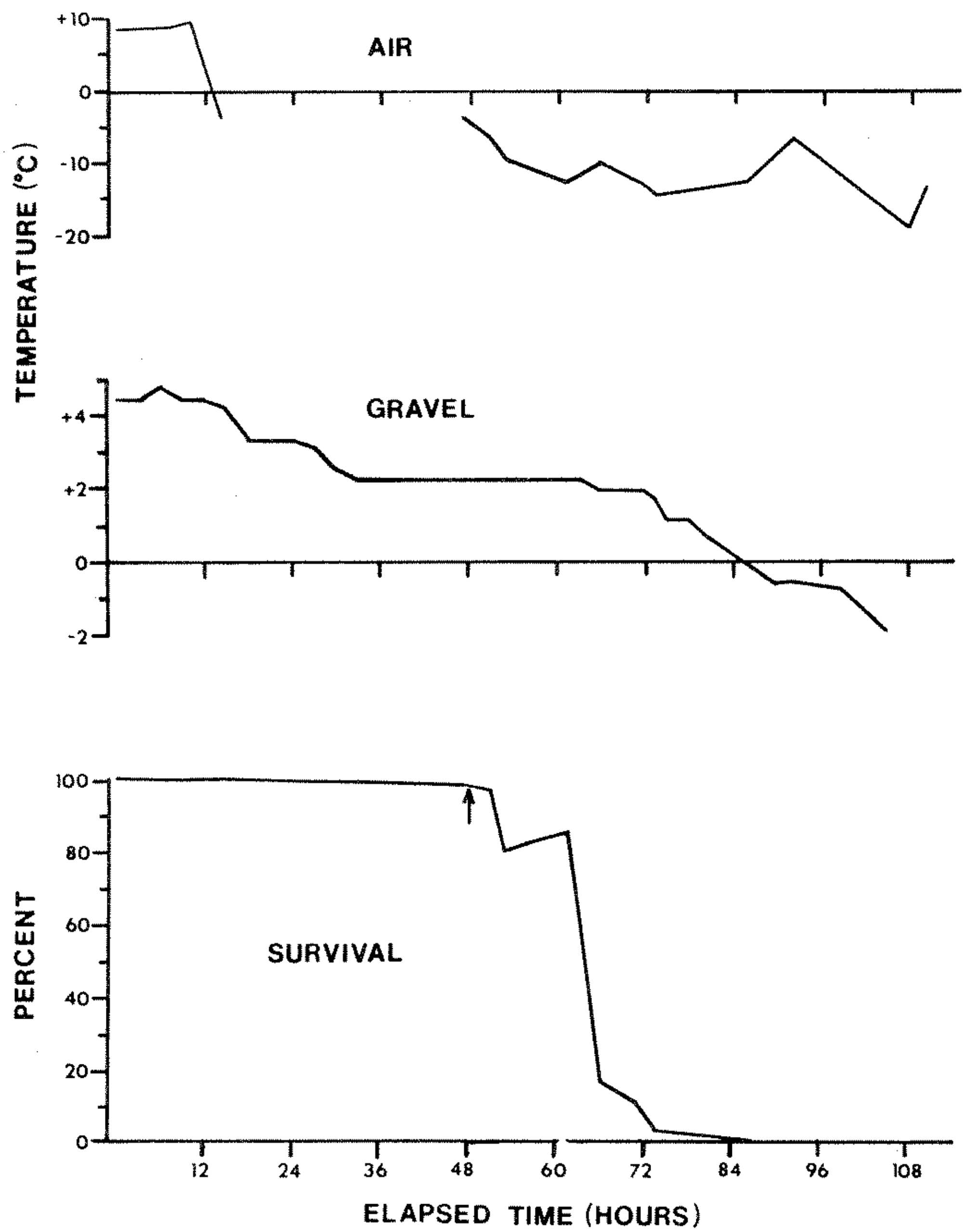

Figure 9. Air temperature, gravel temperature (10 cm depth) and survival of dewatered green kokanee eggs at Hoerner spawning site, December 4-8, 1981. Arrow indicates beginning of weekend dewatering.

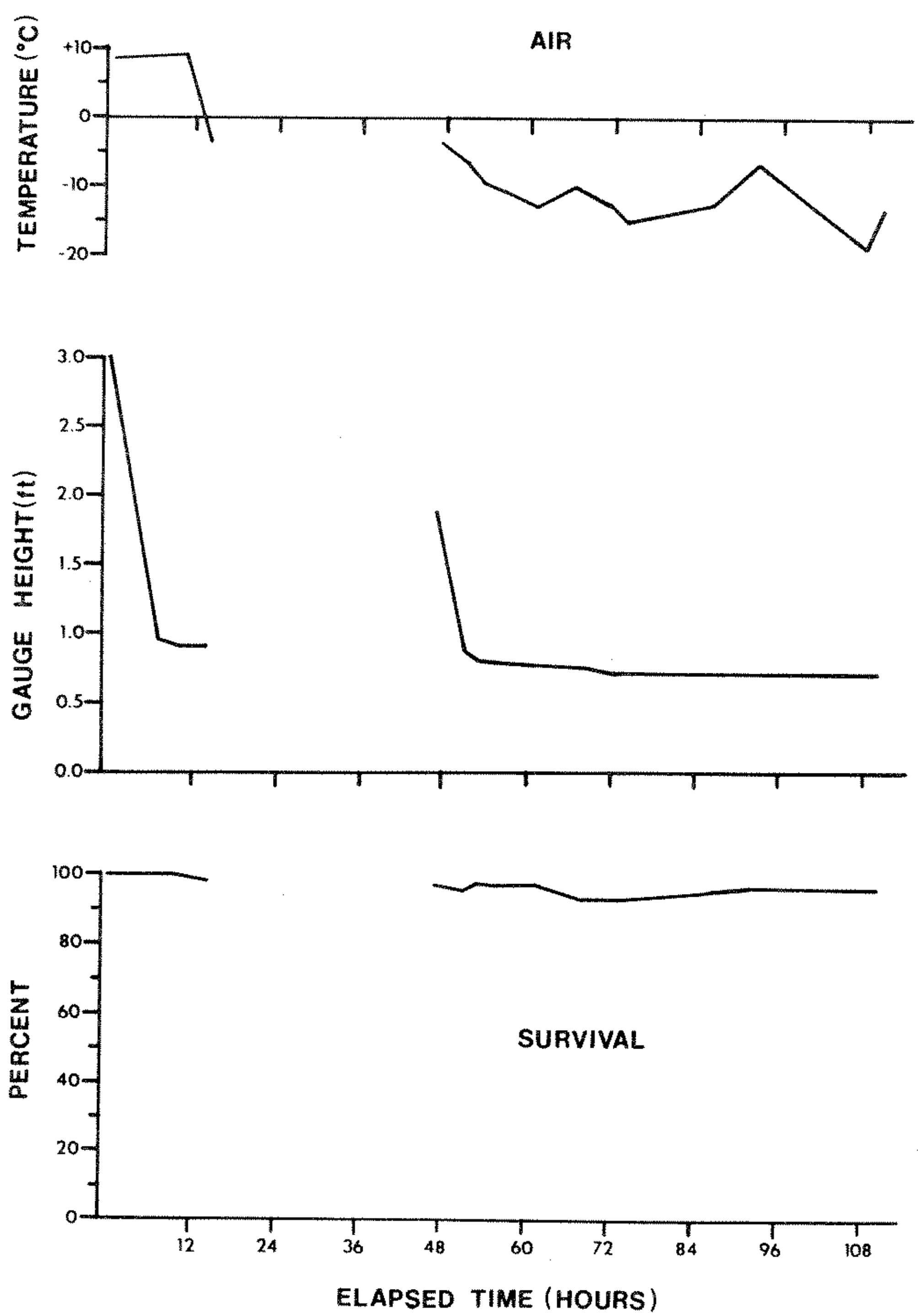

Figure 10. Air temperature, change in gauge height and survival of green kokanee eggs buried in a continuously wetted area of Hoerner spawning site, December 4-8, 1980.

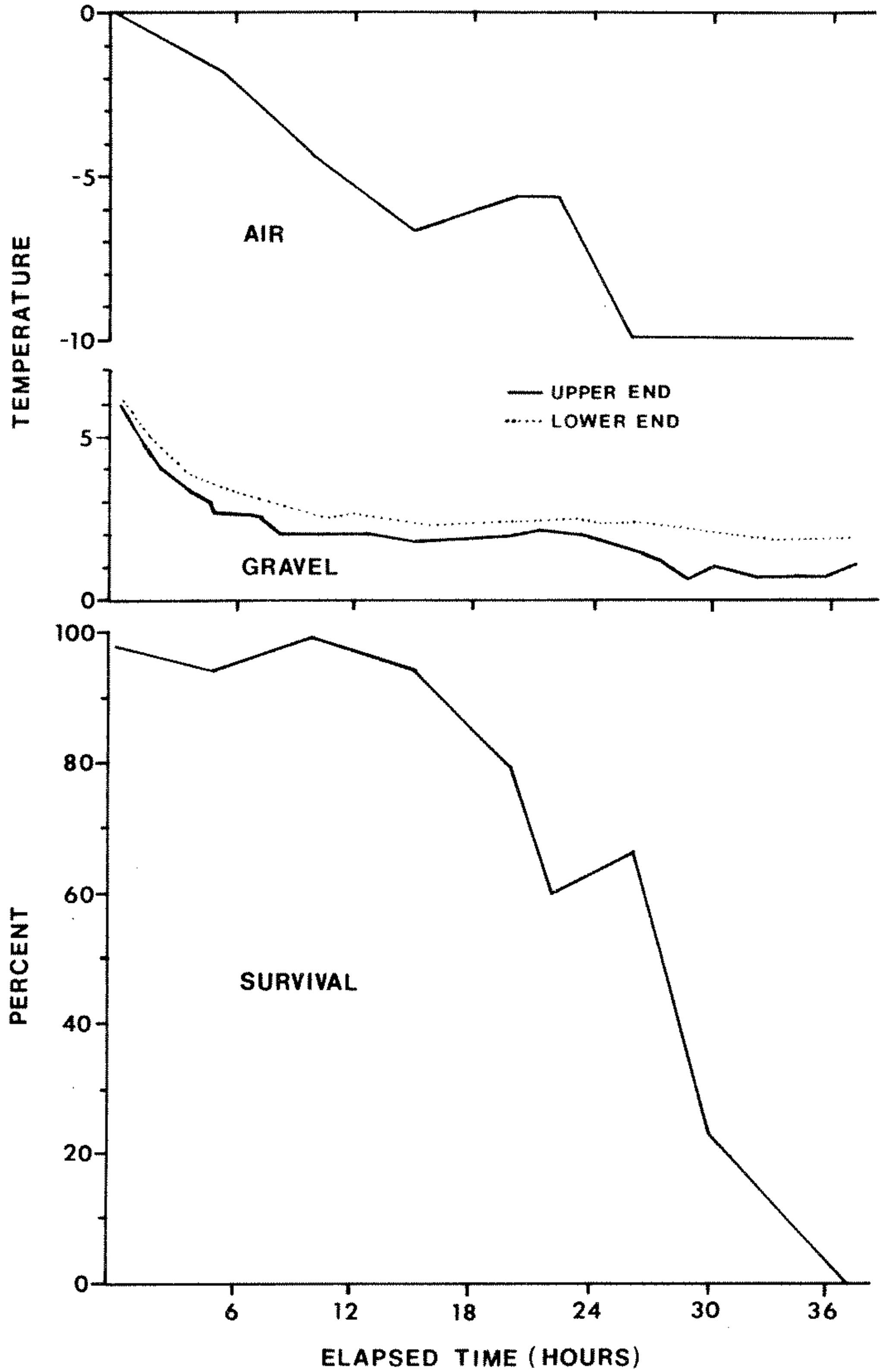

Figure 11. Air temperature, gravel temperature (10 cm depth) at either end and survival of dewatered green kokanee eggs buried in a 15 cm-deep artificial stream channel at Somers hatchery, December 6-8, 1980.

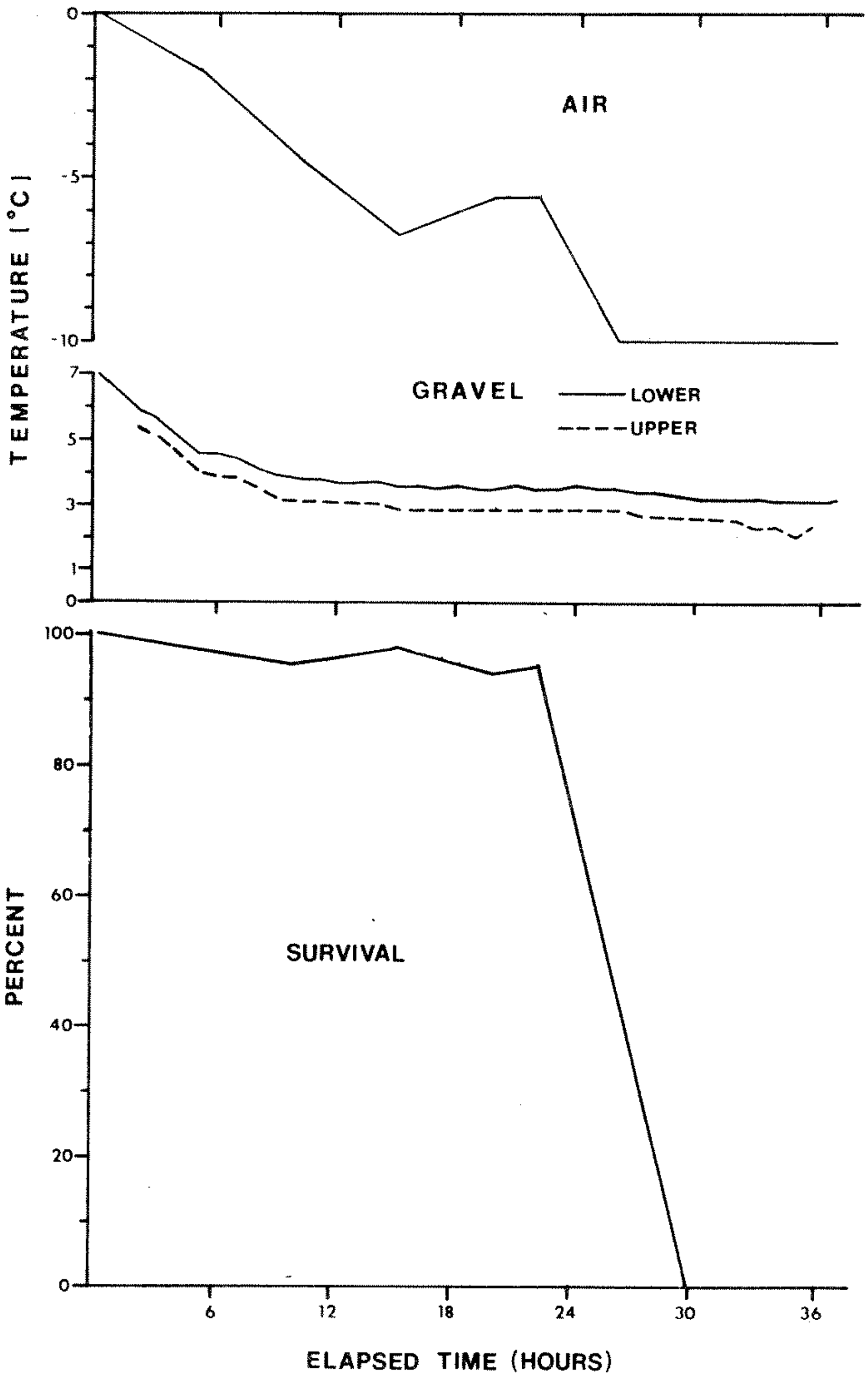

Figure 12. Air temperature, gravel temperature (10 cm depth) at either end and survival of dewatered green kokanee eggs buried in a 25 cm-deep artificial stream channel at Somers hatchery, December 6-8, 1980.

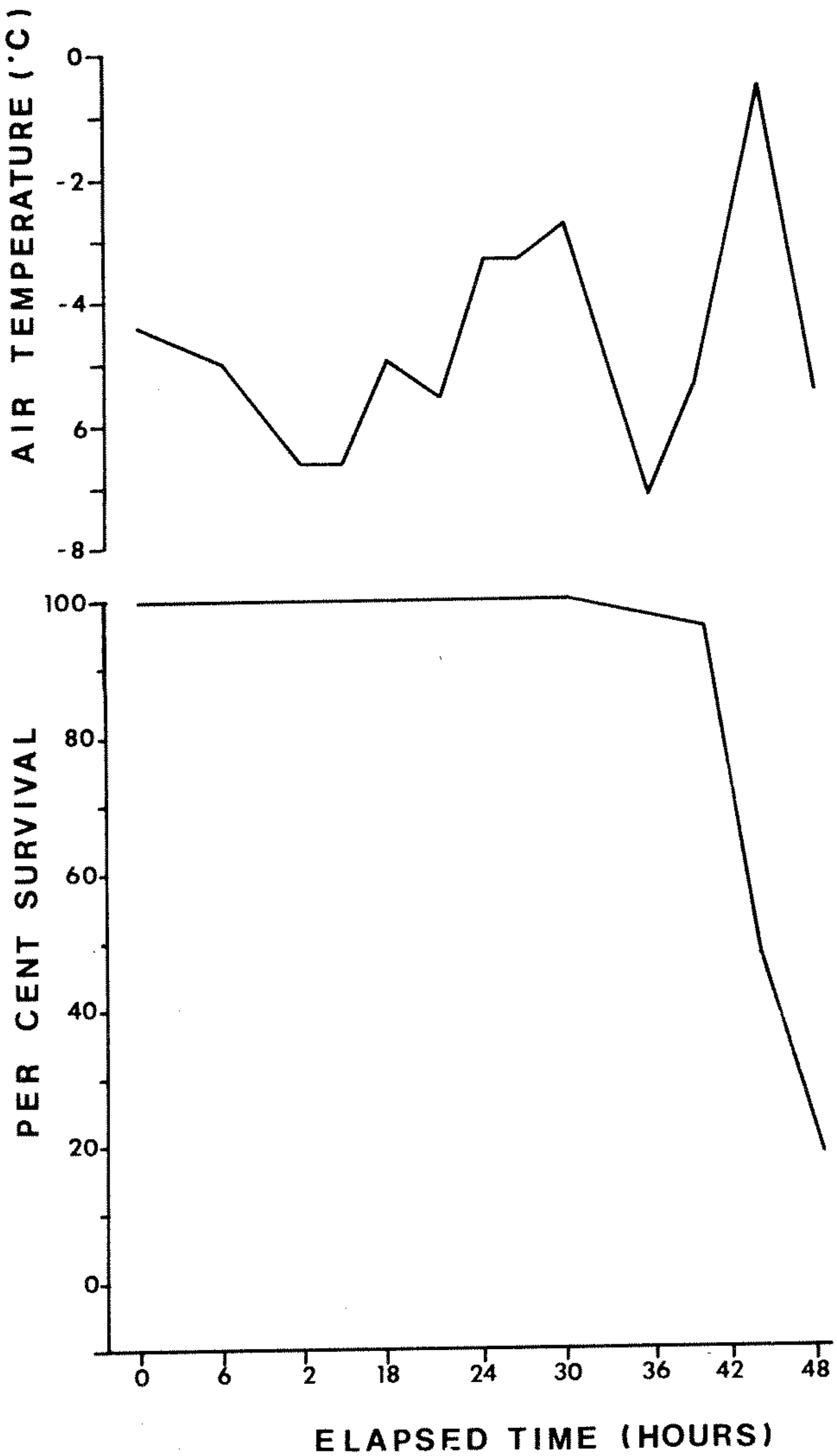

Figure 13. Air temperature and survival of dewatered eyed kokanee eggs buried at Hoerner spawning site, February 6-9, 1981.

were unseasonably mild.

Eyed eggs - channels

Eyed eggs in the 25 cm-deep channel at Somers experienced better survival than those at the Hoerner site. Survival dropped slightly when the temperature at 10 cm depth in the gravel reached freezing (Figure 14). Approximately 50 percent of the eyed eggs at Somers survived weekend dewatering.

A slight rise in survival coincided with a brief period of sunshine that warmed gravels appreciably. The rise in survival may be a reflection of the method of assessing mortality. An eyed egg was considered dead if repeated agitation failed to cause embryo movement. Eggs were allowed to warm up for several minutes as we sorted live eggs from dead, and occasionally an egg thought to be dead was found to be alive. At freezing temperature levels, metabolism may have been slowed to the point that live eggs were mistaken for dead. However, allowing eggs to warm up should have minimized erroneous sorting.

At the Hoerner site, we were unable to warm the eggs. Thus, survival may have been slightly better than observed.

A second experiment with eyed eggs was conducted during much colder weather. Eyed eggs in the 25 cm-deep channel at Somers suffered complete mortality within 11 hours after dewatering (Figure 15). Increased mortality coincided with freezing temperatures at the depth where eggs were buried.

Results of the series of egg dewatering experiments have significant implications when applied to incubation success and flow patterns in the Flathead River. Except during extremely cold weather (less than -10° C), kokanee eggs appear to tolerate overnight dewatering. During cold weather, less than 12 hours of dewatering can cause complete mortality. Periods of dewatering exceeding 16 hours result in excessive mortality of green eggs while eyed eggs appear to tolerate at least 40 hours of dewatering during mild weather. However, repeated weekend dewatering of eyed eggs would probably result in complete or nearly complete mortality.

Long-term channel experiment

Even if some generation occurred every day, mortality could be high. In long-term dewatering experiments conducted in the artificial channels, mortality was significantly higher under fluctuating flow regimes than under a constant flow regime.

A total of 563 fry (56 percent) emerged from the control channel at Somers. Only 1.4 percent of the eggs subjected to a seven-day peaking regime survived to produce emergent fry. Eggs subjected to a six-day peaking regime suffered complete mortality.

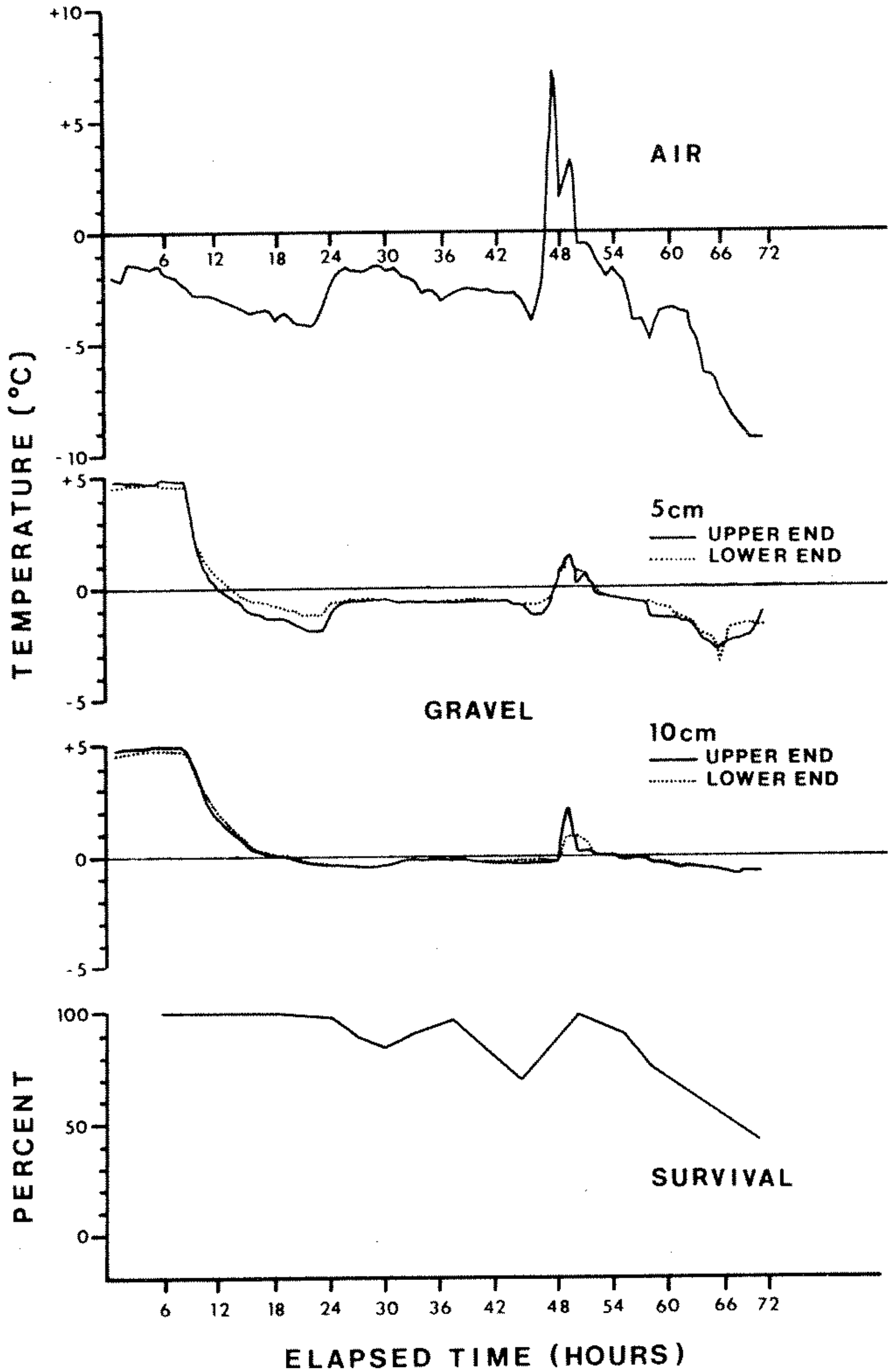

Figure 14. Air temperature, gravel temperature at either end and survival of dewatered eyed kokanee eggs buried in a 25 cm-deep artificial stream channel at Somers hatchery, February 6-9, 1981.

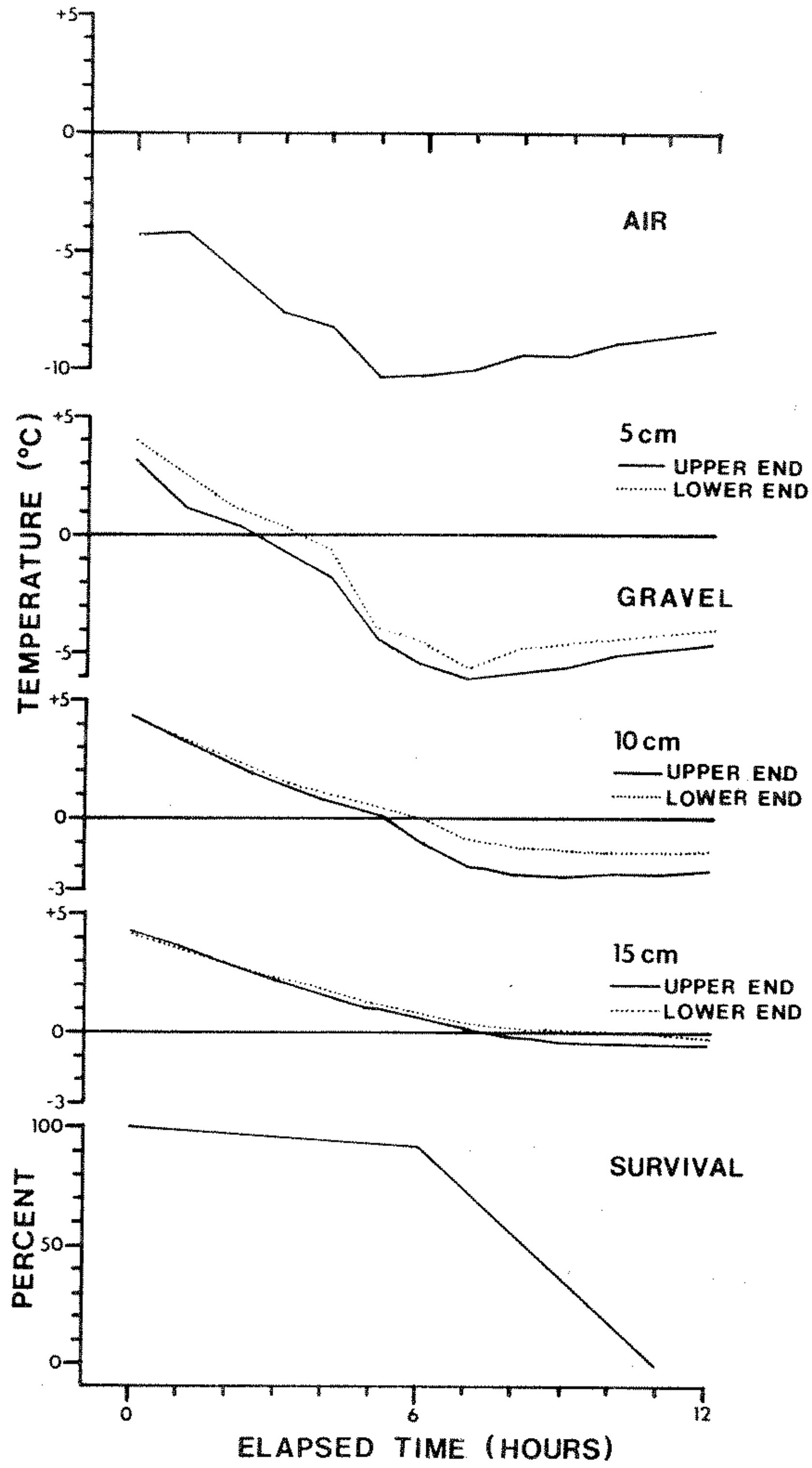

Figure 15. Air temperature, gravel temperature at either end and survival of dewatered eyed kokanee eggs buried in a 25 cm-deep artificial stream channel at Somers hatchery, February 10, 1981.

Emergence of fry in the seven-day peaking channel occurred one month later than in the control channel (Figure 16). Eggs were planted in all three channels on November 18, 1980. Emergence in the control channel began on April 12, 1981 and peaked from April 21 through April 23. Eighty-six percent of the emergent fry emigrated from the control channel between April 17 and April 27. Emergence in the seven-day peaking channel did not begin until May 6.

Nightly dewatering in the peaking channel probably resulted in accumulation of fewer temperature units, thereby slowing development. Fry in the control channel began emerging after accumulating approximately 600 temperature units (C). Peak emergence occurred between 630 and 700 temperature units (Figure 17). Emergence in the seven-day peaking channel did not begin until the control channel had accumulated approximately 780 temperature units.

Stream flow-year class strength relationships

Mean length of kokanee spawners in 1980 was much larger than that predicted by the models developed in our previous report (Figure 18). Although mean flow conditions in water year 1977 were moderately favorable, a poor run of extremely large kokanee was produced in 1980. The models were based on mean monthly flows, not accounting for the wide variation in daily flows that occur. Continued monitoring of Flathead kokanee spawning runs will be needed to document relationships between Hungry Horse discharges and kokanee year class strength.

We obtained records for the U.S.G.S. gauge at Columbia Falls dating back to 1954. Hourly gauge records were used to determine mean flows during the hours of peak spawning activity, between approximately 1700 hours until 2300 hours at Columbia Falls in November. We felt mean flows during those hours would be more representative of flow conditions during spawning than monthly mean flow. We also analyzed flows during the incubation period to determine the extent of redd dewatering. We estimated that significant redd dewatering would begin to occur when incubation period flows dropped 0.37 m (1.2 ft.) below mean spawning flow. Thus, whenever the gauge reading at Columbia Falls between December 1 and March 31 reached a level 0.37 m lower than mean spawning flow, one hour of redd dewatering was counted.

Flow data associated with kokanee lengths prior to water year 1962 was not used in the models. The kokanee population in the Flathead River was increasing as a result of Hungry Horse operation and the population did not stabilize for at least two generations after construction of Hungry Horse Dam, or approximately 1962.

Correlation of several flow variables with kokanee lengths after water year 1962 yeilds strong indications that Hungry Horse operation affects Flathead kokanee populations. Flow variables and corresponding kokanee lengths are listed in Table 4.

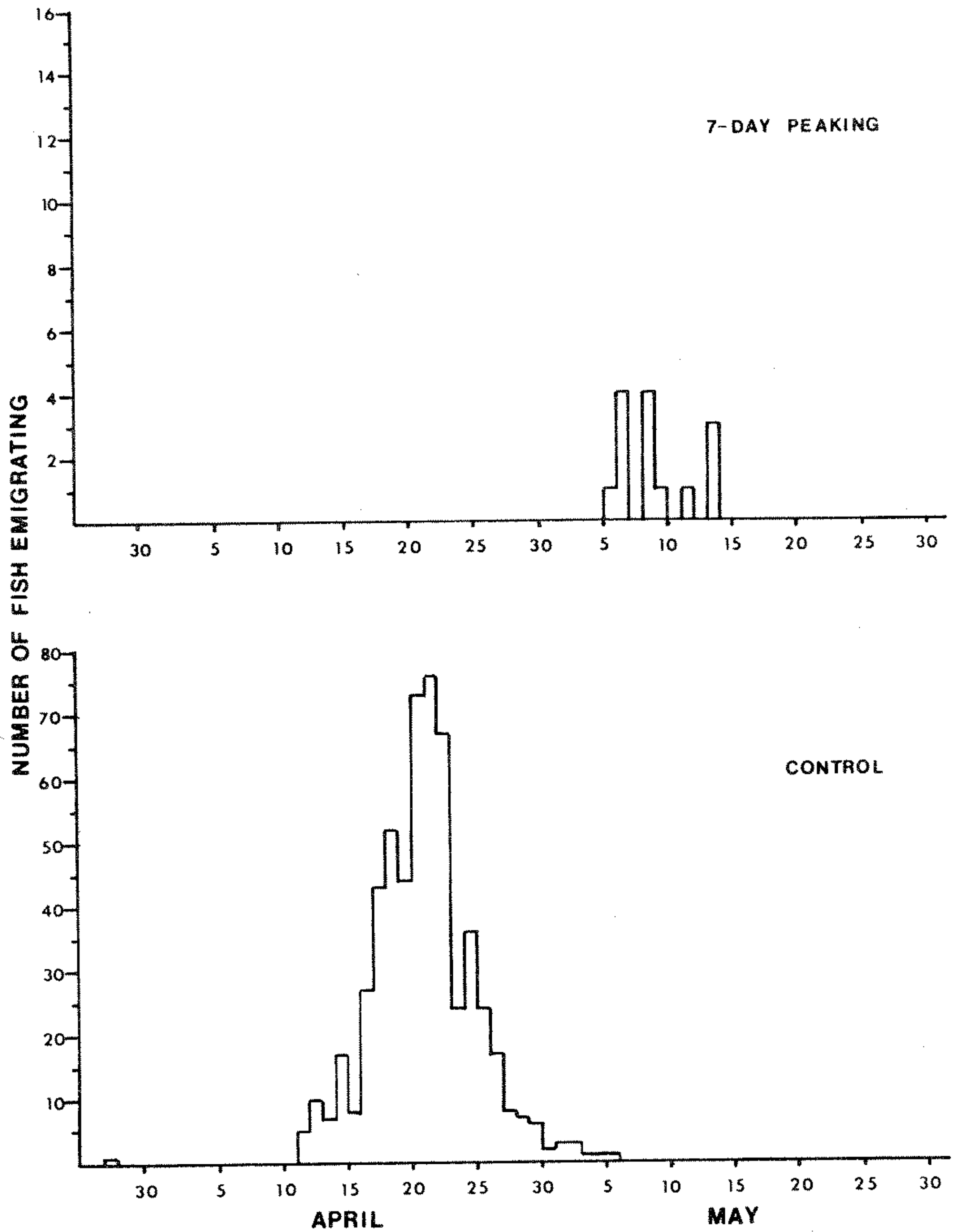

Figure 16. Emigration of kokanee fry from artificial stream channels after being subjected to constant flow (control) and seven-day peaking regimes. 1000 eggs were planted in each channel.

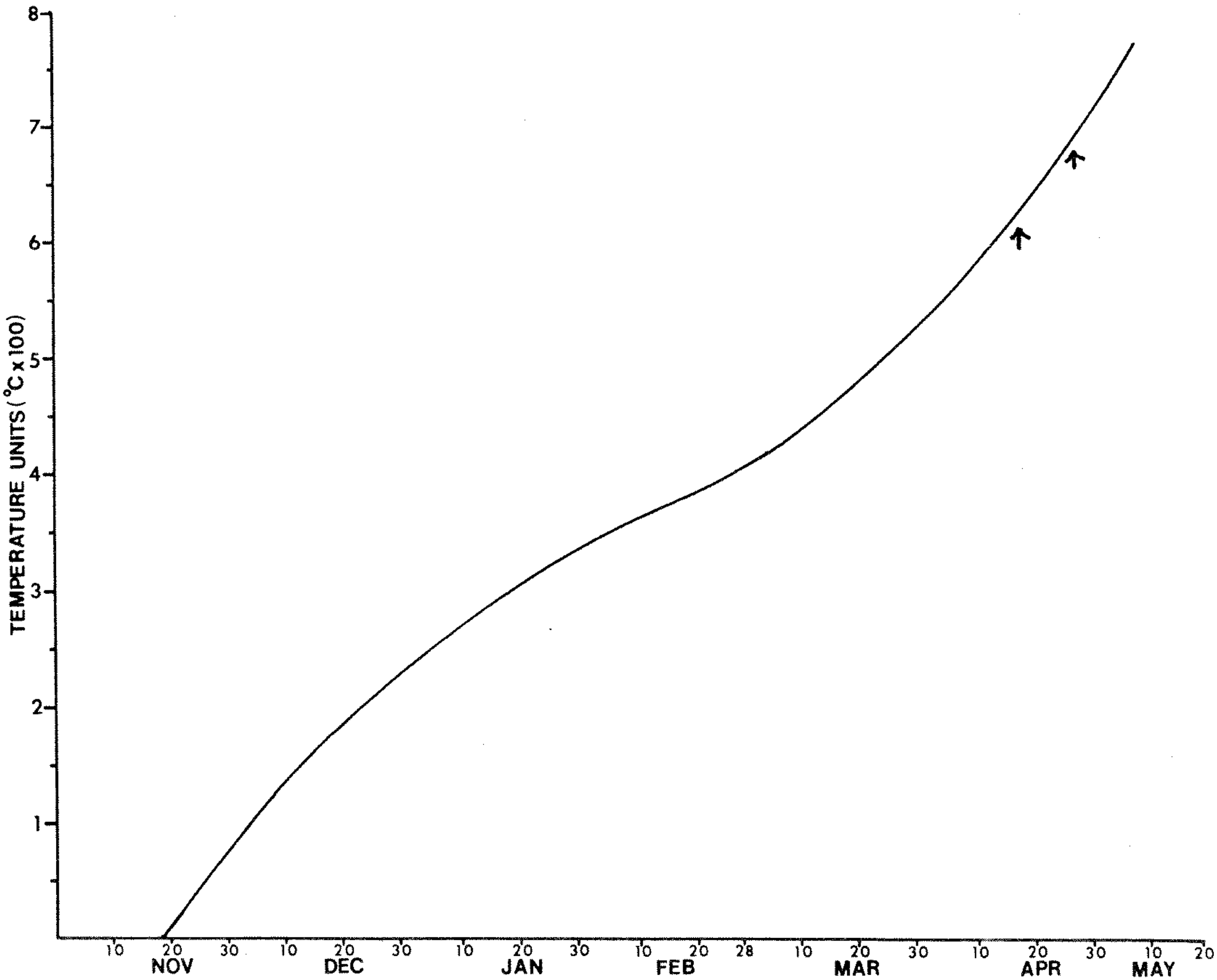

Figure 17. Temperature units (C) accumulated by kokanee eggs planted in the control channel at Somers hatchery. Arrows denote period of peak emigration.

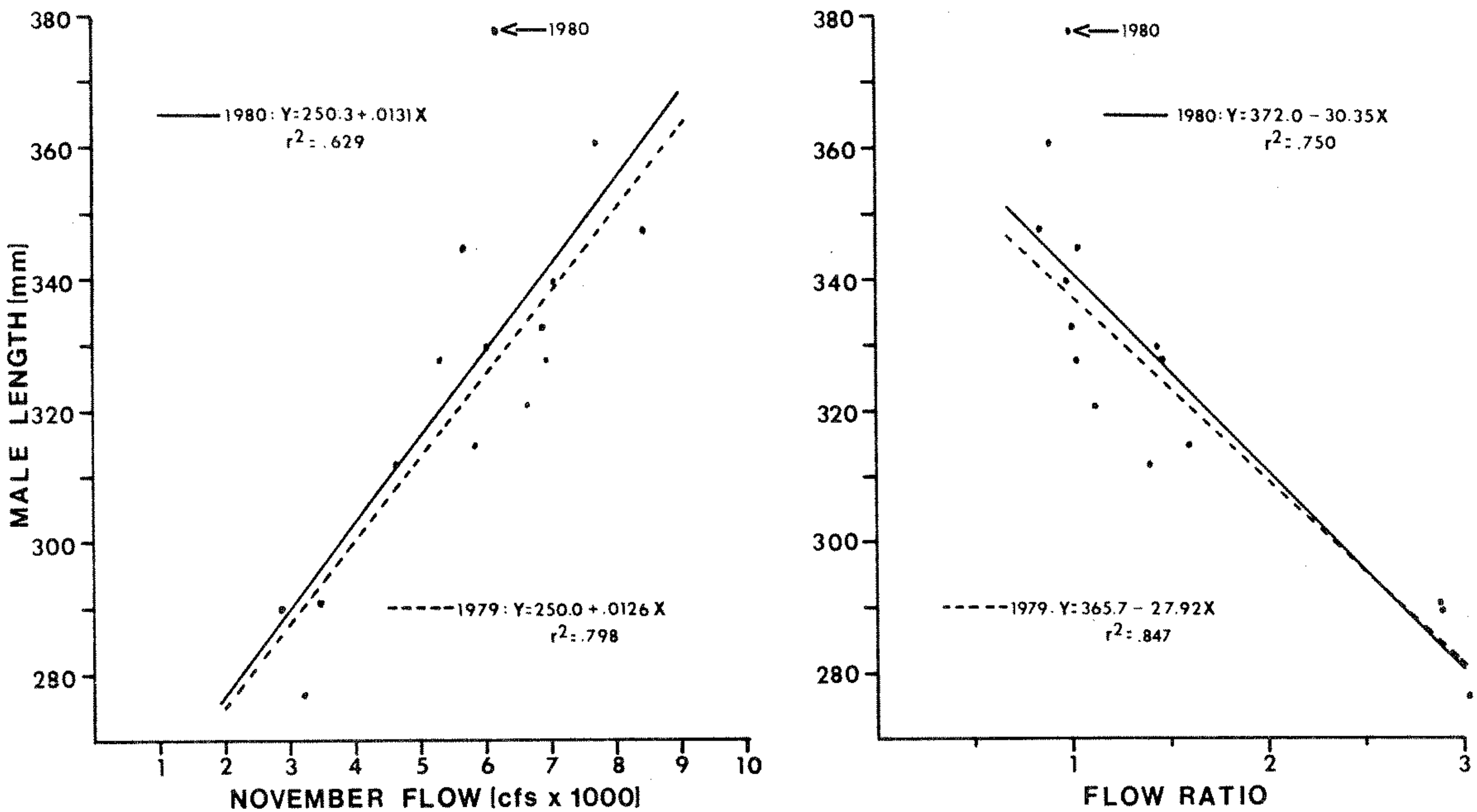

Figure 18. Relationships between mean kokanee spawner length, weighted three-year moving average November (spawning) flow and weighted three-year moving average ratio of incubation (December-March) to spawning flows in the Flathead River at Columbia Falls.

Table 4. Flathead River flow and kokanee length variables used in assessing stream flow-year class strength relationships.

Water year	Water years used in 3-year mean	Incubation-spawning gauge height difference (ft)	Weighted 3-year moving average (ft)	Total hours dewatered	Weighted 3-year moving average	Hours/day dewatered	Weighted 3-year moving average	Spawn year	Kokanee total length (mm)
1954		-0.68		1,504		12.43		1957	294
1955	1954-56	1.21	0.56	277	689	2.29	5.69	1958	---
1956	1955-57	0.94	1.03	423	535	3.47	4.47	1959	312
1957	1956-58	0.96	-0.30	941	1,251	7.97	10.41	1960	348
1958	1957-59	-3.22	-0.96	2,491	1,488	20.59	12.36	1961	339
1959	1958-60	0.15	-1.22	697	1,512	5.76	12.62	1962	330
1960	1959-61	-1.06	-0.42	1,621	858	13.78	7.24	1963	338
1961	1960-62	-0.15	0.13	0	502	0	4.27	1964	347
1962	1961-63	1.68	1.09	53	21	0.44	0.18	1965	326
1963	1962-64	1.53	2.06	0	16	0	0.13	1966	287
1964	1963-65	3.16	2.44	0	12	0	0.10	1967	272
1965	1964-66	2.39	2.20	40	297	0.33	2.45	1968	286
1966	1965-67	0.99	0.65	936	906	7.74	7.49	1969	313
1967	1966-68	-1.54	-0.36	1,732	1,423	14.31	11.73	1970	323
1968	1967-69	-0.14	-0.29	1,498	1,338	12.28	11.01	1971	334
1969	1968-70	0.76	-0.14	730	1,415	6.03	11.66	1972	338
1970	1969-71	-1.35	0.22	2,244	1,118	18.55	9.24	1973	308
1971	1970-72	1.78	0.23	4	1,006	0.03	8.31	1974	320
1972	1971-73	-0.27	0.41	1,104	899	9.12	7.43	1975	324
1973	1972-74	-0.04	0.06	1,522	1,208	12.58	9.99	1976	316
1974	1973-75	0.52	-0.43	894	1,484	7.39	12.26	1977	327
1975	1974-76	-2.07	-0.97	2,231	1,576	18.44	13.00	1978	341
1976	1975-77	-0.97	-0.87	1,384	1,675	11.34	13.80	1979	353
1977	1976-78	0.46	-0.48	1,507	1,603	12.45	13.22	1980	367
1978	1977-79	-1.22	-0.94	1,950	1,757	16.12	14.52	1981	
1979	1978-80	-1.97	-2.31	1,749	2,099	14.45	17.29	1982	
1980	1979-81	-3.86		2,715		22.25			

We correlated kokanee length with the difference between mean incubation and spawning gauge heights. A logarithmic plot of the relationship (Figure 19) illustrates the excellent fit of the model. Prediction of mean length of 1980 spawners however, falls short of actual length. Natural log of kokanee length also correlates well with mean hours per day of incubation flows more than 0.37 m lower than spawning flows (Figure 20).

Egg dewatering experiments demonstrated that air temperature can be an important factor in determining egg mortality. We added mean minimum temperature (on days when dewatering occurred) to the models in multiple regression analysis. Addition of temperature had no effect on the gauge height difference model (Table 5) and improved the fit of the hours dewatered model only slightly (Table 6). It is likely that winter temperatures were always cold enough (on the average) to cause substantial mortality during periods of dewatering. Although mortality of kokanee eggs can occur in a single dewatering period, repeated dewatering increases the chance of mortality occurring. Frequency of egg dewatering is highly correlated with kokanee length (Figure 21).

Year class strength of anadromous sockeye salmon populations often reflects the phenomenon of quadrennial dominance. Sockeye and kokanee spawning runs are usually dominated by four-year old fish. Consequently, four relatively distinct cycles in population abundance usually occur, each with its own inherent level of productivity (Killick and Clemens 1963).

We do not have enough data to adequately assess the quadrennial dominance phenomenon in the Flathead. Despite small samples however, correlation of kokanee length with total hours dewatered during the incubation period within cycles removes much of the variation occurring in the whole samples (Figure 22). Slope of the regression lines suggests the 1967, 1971, 1975, 1979 and 1968, 1972, 1976 and 1980 cycles are both more susceptible to dewatering mortality than either the 1966, 1970, 1974, 1978 or 1969, 1973 and 1977 cycles. Differences in susceptibility to dewatering could result from genetically distinct cycles homing accurately to different spawning areas. Thus, kokanee in the 1966-78 cycle may tend towards spawning in areas where dewatering occurs less frequently than in spawning areas utilized by the 1968-80 cycle.

Flow redistribution

Redistribution of flows from Hungry Horse Dam and the regulating dam would be contingent upon two variables. First, we determined if enough water was available to provide the desired flow. Second, we calculated the capacity of the reregulating dam to provide necessary flows under various flow regimes at Hungry Horse Dam.

Between water years 1962 and 1979, median storage loss in Hungry Horse Reservoir for the period November 1 through March 31 was 1,061,000 af. Under the November generation schedule outlined previously, we estimate storage losses ranging from 138,629 af at a spawning flow of 3,500 cfs

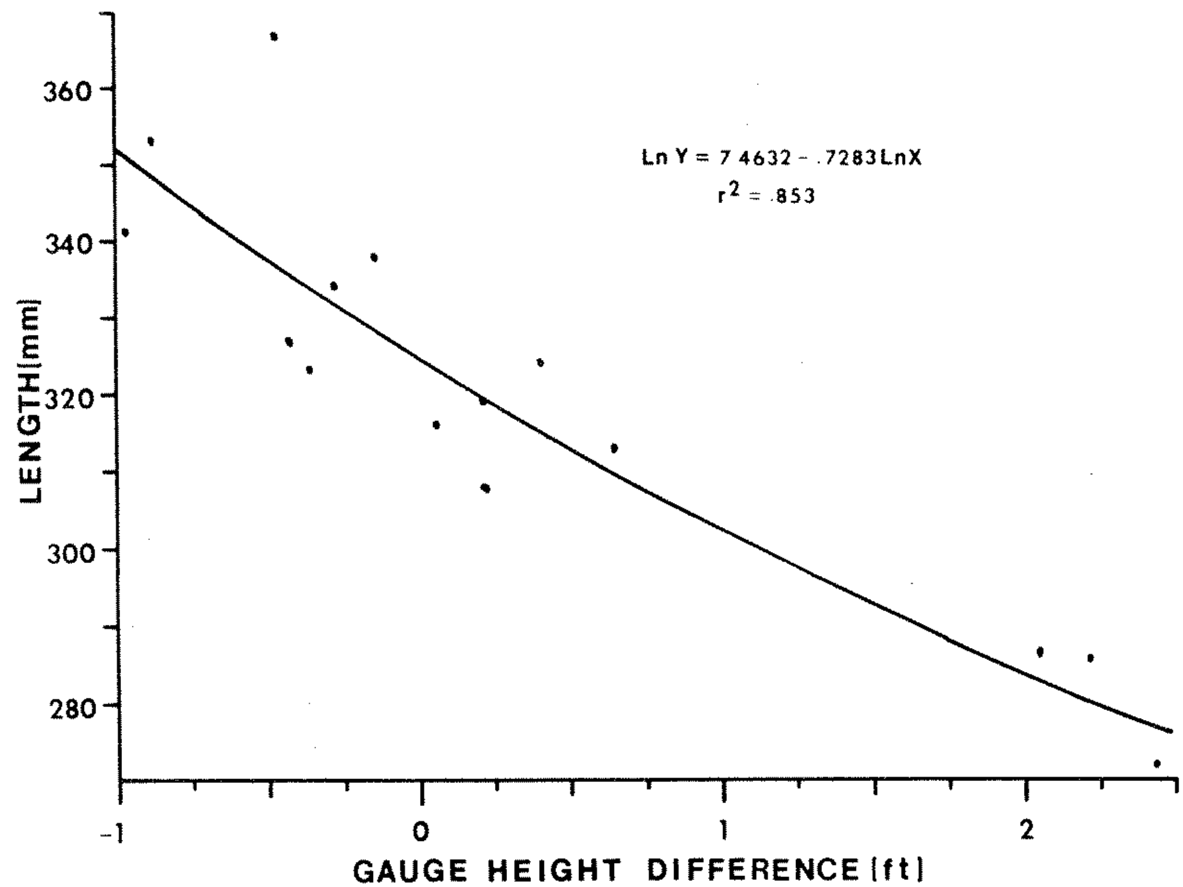

Figure 19. Relationship between mean kokanee spawner length and weighted three-year moving average difference between incubation and spawning gauge heights (at Columbia Falls).

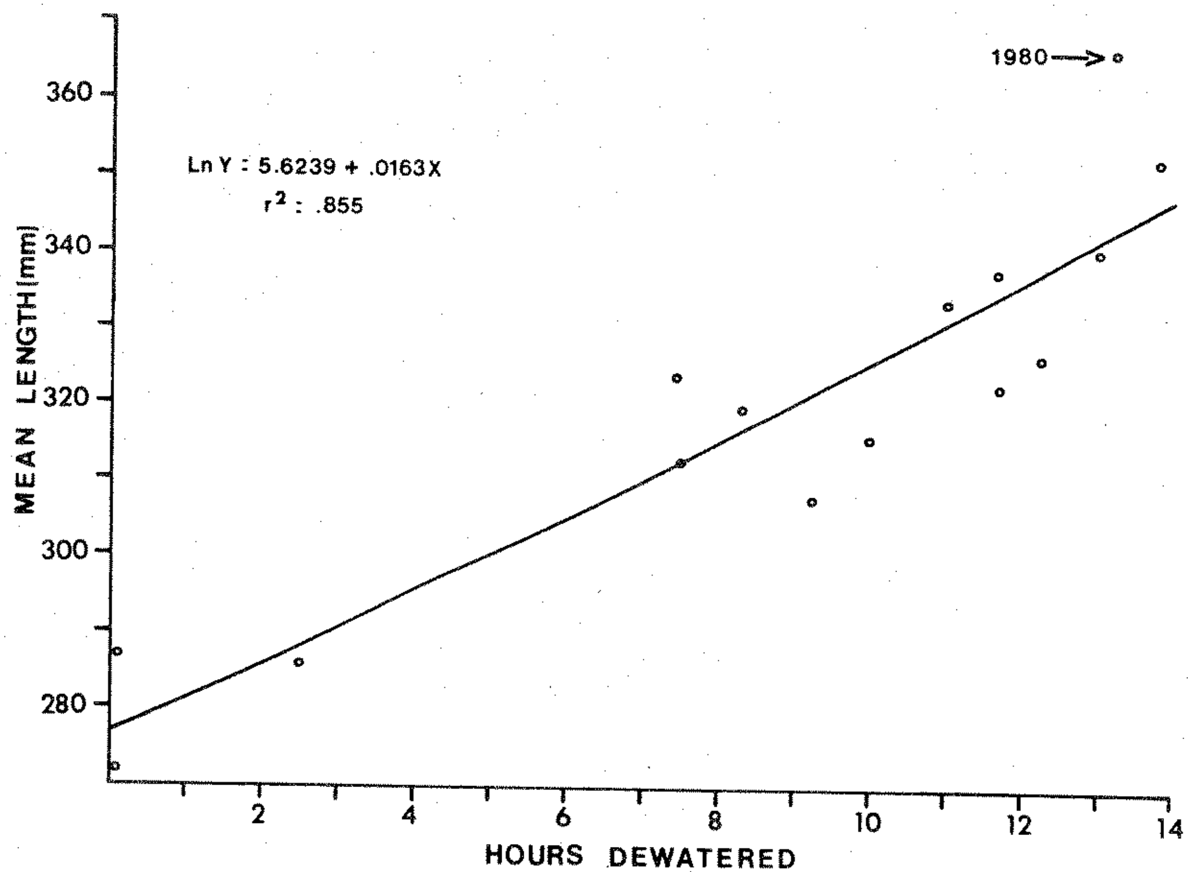

Figure 20. Relationship between mean kokanee length and weighted three year moving average hours per day gauge height more than 0.37 m (1.2 ft) below mean spawning gauge height (at Columbia Falls).

Table 5. Incubation-spawning gauge height differences, mean minimum temperature on days when dewatering occurred, predicted kokanee lengths, actual lengths and residuals for the model
$\text{Ln } Y = 7.45855 - 0.73456X_1 + 0.00976X_2$.
Y = kokanee length, X_1 = gauge height difference, X_2 = temperature
$R^2 = 0.843$.

Gauge height difference (Ft.)	Temperature (°C)	Predicted length (mm)	Actual length (mm)	Residual
2.06	-23.02	287	287	0
2.44	- 4.25	276	272	-4
2.20	- 6.69	281	286	+5
0.65	- 5.54	310	313	+3
-0.36	- 5.26	334	323	-11
-0.29	- 5.55	332	334	+2
-0.14	- 7.85	330	338	+8
0.22	- 9.15	321	308	-13
0.23	- 8.93	321	320	-1
0.41	- 6.18	316	324	+8
0.06	- 5.46	324	316	-8
-0.43	- 6.71	336	327	-9
-0.97	- 7.83	352	341	-11
-0.88	- 7.42	349	353	+4
-0.48	- 6.69	338	367	+29

Table 6. Mean hours per day dewatering of kokanee redds, mean minimum temperature on days when dewatering occurred, predicted kokanee lengths, actual lengths and residuals for the model $\ln Y = 5.59540 + 0.01730X_1 - 0.00254X_2$. Y = kokanee length, X_1 = hours per day dewatered, X_2 = temperature. $R^2 = 0.872$.

Mean hours dewatered	Temperature (°C)	Predicted length (mm)	Actual length (mm)	Residual
0.13	-23.02	286	287	+1
0.10	- 4.25	273	272	-1
2.45	- 6.69	286	286	0
7.49	- 5.54	311	313	+2
11.73	- 5.26	334	323	-11
11.01	- 5.55	330	334	+4
11.66	- 7.85	336	338	+2
9.24	- 9.15	323	308	-15
8.31	- 8.93	318	320	+2
7.43	- 6.18	311	324	+13
9.99	- 5.46	324	316	-8
12.26	- 6.71	339	327	-12
13.00	- 7.83	344	341	-3
13.80	- 7.42	348	353	+5
13.22	- 6.69	344	367	+23

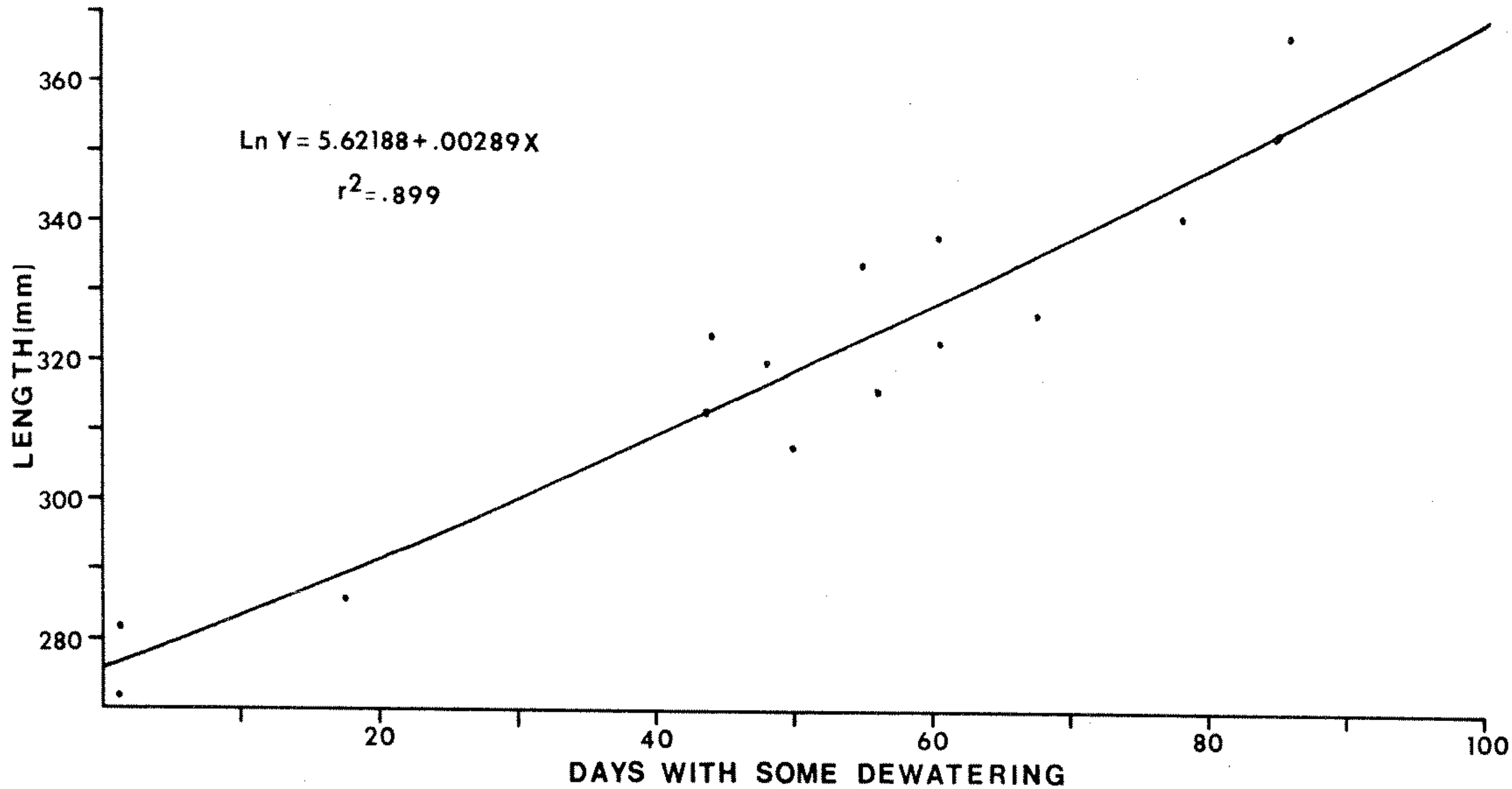

Figure 21. Relationship between mean kokanee spawner length and weighted three-year moving average number of days during the incubation period with some flows more than 0.37 m (1.2 ft) below mean spawning gauge height (at Columbia Falls).

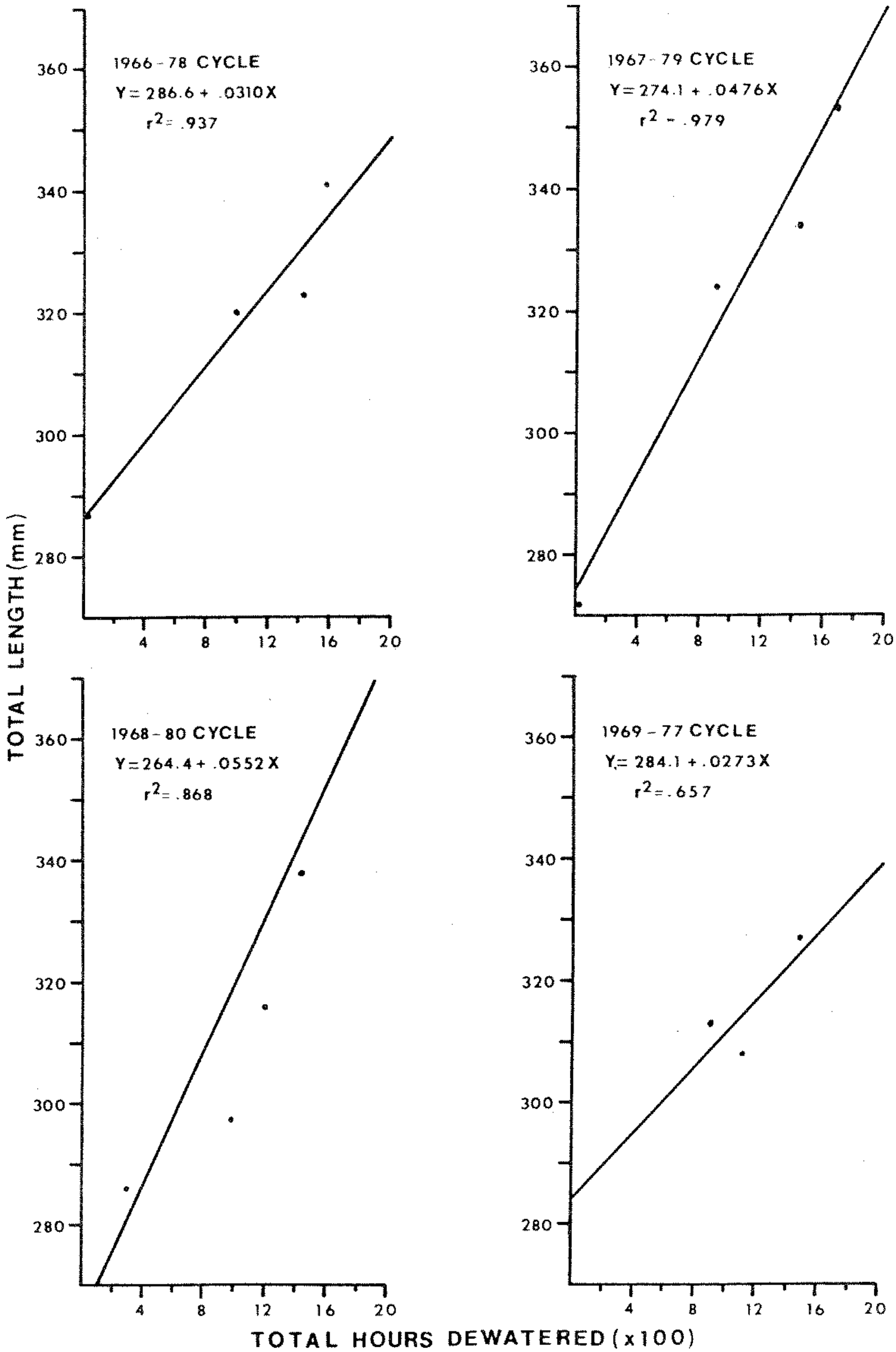

Figure 22. Relationships between mean kokanee spawner length and weighted three-year moving average total hours flows more than 0.37 m (1.2 ft) below mean spawning gauge height (at Columbia Falls) during the incubation period for each of four distinct spawning cycles.

to 383,794 af at a spawning flow of 6,000 cfs, if main stem kokanee redds were wetted continuously under median flow conditions (Table 7). Surplus storage, in addition to that needed to wet redds would amount to 922,371 af at a spawning flow of 3,500 cfs and 677,206 af at a spawning flow of 6,000 cfs.

Ability to supply flows adequate to wet redds would depend on the capacity of a reregulating dam to provide a specified flow. The capacity of a reregulating dam to provide incubation flows during periods of no generation at Hungry Horse Dam would likely limit the ability to continuously wet redds. If a normal weekend down period lasted 61 hours (1800 hours Friday until 0700 hours Monday), the proposed reregulating dam would be able to provide adequate incubation flows only if spawning flow was limited to 3,500 cfs and Hungry Horse provided a minimum flow of 500 cfs (Table 8).

Dewatering experiments indicate kokanee eggs can tolerate up to 12 hours dewatering without incurring excessive mortality, if air temperature exceeds -10° C. The cumulative effects of dewatering for 12 hours daily however, could result in significant egg mortality.

If Hungry Horse Dam were operated on a cyclic regime consisting of five days on line and two days off line, a reregulating dam could be a significant benefit to main stem Flathead River kokanee spawners. The proposed reregulating dam could provide adequate incubation flows throughout overnight down periods and for at least 12 hours daily on weekends if spawning flows were limited to 4,000 cfs (145 cfs Hungry Horse minimum flow) or 4,500 cfs (500 cfs Hungry Horse minimum flow). At higher spawning flows, critical dewatering could occur on weekends unless some generation at Hungry Horse Dam occurred. Critical periods would most likely occur in January and February when North Fork and Middle Fork flows are lowest and air temperatures are coldest.

Sound management of Flathead system kokanee depends on planning for low water years. To that end, we calculated water use statistics assuming eightieth percentile flows in the North, Middle, and upper South Forks. During the 1962-79 period, eightieth percentile Hungry Horse storage use was 629,000 af.

Storage losses in an eightieth percentile flow year would range from 66,718 af at a spawning flow of 3,500 cfs to 597,174 af at a spawning flow of 6,000 cfs (Table 9). Surplus storage would amount to 562,282 af at a spawning flow of 3,500 cfs and 31,826 af at a spawning flow of 6,000 cfs.

The proposed reregulating dam would be ineffective at reducing dewatering mortality if spawning flows exceeded 4,000 cfs (145 cfs Hungry Horse minimum flow) or 4,500 cfs (500 cfs minimum flow, Table 10).

Table 7. South Fork flows needed to meet spawning and incubation criteria and effects on Hungry Horse storage (50th percentile flows).

Spawn flow (cfs)	Month	South Fork flow needed (cfs)	HH outflow needed (AF)	HH inflow (cfs)	HH inflow (AF)	Net (AF)
3,500	NOV	145	30,645	986	58,671	+28,026
	DEC	400	24,595	981	60,319	+35,724
	JAN	601	36,954	944	58,044	+21,090
	FEB	568	31,827	841	47,124	+15,297
	MAR	366	22,504	992	60,996	+38,492
						+138,629
4,000	NOV	275	43,885	986	58,671	+14,786
	DEC	710	43,656	981	60,319	+16,663
	JAN	911	56,015	944	58,044	+ 2,029
	FEB	878	49,197	841	47,124	- 2,073
	MAR	676	41,566	992	60,996	+19,430
						+50,835
4,500	NOV	615	66,496	986	58,671	- 7,825
	DEC	1,050	64,562	981	60,319	- 4,243
	JAN	1,251	76,921	944	58,044	-18,877
	FEB	1,218	68,248	841	47,124	-21,124
	MAR	1,016	62,471	992	60,996	- 1,475
						-53,544
5,000	NOV	955	89,108	986	58,671	-30,437
	DEC	1,390	85,468	981	60,319	-25,148
	JAN	1,591	97,827	944	58,044	-39,783
	FEB	1,558	87,299	841	47,124	-40,175
	MAR	1,356	83,377	992	60,996	-22,381
						-157,924
5,500	NOV	1,325	113,058	986	58,671	-54,387
	DEC	1,760	108,218	981	60,319	-47,899
	JAN	1,961	120,577	944	58,044	-62,533
	FEB	1,928	108,032	841	47,124	-60,908
	MAR	1,726	106,128	922	60,996	-45,132
						-270,859
6,000	NOV	1,695	137,009	986	58,671	-78,338
	DEC	2,130	130,969	981	60,319	-70,650
	JAN	2,331	143,328	944	58,044	-85,284
	FEB	2,298	128,764	841	47,124	-81,640
	MAR	2,096	128,878	992	60,996	-67,882
						-383,794

Table 8. Capacity of Hungry Horse Reregulating Dam (in hours) to meet spawning and incubation flow criteria at various spawn flows, assuming a full rereg pool at the beginning of the period and an inflow of either 145 cfs or 500 cfs. Estimates based on 50th percentile flows in the North and Middle Forks.

Spawn flow (cfs)	Month	Capacity of rereg to meet criteria (hr)	
		145 cfs inflow	500 cfs inflow
3,500	NOV	15.9	21.0
	DEC	92.5	----
	JAN	51.7	233.6
	FEB	55.8	347.0
	MAR	106.8	----
4,000	NOV	11.9	14.5
	DEC	41.8	112.4
	JAN	30.8	57.4
	FEB	32.2	62.4
	MAR	44.4	134.1
4,500	NOV	9.5	11.1
	DEC	26.1	42.9
	JAN	21.3	31.4
	FEB	22.0	32.9
	MAR	27.1	45.7
5,000	NOV	7.9	9.0
	DEC	19.0	26.5
	JAN	16.3	21.6
	FEB	16.7	22.3
	MAR	19.5	27.6
5,500	NOV	6.8	7.6
	DEC	14.6	18.7
	JAN	13.0	16.1
	FEB	13.2	16.5
	MAR	14.9	19.2
6,000	NOV	5.9	6.5
	DEC	11.9	14.5
	JAN	10.8	12.9
	FEB	11.0	13.1
	MAR	12.1	14.8

Table 9. South Fork flows needed to meet spawning and incubation criteria and effects on Hungry Horse storage (80th percentile flows).

Spawn flow (cfs)	Month	South Fork flow needed (cfs)	HH outflow needed (AF)	HH inflow (cfs)	HH inflow (AF)	Net (AF)
3,500	NOV	596	60,158	563	33,501	-26,657
	DEC	798	49,067	676	41,566	- 7,501
	JAN	854	52,510	554	34,064	-18,446
	FEB	874	48,973	587	32,891	-16,082
	MAR	684	42,057	716	44,025	+ 1,968
						-66,718
4,000	NOV	906	81,431	563	33,501	-47,930
	DEC	1,108	68,128	676	41,566	-26,562
	JAN	1,164	71,572	554	34,064	-37,507
	FEB	1,184	66,343	587	32,891	-33,452
	MAR	994	61,119	716	44,025	-17,094
						-162,545
4,500	NOV	1,246	104,043	563	33,501	-70,542
	DEC	1,448	89,034	676	41,566	-47,468
	JAN	1,504	92,477	554	34,064	-58,413
	FEB	1,524	85,394	587	32,891	-52,503
	MAR	1,334	82,024	716	44,025	-37,999
						-266,925
5,000	NOV	1,586	126,654	563	33,501	-93,153
	DEC	1,788	109,940	676	41,566	-68,374
	JAN	1,844	113,383	554	34,064	-79,319
	FEB	1,864	104,446	587	32,891	-71,555
	MAR	1,674	102,930	716	44,025	-58,905
						-371,306
5,500	NOV	1,956	150,605	563	33,501	-117,104
	DEC	2,158	132,690	676	41,566	-91,124
	JAN	2,214	136,133	554	34,064	-102,069
	FEB	2,234	125,178	587	32,891	-92,287
	MAR	2,044	125,681	716	44,025	-81,656
						-484,240
6,000	NOV	2,326	174,555	563	33,501	-141,054
	DEC	2,528	155,441	676	41,566	-113,875
	JAN	2,584	158,884	554	34,064	-124,820
	FEB	2,604	145,910	587	32,891	-113,019
	MAR	2,414	148,431	716	44,025	-104,406
						-597,174

Table 10. Capacity of Hungry Horse Reregulating Dam (in hours) to meet spawning and incubation flow criteria at various spawn flows, assuming a full rereg pool at the beginning of the period and an inflow of either 145 cfs or 500 cfs. Estimates based on 80th percentile flows in the North and Middle Forks.

Spawn flow (cfs)	Month	Capacity of rereg to meet criteria(hr) 145 cfs inflow	500 cfs inflow
3,500	NOV	11.2	13.4
	DEC	36.1	79.2
	JAN	33.3	66.7
	FEB	32.4	63.1
	MAR	43.8	128.2
4,000	NOV	9.0	10.5
	DEC	24.5	38.8
	JAN	23.2	35.5
	FEB	22.7	34.5
	MAR	27.8	47.8
4,500	NOV	7.6	8.6
	DEC	18.1	24.9
	JAN	17.4	23.5
	FEB	17.1	23.0
	MAR	19.8	28.3
5,000	NOV	6.5	7.2
	DEC	14.4	18.3
	JAN	13.9	17.6
	FEB	13.7	17.3
	MAR	15.4	20.1
5,500	NOV	5.7	6.3
	DEC	11.7	14.2
	JAN	11.4	13.8
	FEB	11.3	13.6
	MAR	12.4	15.3
6,000	NOV	5.1	5.5
	DEC	9.9	11.6
	JAN	9.7	11.3
	FEB	9.6	11.2
	MAR	10.4	12.3

Mean length of kokanee spawners has varied greatly since 1951 (Figure 23). Our stream flow-year class strength models illustrate that a portion of the variability can be attributed to Hungry Horse operations. We judged flow conditions to be fair to good for kokanee spawning and incubation in 12 (44 percent) of the years between 1954 and 1980. Fifteen years (56 percent) were judged to be poor. Water years were judged on the basis of November flows and the ratio of incubation period flows to November flows.

It appears that water supply is ample, even in low water years, to sustain kokanee reproduction in the Flathead River. However, providing water during critical incubation periods can only be done if peaking operation of Hungry Horse Dam is curtailed until kokanee spawning is complete. In recent years, drafting of the reservoir in November has resulted not only in spawning in areas vulnerable to extensive dewatering, but also in extended periods of no generation during critical mid-winter incubation periods, thereby assuring high mortality rates.

Further modeling of flows, expanded to include the entire Flathead-Clark Fork system and eventually the entire Columbia system, is needed. Modeling of water supply, flood control management and hydroelectric energy production for the entire Columbia system is beyond the scope of our facilities, but can be achieved in cooperation with the Bureau of Reclamation and Bonneville Power Administration. We need to determine the effects of altering seasonal operations on kokanee, resident fish populations and insects in the Flathead River. Further modeling of Flathead River spawning and incubation flows, under the various Hungry Horse power alternatives, will be conducted.

CUTTHROAT TROUT AND RESIDENT FISH POPULATIONS

INTRODUCTION

Three forms of westslope cutthroat trout are found in the Flathead drainage, resident, fluvial and adfluvial (Fraley et al. 1981). Resident cutthroat are found principally in small headwater streams of all three forks. Fluvial cutthroat populations exist in the upper Middle and South Forks. The status of fluvial cutthroat in the North Fork and main stem Flathead River is undetermined. Adfluvial cutthroat are found throughout the drainage. Adfluvial fish spawn primarily in tributaries of the North and Middle Forks. Juvenile adfluvial cutthroat rear from one to four years in the upper drainage before migrating to Flathead Lake to mature.

Our specific concern with westslope cutthroat has been to identify impacts of Hungry Horse Dam operations upon the spawning migration of adfluvial cutthroat. Cutthroat spawning in North and Middle Fork tributaries occurs in May and June but Huston and Schumacher (1978) reported adult cutthroat migrating upstream as early as February.

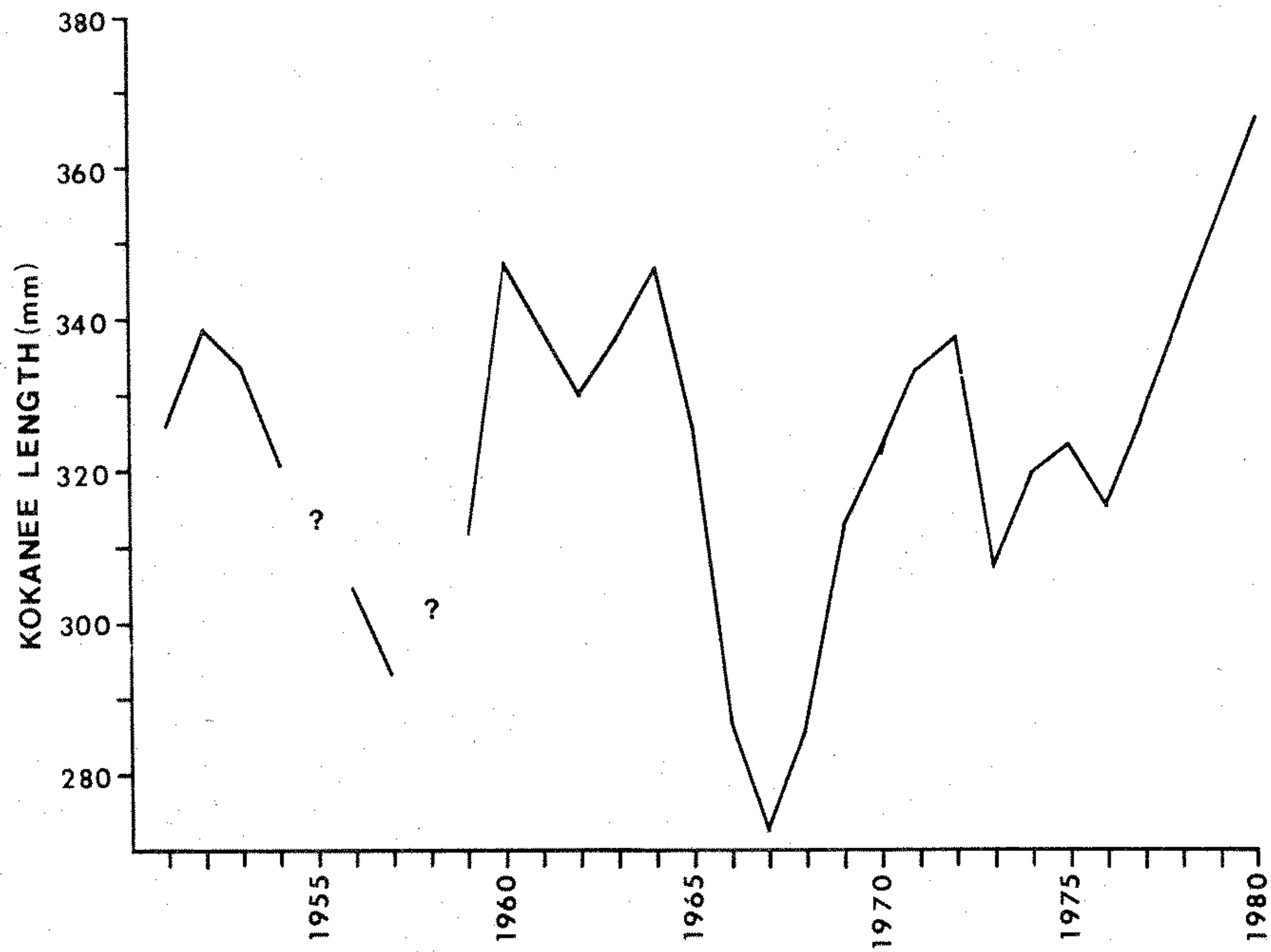

Figure 23. Mean length of kokanee spawners in the Flathead Lake-River system, 1951-80. Question marks indicate years in which no length data were obtained.

They postulated that releases of large volumes of warmer water (4° C vs. 0-1° C) from Hungry Horse might act as a migration cue to cutthroat, thus attracting the fish into the river earlier than they should be.

Our approach to monitoring migration of cutthroat has involved biotelemetry and conventional tag and recapture techniques. In addition, we have sampled three areas of the river frequently to develop catch per unit effort curves for all species. Low flows and ice conditions hampered our efforts in the winter of 1979-80. We were unable to begin electrofishing until late March. Unusually warm conditions during the winter of 1980-81 allowed us to begin sampling earlier than ever before. We were not able to use biotelemetry equipment in 1980-81 because of budget cutbacks. We were able to tag more trout than in previous years.

Our frequent electrofishing samples at three main stem sites helped to identify population trends of mountain whitefish. We also monitored abundance and movement of rainbow trout and bull trout.

METHODS

Cutthroat Trout Spawning Migration

Migration of adult westslope cutthroat trout was monitored by several methods. Biotelemetry methods were used in spring 1980. Conventional mark and recapture techniques were used throughout the study period. We also monitored abundance (catch per unit effort) in several areas of the river throughout the period.

Radio transmitters were used to track movements of two cutthroat in March, 1980. Transmitters were surgically implanted in a male (445 mm, 810 g) and a female (390 mm, 570 g). Both fish were caught by electrofishing in the Kalispell section. The fish were held in a cage overnight to allow time to recover from the stress of electrofishing (Schreck et al. 1976). Each fish was anesthetized in a buffered solution (Allen and Harman 1970) prior to surgery. A 25 mm-long incision was made in the ventral body wall between the vent and pelvic girdle. The transmitter was inserted and the wound closed with four sutures. Rectangular transmitters (21 mm x 46 mm x 17 mm) with an expected life of 28 days were used. Both fish were held for one hour before being released. Radio signals were tracked from shore, boat or from an airplane.

Frequent electrofishing samples were taken in several areas of the river to monitor abundance of cutthroat. Cutthroat longer than 225 mm were tagged with yellow anchor tags inserted into the muscle tissue beneath the dorsal fin. Smaller fish were marked with green or yellow dangler tags. Dangler tags were also inserted into the muscle tissue beneath the dorsal fin. Vinyl thread was used to attach the tag to the fish.

Fish Population Monitoring

Three sections of the main stem Flathead River were sampled by electrofishing frequently between June 1979 and March 1981. Two sections were located in the partially regulated portion of the river. The Kalispell section is located in the area of the U.S. Highway No. 2 bridge near Kalispell (Figure 5). The Columbia Falls section is located in the area of the Montana Highway 40 bridge at Columbia Falls. The Upper River Section is located just upstream of the mouth of the South Fork in the unregulated portion of the main stem.

Shoal areas in each section were electrofished at night from a jet powered boat. We normally sampled 2.95 km of shoreline in the Kalispell section, 2.00 km in the Columbia Falls section and 1.15 km in the Upper River section. We attempted to net all fish that responded to the electric field. Length and weight information and scale samples were collected, fish were marked and then released. Trout and whitefish longer than 225 mm were tagged with numbered anchor tags. We used yellow tags for cutthroat and rainbow trout, international orange tags for bull trout and blue tags for mountain whitefish. Smaller trout, of all species, were tagged with either green or yellow dangler tags. Smaller mountain whitefish were fin clipped. We clipped the adipose fin from whitefish caught at Columbia Falls. In the Upper River section we clipped the adipose and left pelvic fin. At Kalispell we clipped adipose and right pelvic fins.

Age and growth of cutthroat, rainbow and bull trout and mountain whitefish was determined from scale samples. Scales were collected from all trout throughout the study period. Mountain whitefish scales were collected in each sampling area during July. Fish were aged from acetate impressions of scales. Growth was back-calculated using the Monastyrsky method (Tesch 1971). Data analysis was facilitated by use of the FIRE 1 computer program developed by the Nebraska Game and Parks Commission (Hesse 1977) and adapted by the Montana Department of Fish, Wildlife and Parks.

RESULTS AND DISCUSSIONS

Cutthroat Trout Spawning Migration

Low flows and cold temperatures during the winter of 1979-80 resulted in build up of ice in the Flathead River. Ice limited access to the river until late March, 1980, more than one month after we had hoped to begin adult cutthroat trout studies. Flow and temperature conditions in winter 1980-81 were much milder. We were able to begin sampling adult cutthroat in early January, 1981.

Biotelemetry

If timing of cutthroat trout spawning migrations is affected by operations at Hungry Horse Dam, the greatest impacts on the river environment would be expected in January and February when water temperatures in the North and Middle Forks are coldest. However, due to accumulation of ice in the main stem, we were unable to begin sampling cutthroat until March 19, 1980.

Each of the two adult cutthroat radio tagged on March 28 was relocated only once after release. The male was located 1.0 km upstream from the release site approximately eight hours after release. The female was found 1.6 km downstream approximately 48 hours after being released. Despite intensive tracking efforts from shore, boats and airplanes, neither fish was located again.

In subsequent testing of identical transmitters we were unable to detect a signal from most transmitters immersed in less than one meter of water. The remaining transmitters were returned to Telonics and refitted with induction antennas. The transmitters were identical to one we used successfully in Young Creek (Graham et al. 1980a) except for an additional battery. Testing by Telonics personnel revealed that addition of the second battery reduced space available for the antenna, thus reducing transmission power.

We tested the reworked transmitters as soon as they were returned. Their performance was variable but, in general, not much better than before. We decided to use the best of the reworked transmitters but unseasonably warm weather resulted in early runoff, hampering our efforts. Because of questionable equipment performance and reduced impact by Hungry Horse on a flooding Flathead River, we elected to discontinue efforts to radio track cutthroat trout in 1980.

We did not attempt to radio track cutthroat in 1981. Reduced project funding limited our studies of adult cutthroat in 1981.

Electrofishing and Mark and Recapture

Huston and Schumacher (1978) speculated that releases of large volumes of warmer water from Hungry Horse might act as a migration cue to adult cutthroat in Flathead Lake. They reported large numbers of adult cutthroat near the mouth of the Stillwater River (36 km above the lake) as early as February. Peak abundance in the Kalispell area usually occurred in mid-April (Figure 24).

Throughout the current study, we have found adult cutthroat abundance increasing in the lower main stem as early as October. By December, adult cutthroat were noticeably more abundant in the Kalispell area than during summer months in both 1979 and 1980 (Figure 25). Increased abundance of adult cutthroat in the lower river during fall and winter months may be related to Hungry Horse operations. Seasonal drafting of Hungry Horse Reservoir usually begins in late fall.

Fall migrations of spring spawning fish are not uncommon in steelhead populations, especially among fish that migrate long distances. There

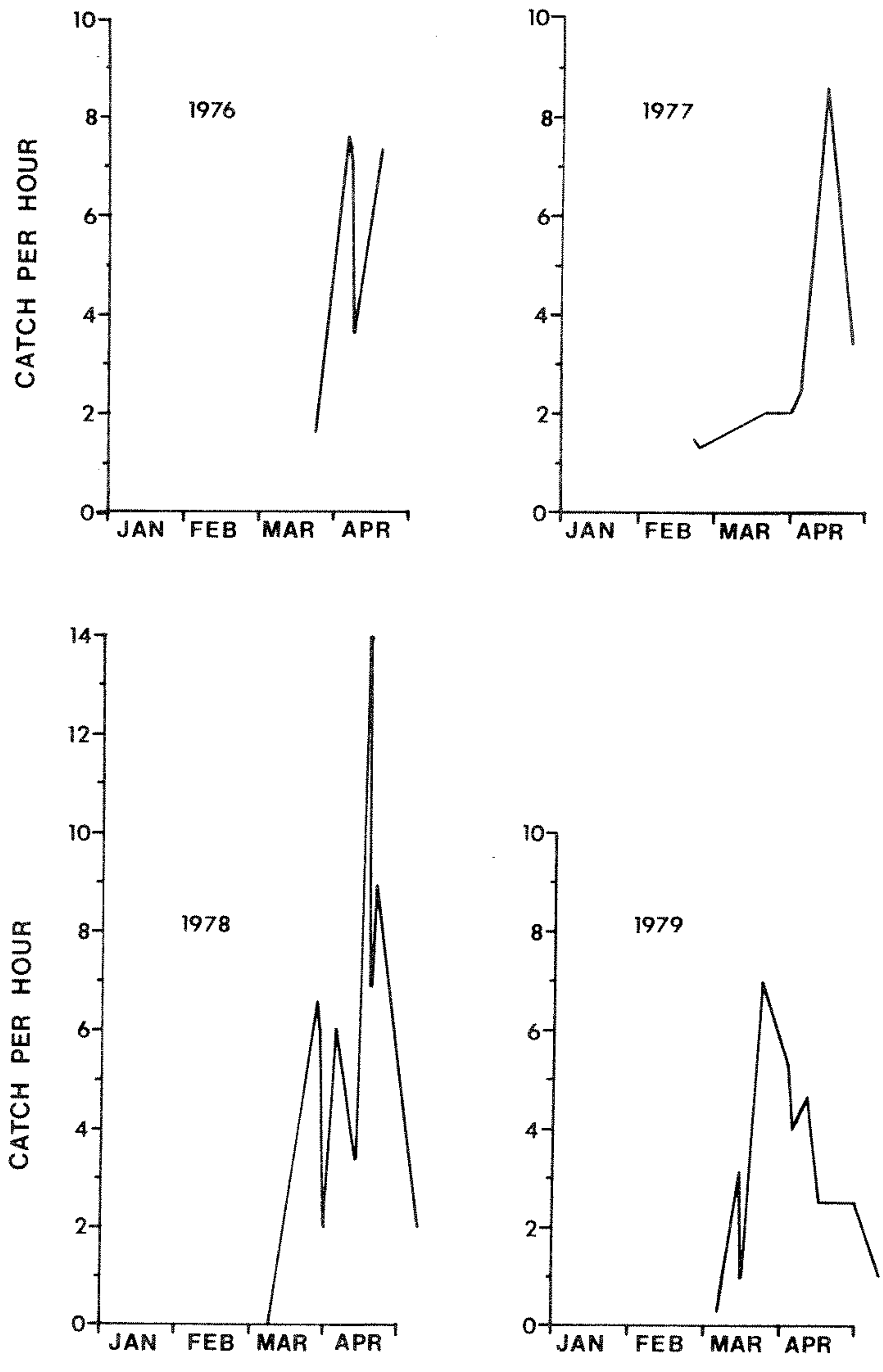

Figure 24. Adult westslope cutthroat trout catch per hour of electrofishing effort in the Kalispell section, 1976-79.

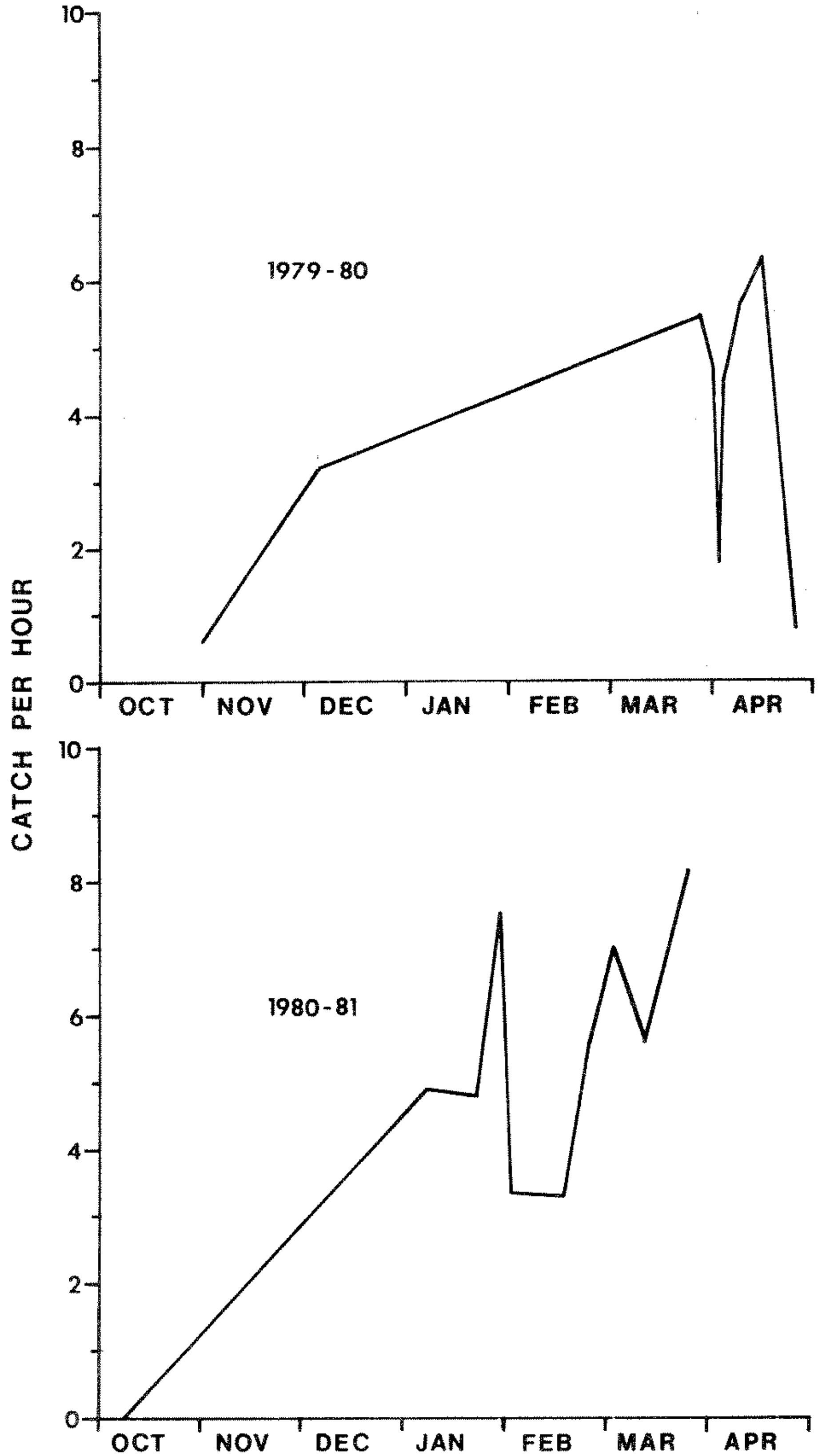

Figure 25. Adult westslope cutthroat trout catch per hour of electrofishing effort in the Kalispell section, 1979-81.

is not however, any record of which we are aware of a fall migration of cutthroat trout. Dr. Robert Behnke (Ft. Collins, Colorado, personal communication) inspected some fish thought to be cutthroat trout that were found spawning in a spring area of the upper Snake River in November. Dr. Behnke felt the fish were probably rainbow-cutthroat hybrids. Thus, it appears the Flathead Lake stock may be unique in that preliminary movement prior to spawning migrations may begin up to seven months prior to spawning. Peak migration does not occur until late winter or early spring but a significant number of fish begin their upstream migration much earlier.

A computer program developed by Graham et al. (1980b) was used to analyze data generated from nearly 800 tag returns since 1962. Use of the program allowed us to explore patterns in fish recaptures in greater detail than previously and helps explain some migration patterns of adult cutthroat trout.

Montana Department of Fish, Wildlife and Parks personnel have been tagging adult cutthroat during their spawning migration since 1976. During that time, it has become clear that the area of the Flathead River near the mouth of the Stillwater River is important as a holding area for spawning cutthroat trout. The area is commonly called the salmon hole (Figure 5).

Impoundment of Flathead Lake by Kerr Dam added approximately three meters to the lake surface elevation. Added elevation altered the lower 36 km of the Flathead River from a slow moving river to an estuary of Flathead Lake. At full pool elevation, the estuary ends at the salmon hole. The interface between lake and river creates a natural holding area for migrating fish. Large, flat areas in relatively shallow water make an excellent area to electrofish for adult cutthroat as they concentrate in the salmon hole. A large percentage of the cutthroat tagged since 1976 have been captured in the salmon hole area.

Since 1976, 11 adult cutthroat have been tagged in the salmon hole area and subsequently recaptured in the Kalispell electrofishing section (Figure 26). Average elapsed time between captures was 49 days, much longer than needed to travel the seven km between sections. Cutthroat that arrive at the salmon hole early in the migration season tend to hold in the area longer than those that arrive later. Six cutthroat tagged at the salmon hole in February were recaptured in the Kalispell section an average of 56 days later. Five cutthroat tagged at the salmon hole in March and April were recaptured in the Kalispell section an average of 40 days later.

Early arrival and long holding period of adult cutthroat may be related to food availability. Leathe and Graham (1981) reported extremely limited feeding by cutthroat in Flathead Lake during winter months. Unlike cutthroat in Lake Koocanusa, Montana, which convert from an insectiverous to a planktiverous diet in winter (McMullin

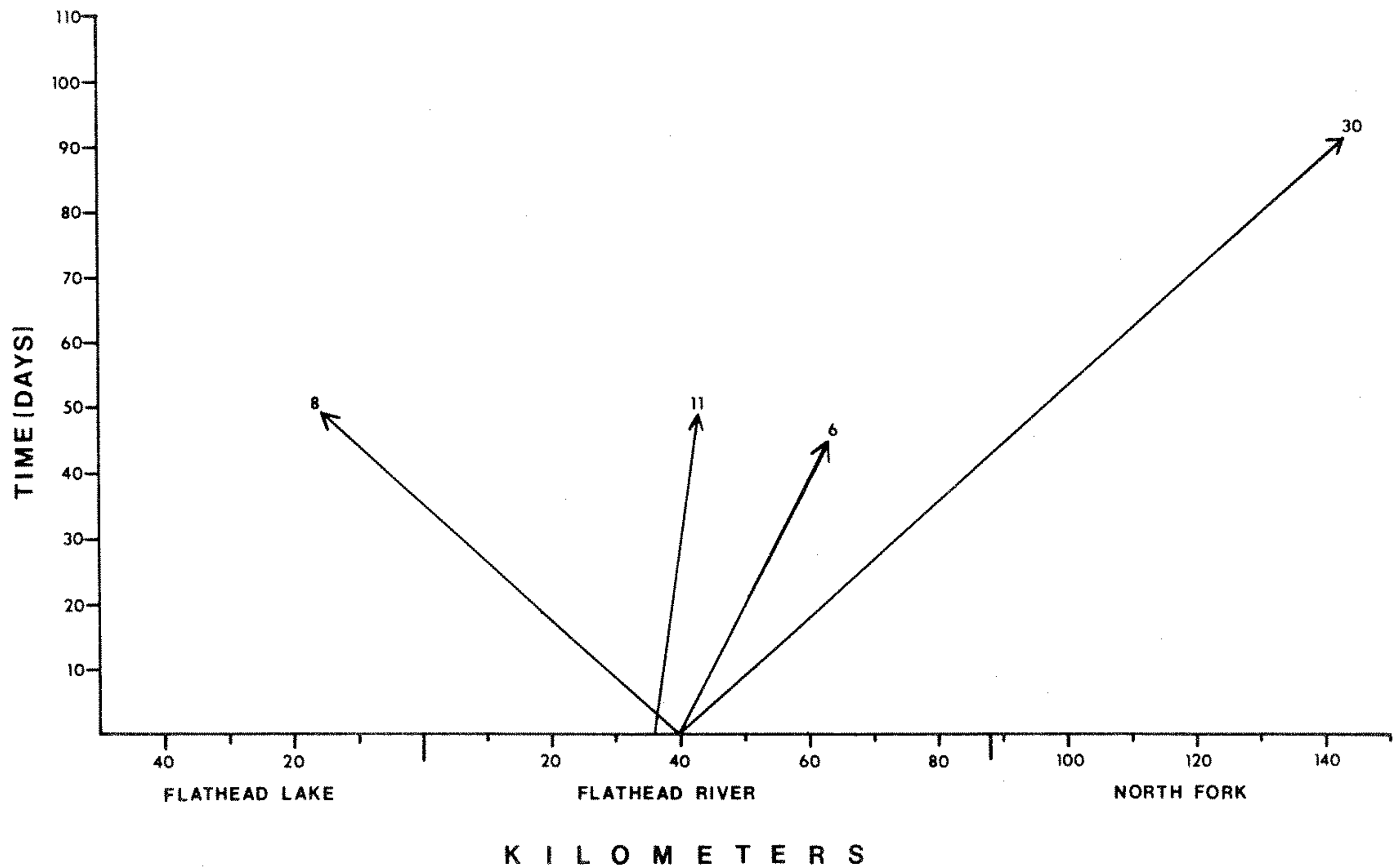

Figure 26. Mean minimum rates of movement of adult westslope cutthroat trout tagged in the lower Flathead River and recaptured in various areas of the Flathead drainage, 1976-81.

1979), Flathead Lake cutthroat appear to feed on insects when available, and cease feeding when insects are not available. A small sample of cutthroat taken at the salmon hole in January, 1981 were found to be feeding extensively upon stoneflies and midges.

Seven cutthroat tagged in the salmon hole and Kalispell sections in 1977 and 1978 were subsequently recaptured in Flathead Lake in April or May (Figure 26). It is doubtful that these fish migrated upstream, spawned and returned to Flathead Lake in such a short period. In all cases, these fish were recaptured in Flathead Lake shortly after periods of high turbidity in the river, which would have impaired feeding ability. Activity of terrestrial insects (an important component of the diet of cutthroat in lakes) usually increases in late April and May as air temperatures become warmer, thus making them more available in the lake's surface film.

There is a tendency for cutthroat arriving at the salmon hole early to travel further upstream than later arrivals. Twelve cutthroat tagged at the salmon hole during the period February 17-23 (1976-81) and recaptured upstream of Kalispell had traveled an average of at least 99 km. Fifteen cutthroat tagged at the salmon hole during the period March 14-31 (1976-81) were recaptured an average of 83 km upstream.

In many trout populations, older fish, especially repeat spawners, tend to migrate earlier than first time spawners. Migration of Lahontan cutthroat trout (*Salmo clarki henshawi*) out of Pyramid Lake, Nevada, displays two peaks. The February peak consists largely of older, larger repeat spawners while the April peak is composed chiefly of smaller first time spawners (Dr. Robert Behnke, Fort Collins, Colorado, personal communiction). Analysis of spawner length gives no indication of this phenomenon in the Flathead system. Adult cutthroat caught in the Kalispell section in January through April average approximately the same length each month for the period 1976-81.

It would be difficult to determine if older cutthroat migrate up the Flathead earlier than younger fish. The longer holding period of early arrivals in the salmon hole area results in both early and late arrivals passing through the Kalispell section at approximately the same time. Median date of recapture in the Kalispell section of cutthroat tagged at the salmon hole in February (1976-81) was April 16. Median date of recapture in the Kalispell section of cutthroat tagged at the salmon hole in March was April 13.

Fish Population Monitoring

Westslope Cutthroat Trout

Relative abundance and movement

Patterns in relative abundance of westslope cutthroat trout, as determined by electrofishing, were similar for all three electrofishing sections in 1979 and 1980.

Adult cutthroat were rarely captured in the Upper River section. Migrating adults probably spent little time in the Upper River section. Excellent holding areas were found just above and below the section.

Abundance of juvenile cutthroat (<300 mm total length) peaked in early September, 1979 (Figure 27). Catches of juvenile cutthroat were low in the Upper River section throughout 1979 however. It is doubtful that peak downstream migration occurs as late as September, since peak abundance in the Columbia Falls section (10 km downstream) occurred nearly one month earlier.

More frequent sampling during 1980 resulted in a clearer picture of juvenile cutthroat migration through the Upper River section (Figure 28). Peak abundance was reached in late July but fell off sharply in August.

Lack of good holding area also results in inconsistent catches of adult cutthroat in the Columbia Falls section. We caught too few adults at Columbia Falls in 1979 to draw any conclusions (Figure 27). Adults were relatively abundant at Columbia Falls when we began sampling in March, 1980 (Figure 28). Abundance dropped after the first sample although adults continued to pass through the section. In 1981, abundance of adults again peaked in March, however, sampling was discontinued while the spawning migration was still in progress (Figure 29).

Abundance of juvenile cutthroat in the Columbia Falls section peaked in mid-August, 1979 (Figure 27). Abundance dropped rapidly thereafter, but juvenile cutthroat were present throughout the sampling period. Juvenile cutthroat abundance peaked in mid-September, 1980, but at a lower level than in 1979 (Figure 28). Peak downstream migration of juvenile cutthroat through the Columbia Falls section in 1980 probably occurred in late August or early September. Angling by project personnel revealed juvenile cutthroat were very abundant two km downstream from the Columbia Falls section on September 3, 1980. Abundance of juveniles dropped rapidly after the September 1980 peak, but cutthroat were present in low densities throughout the winter of 1980-81 (Figures 28 and 29).

Abundance of adult cutthroat in the Kalispell section was discussed previously. Juvenile cutthroat were present in the Kalispell section throughout the entire sampling period. Abundance of juveniles increased noticeably in fall of both 1979 and 1980. Abundance was increasing as sampling was discontinued in December, 1979 (Figure 27). A similar pattern developed in 1980, however, mild winter weather allowed us to continue sampling throughout the winter. Juveniles remained relatively abundant until late January when abundance increased dramatically (Figure 29). Abundance decreased rapidly thereafter except for a second minor peak in March.

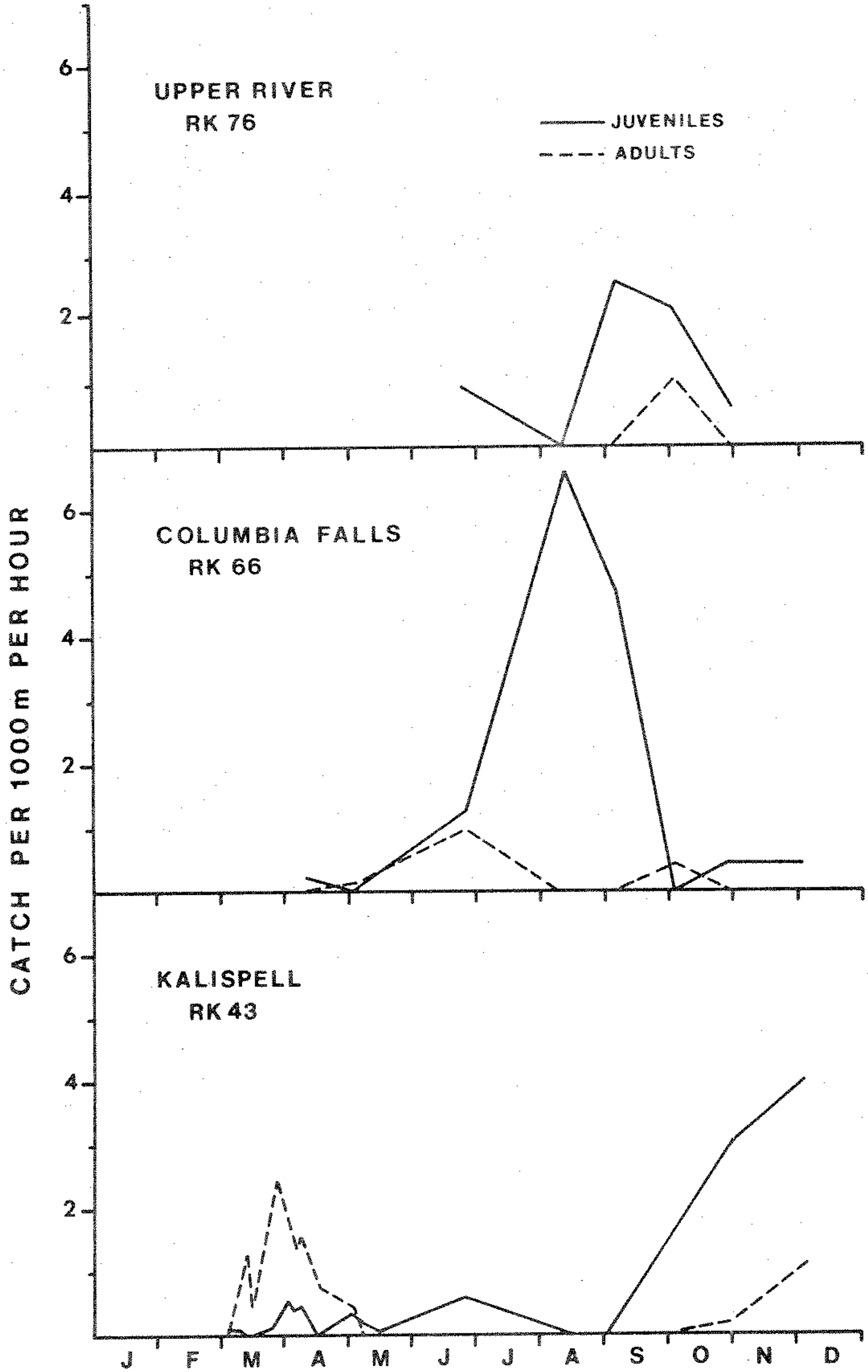

Figure 27. Cutthroat trout catch per 1000 m of shoreline sampled per hour of electrofishing effort in three sections of the Flathead River, 1979.

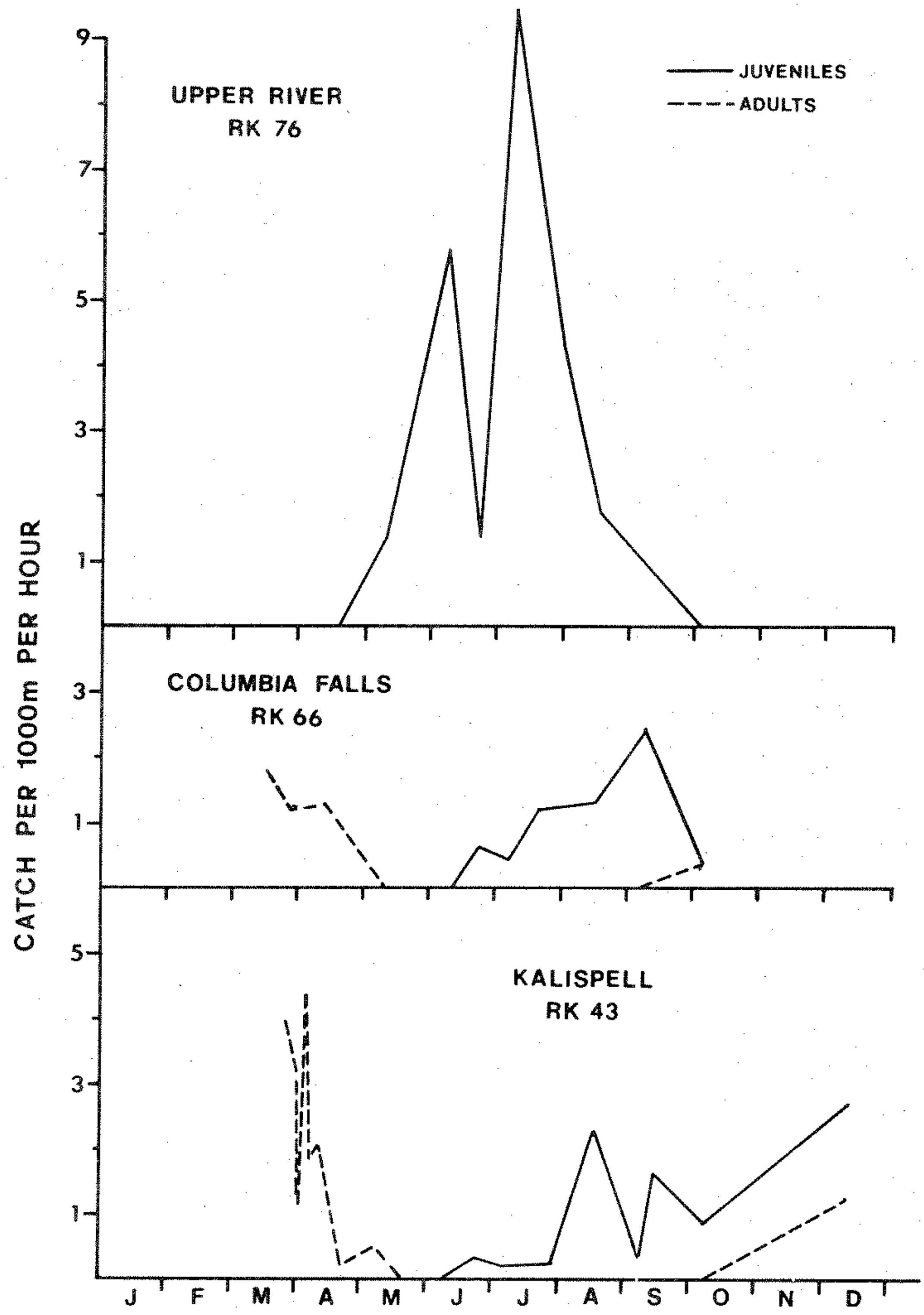

Figure 28. Cutthroat trout catch per 1000 m of shoreline per hour of electrofishing effort in three sections of the Flathead River, 1980.

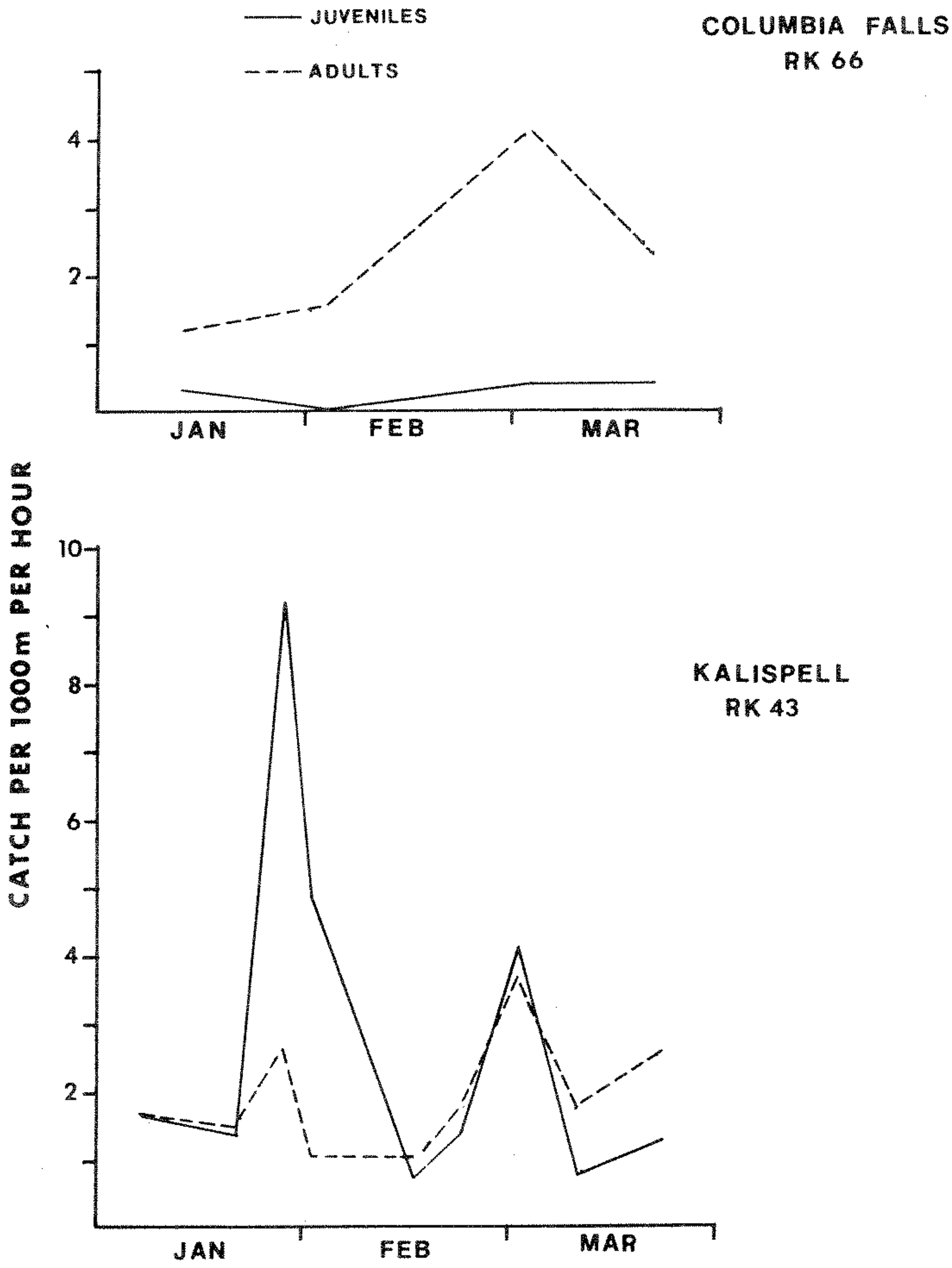

Figure 29. Cutthroat trout catch per 1000 m of shoreline per hour of electrofishing effort in two sections of the Flathead River, 1981.

Prior to 1980, juvenile cutthroat were marked by cold branding. Angler returns of cold branded fish were negligible. In 1980, we began using dangler tags and the return rate increased significantly. Fourteen dangler tagged juvenile cutthroat were recaptured downstream from their respective release sites (Figure 30). They averaged a minimum of 0.64 km/day to the point of recapture, although rates varied from 0.11 to 4.05 km/day. Two juvenile cutthroat were recaptured at locations upstream of their release points.

Based on our electrofishing results and analysis of tag returns, it appears the partially regulated portion of the Flathead River constitutes important overwintering habitat for juvenile cutthroat. Two of the juvenile cutthroat captured in the Kalispell section on January 28, 1981 had been previously tagged. One was tagged at Round Prairie (North Fork RK 64) on July 14, 1980. The other was tagged near Pressentine Bar (main stem RK 58) on September 4, 1981. It is clear that a significant number of cutthroat smolts spent the entire 1980 growing season in transit to Flathead Lake. The question of whether or not migrating juvenile cutthroat would spend as long a time in the river during a colder winter, or a winter when less generation at Hungry Horse occurred, remains unanswered.

Age and growth

Scales taken from 250 cutthroat trout caught in the main stem Flathead River during the 1980-81 growing season were used for age and growth analysis. The body-scale relationship was very similar to that of 556 cutthroat from the Middle Fork drainage (Figure 31). Relationships for both the Middle Fork and main stem differed from that of the North Fork. The difference can probably be attributed to the lack of adult fish in the North Fork sample. A body-scale relationship calculated for a portion of the juveniles captured in the main stem closely resembled that of the North Fork.

Over 91 percent of the cutthroat trout captured in the main stem during 1980-81 had emigrated from tributary streams at age II and III. The percentage of cutthroat that emigrated from tributaries at age II was considerably higher than in either the North Fork or Middle Fork (Table 11). Percentage of age III migrants was slightly lower, while the percentage of age I migrants was markedly lower. Differences in age structure of outmigrants may reflect the presence of fluvial populations in the upper drainage, especially in the Middle Fork.

The cold, relatively sterile environment in most tributaries of the North and Middle Forks, coupled with a short growing season, results in the lack of annulus formation on the scales of many juvenile cutthroat (Fraley et al. 1981). Twenty-nine percent of the cutthroat captured in the main stem lacked a first annulus, versus 61 percent for the North and Middle Forks combined. Percentage of cutthroat missing the first annulus increased with the number of years spent

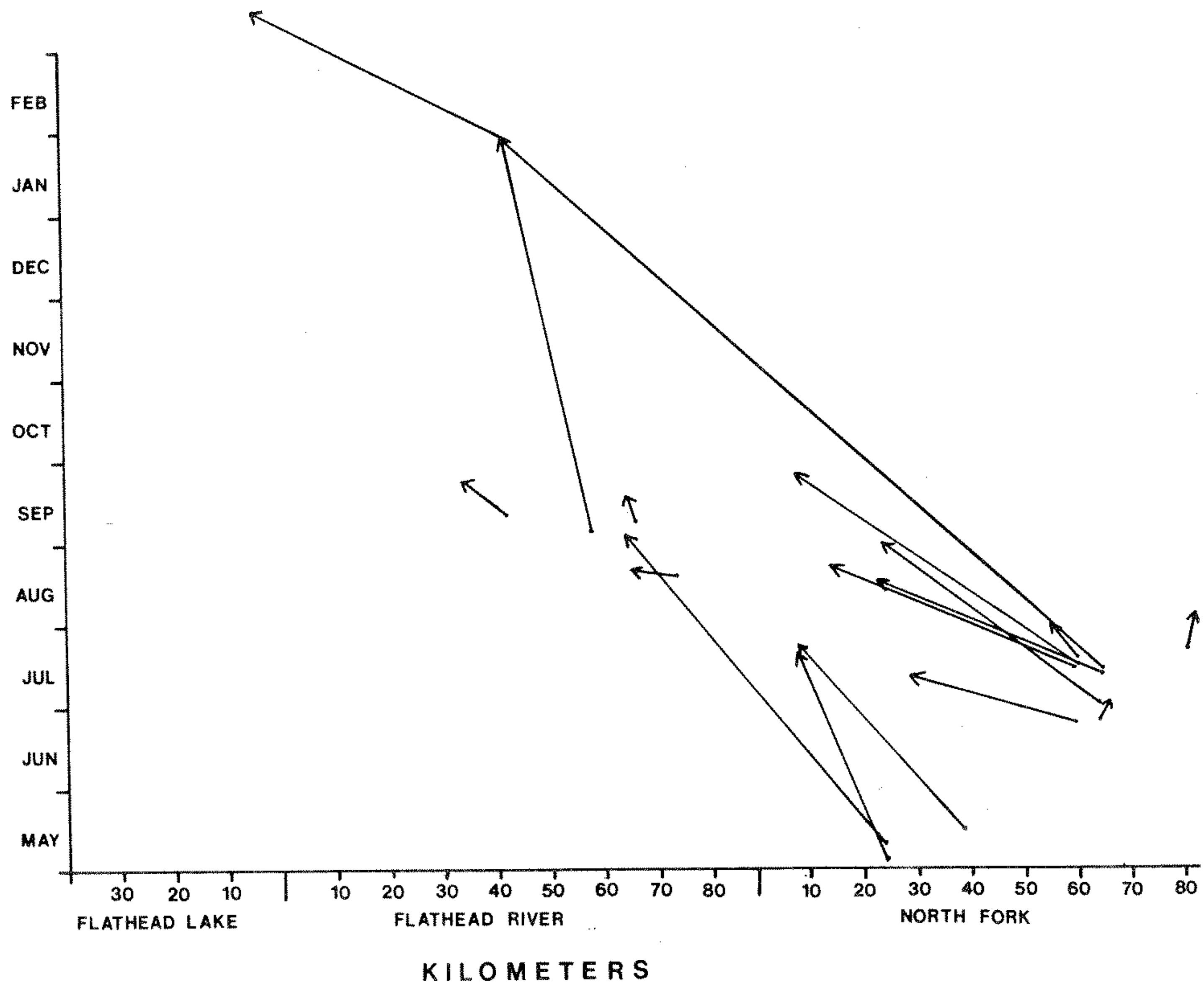

Figure 30. Movements of juvenile westslope cutthroat trout between tagging sites (·) and recapture sites (→) in the upper Flathead drainage, 1980-81.

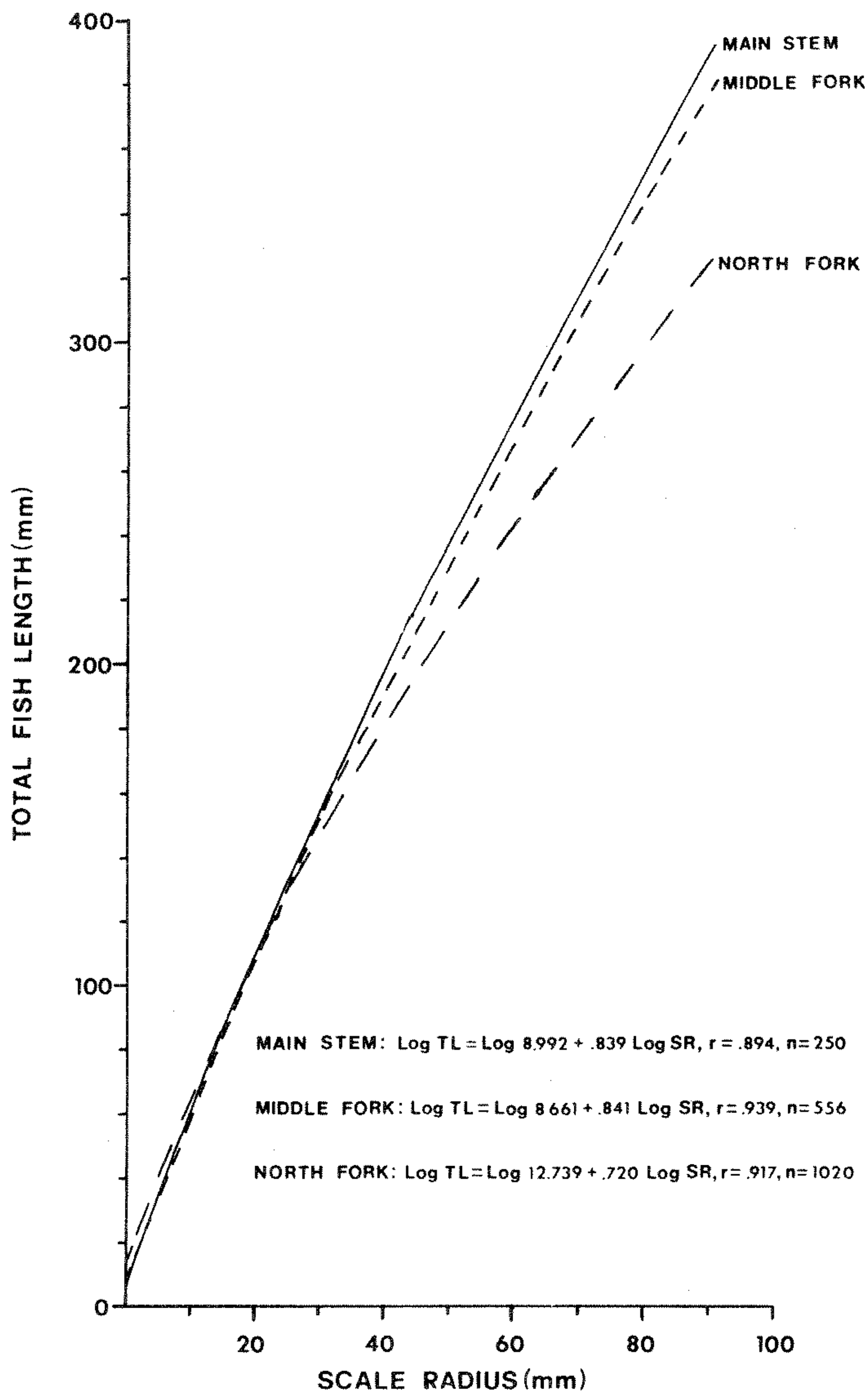

Figure 31. Monastyrsky body-scale relationship for westslope cutthroat trout captured in the North Fork, Middle Fork and main stem Flathead River, 1980-81.

Table 11. Number of westslope cutthroat trout rearing 1, 2, 3, 4 or 5 years before emigrating from a tributary stream into the North Fork, Middle Fork or main stem Flathead River.

Years in tributary	Age class I	II	III	IV	V	VI	VII	Total	(%)
North Fork*									
1	--	13	11	2	--	--	--	26	(21.0)
2	--	14	26	2	--	--	--	40	(32.3)
3	--	--	40	9	1	--	--	50	(40.3)
4	--	--	--	7	1	--	--	8	(6.4)
Middle Fork*									
1	--	2	22	14	5	--	--	43	(23.4)
2	--	14	20	18	3	--	--	55	(29.9)
3	--	--	40	32	7	--	--	79	(42.9)
4	--	--	--	5	1	--	--	6	(3.3)
5	--	--	--	--	1	--	--	1	(0.5)
Main stem									
1	3	10	1	--	--	--	--	14	(5.6)
2	--	125	9	1	5	2	--	142	(56.8)
3	--	--	72	3	--	9	2	86	(34.4)
4	--	--	--	3	1	2	2	8	(3.2)

* Data taken from Fraley et al. 1981

in a tributary stream, suggesting slower growth in the first year is carried over into subsequent years. Only 26 percent of the cutthroat that emigrated from tributaries at age II failed to form a first annulus, versus 36 percent of those that emigrated at age III and 63 percent that emigrated at age IV. Cutthroat that formed a first annulus averaged 15 mm longer in total length at age II than those that did not form a first annulus (Table 12).

Cutthroat that failed to form a first annulus appeared to compensate for slower tributary growth with faster river growth than those that formed a first annulus. In all cases, most rapid growth was attained during the growing season in which the fish emigrated from tributaries. Most cutthroat grew approximately 100 mm in length during their first year out of the tributaries. Growth patterns for all migration classes are listed in Tables 13 through 16.

Rainbow trout

Relative abundance and movement

The first recorded introduction of rainbow trout in the upper Flathead drainage occurred in 1914, although Elrod et al. (1929) report introductions in Flathead Lake may have occurred as early as 1900. Stocking of rainbows throughout much of the basin continued through the mid-1960's. Over six million rainbows were planted in or above Flathead Lake through 1954 (Hanzel 1977). Stocking in most of the drainage was discontinued in 1966 when a final plant of catchable rainbow was made in Swan Lake, Holland Lake and the Swan River. A low return rate from catchable plants and a change in policy resulted in the end of rainbow plants in the Flathead. Lake Mary Ronan was stocked with rainbow through 1974. Rainbow stocked in Lake Mary Ronan could have invaded Flathead Lake through Ronan Creek although it is thought few did (Bob Domrose, Montana Department of Fish, Wildlife and Parks, Kalispell, personal communication).

After stocking was discontinued, rainbow remained common in the Swan River and some of its tributaries. In Flathead Lake and the Flathead River, however, rainbow have been present only in low densities. Rainbow comprised only 1.4 percent of the summer catch in a creel census of the Flathead drainage above Flathead Lake in 1975 (Hanzel 1977).

Most rainbow caught during the creel census came from the following three areas: 1) the main stem near the outfall of Sekokoni Springs (a private commercial rainbow trout hatchery near Coram in operation since 1958); 2) the confluence of the main stem and the South Fork; and 3) the lower main stem near Kalispell. A few rainbow were reported from both the North and Middle Forks but identification by untrained field personnel and anglers were suspect (Hanzel 1977). No rainbow were reported in either fork during studies in the 1950's and 1960's (Block 1955, Johnson 1963).

Table 12. Back-calculated length at age II of cutthroat trout spending one to four years in a tributary stream that did or did not form a first annulus.

Years in tributary	With first annulus		Without first annulus	
	Sample size	Length (mm)	Sample size	Length (mm)
Main stem				
2	105	114	37	99
3	55	95	31	84
4	3	103	5	92
Total	163	107	73	92
Combined North and Middle Forks*				
Total	491	105	828	91

* Data taken from Fraley et al. 1981.

Table 13. Back-calculated lengths and increments of growth for cutthroat trout collected in the main stem Flathead River that spent one year rearing in a tributary stream.

Age	Sample Size	Length at annulus (mm) I		II		III
1	3	72				
2	10	50		145		
3	1	62		147		235
Mean		56		145		235
Sample size		14		11		1
Growth increment			89		90	

Table 14. Back-calculated lengths and increments of growth for cutthroat trout collected in the main stem Flathead River that spent two years rearing in a tributary stream.

		Length at annulus (mm)					
Age	Sample size	I	II	III	IV	V	VI
Fish that formed first annulus							
2	96	57	114				
3	4	53	105	230			
4	1	62	134	239	306		
5	3	59	120	240	289	317	
6	1	29	116	198	263	302	329
	Mean	57	114	231	287	313	329
	Sample size	105	105	9	5	4	1
	Growth increment		57	117	56	26	16
Fish that did not form first annulus							
2	29	---	95				
3	5	---	129	247			
4	0	---	---	---	---		
5	2	---	85	190	289	331	
6	1	---	111	203	279	329	366
	Mean	---	99	227	286	330	366
	Sample size	---	37	8	3	3	1
	Growth increment			128	59	44	36
Total sample							
2	125	57	110				
3	9	53	118	239			
4	1	62	134	239	306		
5	5	59	106	220	289	323	
6	2	29	114	201	271	316	348
	Mean	57	110	229	287	320	348
	Sample size	105	142	17	8	7	2
	Growth increment		53	119	58	33	28

Table 15. Back-calculated lengths and increments of growth for cutthroat trout collected in the main stem Flathead River that spent three years rearing in a tributary stream.

		Length at annulus (mm)						
Age	Sample size	I	II	III	IV	V	VI	VII
Fish that formed first annulus								
3	50	51	96	149				
4	1	57	82	134	223			
5	0	---	---	---	---	---		
6	4	37	81	144	238	291	313	
7	0	---	---	---	---	---	---	---
	Mean	50	95	148	235	291	313	---
	Sample size	55	55	55	5	4	4	---
	Growth increment		45	53	86	56	22	---
Fish that did not form first annulus								
3	22	---	84	136				
4	2	---	82	130	235			
5	0	---	---	---	---	---		
6	5	---	91	157	259	307	339	
7	2	---	67	114	229	294	352	381
	Mean	---	84	138	247	303	343	381
	Sample size	---	31	31	9	7	7	2
	Growth increment			54	109	56	40	38
Total sample								
3	72	51	92	145				
4	3	57	82	131	231			
5	0	---	---	---	---	---		
6	9	37	87	151	250	300	327	
7	2	---	67	114	229	294	352	381
	Mean	50	91	144	243	299	332	381
	Sample size	55	86	86	14	11	11	2
	Growth increment		41	53	99	56	33	49

Table 16. Back-calculated lengths and increments of growth for cutthroat trout collected in the main stem Flathead River that spent four years rearing in a tributary stream.

Age	Sample size	Length at annulus I	II	III	IV	V	VI	VII
Fish that formed first annulus								
4	2	59	102	147	194			
5	1	51	106	160	215	287		
6	0	---	---	---	---	---	---	
7	0	---	---	---	---	---	---	---
	Mean	56	103	151	201	287		
	Sample size	3	3	3	3	1		
	Growth increment		47	48	50	86		
Fish that did not form first annulus								
4	1	---	87	129	173			
5	0	---	---	---	---	---		
6	2	---	82	134	194	302	327	
7	2	---	104	138	199	291	353	381
	Mean	---	92	135	192	297	340	381
	Sample size	---	5	5	5	4	4	2
	Growth increment			42	57	105	43	41
Total sample								
4	3	59	97	141	187			
5	1	51	106	160	215	287		
6	2	---	82	134	194	302	327	
7	2	---	104	138	199	291	353	381
	Mean	56	96	141	195	295	340	381
	Sample size	3	8	8	8	5	4	2
	Growth increment		40	46	54	100	45	41

In the last few years, as studies of the entire upper Flathead drainage have intensified, occasional catches in the lower North Fork have been verified. We have observed rainbow trout while snorkeling in McDonald Creek. Catches of rainbow in the main stem near Kalispell, incidental to electrofishing for adult cutthroat, increased slowly from 1976 through 1980 and dramatically in 1981 (Figure 32).

Our year around sampling since 1979 indicates rainbow were most abundant in the upper main stem, with abundance decreasing progressively further downstream (Figure 33). Our Upper River electrofishing section is located immediately upstream of the confluence with the South Fork and approximately five km downstream from Sekokoni Springs.

Rainbow catches in our electrofishing sections varied widely in 1979 (Figure 34) and failed to establish any clear patterns, although abundance rose in all three sections in fall. More frequent sampling in the 1980-81 season resulted in more distinct patterns of abundance (Figure 35). Rainbow were more abundant, on the average, in the Upper River section than in either the Columbia Falls or Kalispell sections. A sharp increase in abundance of rainbow in late July, 1980 consisted largely of age I+ fish. The sharp increase in numbers of young rainbow indicates either a strong year class produced in 1979 or escape of a large number of rainbow, possibly from Sekokoni Springs. The possibility of escape from the hatchery cannot be ruled out, although inspection of the hatchery's outfall showed the system of retaining screens to be in good working order.

Some natural reproduction by rainbow trout is undoubtedly occurring, but where rainbow spawn in the Flathead River has not been determined. Increased abundance at Columbia Falls in spring 1980 and 1981 (Figure 35) is suggestive of a spawning migration. We have captured mature, pre-spawning adult rainbows at Blankenship Bridge (confluence of North and Middle Forks) during spring sampling, 1980 and 1981. We have received unconfirmed reports that rainbow trout spawn in Abbott Creek, a tributary entering the main stem approximately one km upstream of our Upper River electrofishing section.

Information on movement of rainbow trout in the Flathead has been limited by the small number of recaptures. Prior to 1979, few rainbow were tagged and many of those caught while sampling for adult cutthroat were killed. Most of the tag returns we have received since 1979 have come from the area where fish were tagged. Little movement of rainbow in the Kootenai River was found by May and Huston (1973, 1974, 1975).

Age and growth

Scales from 85 rainbow trout (mostly age I and II) caught in the main stem Flathead River during the 1980-81 growing season were used in age and growth analysis. The Monastyrsky body-scale relationship was Log TL = 0.784 + 0.866 Log SR (r^2 = 0.92).

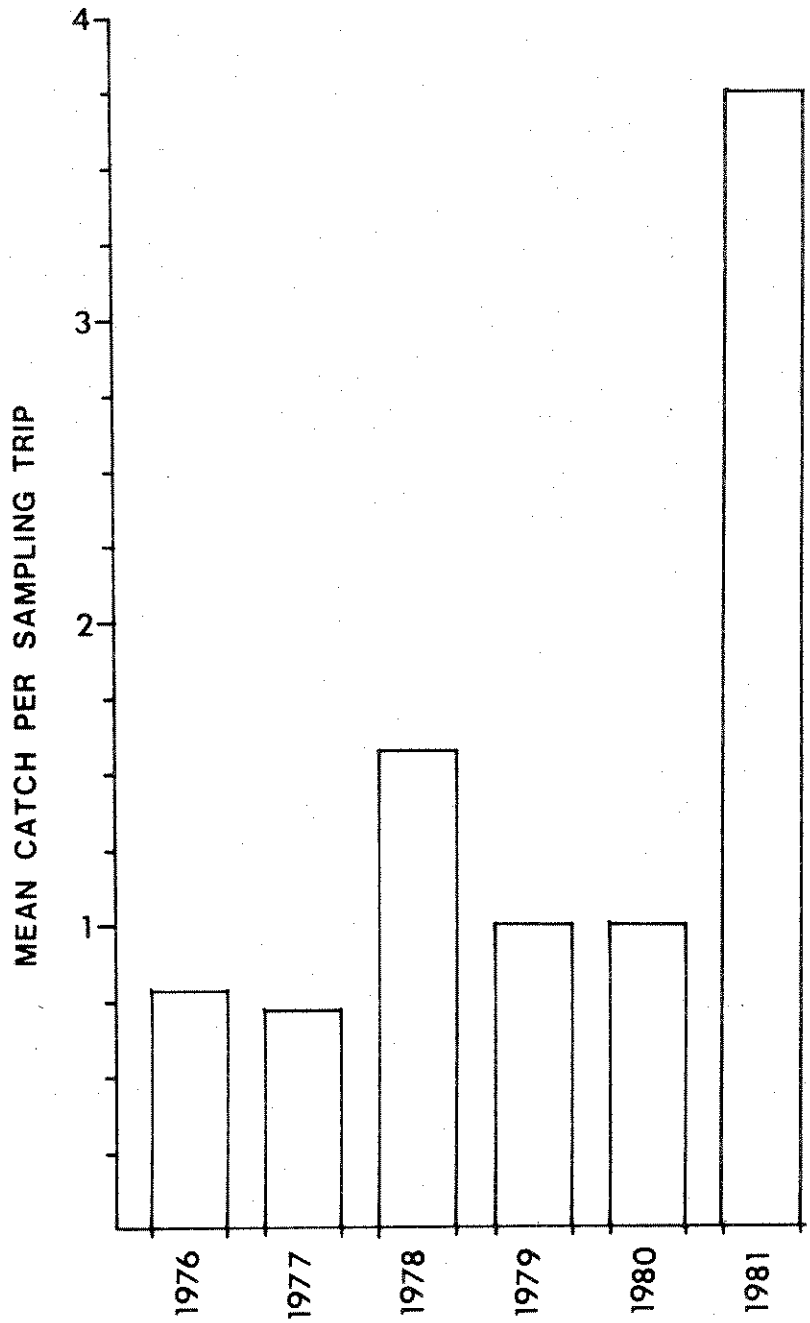

Figure 32. Mean catch of rainbow trout per electrofishing trip in the Kalispell section, 1976-81.

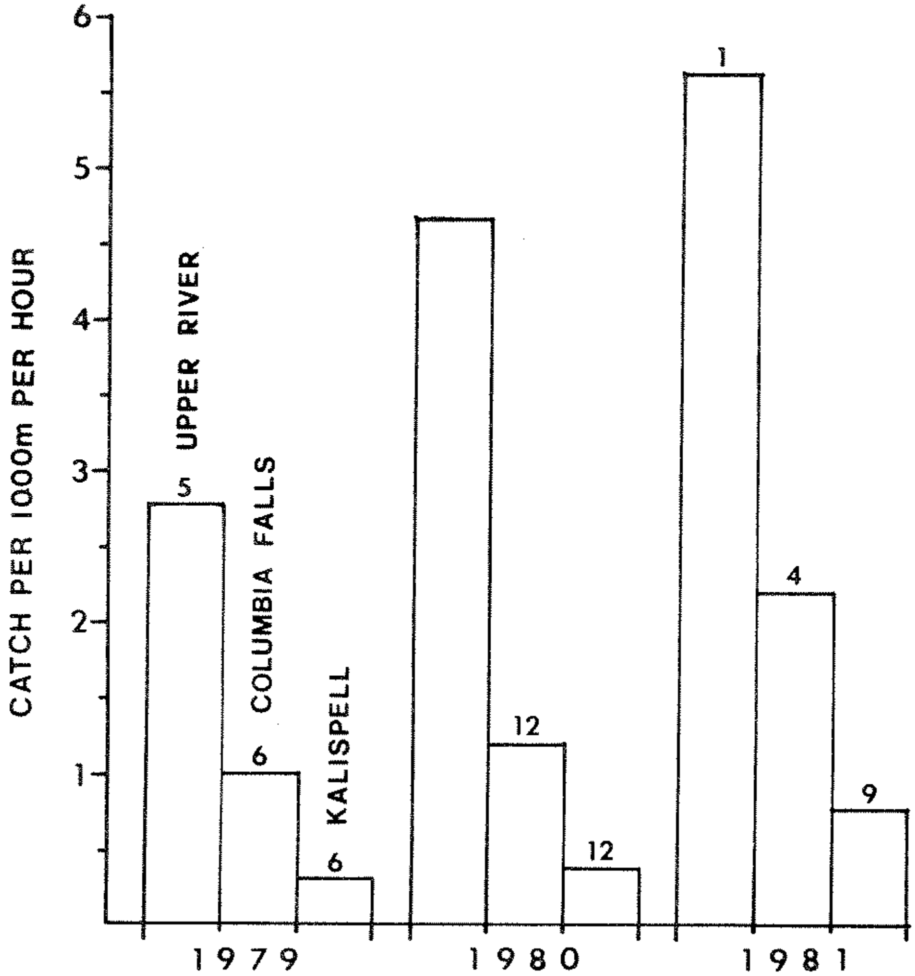

Figure 33. Mean rainbow trout catch per 1000 m of shoreline per hour of electrofishing effort by year for three sections of the Flathead River, 1979-81. Numbers indicate number of sampling trips per section.

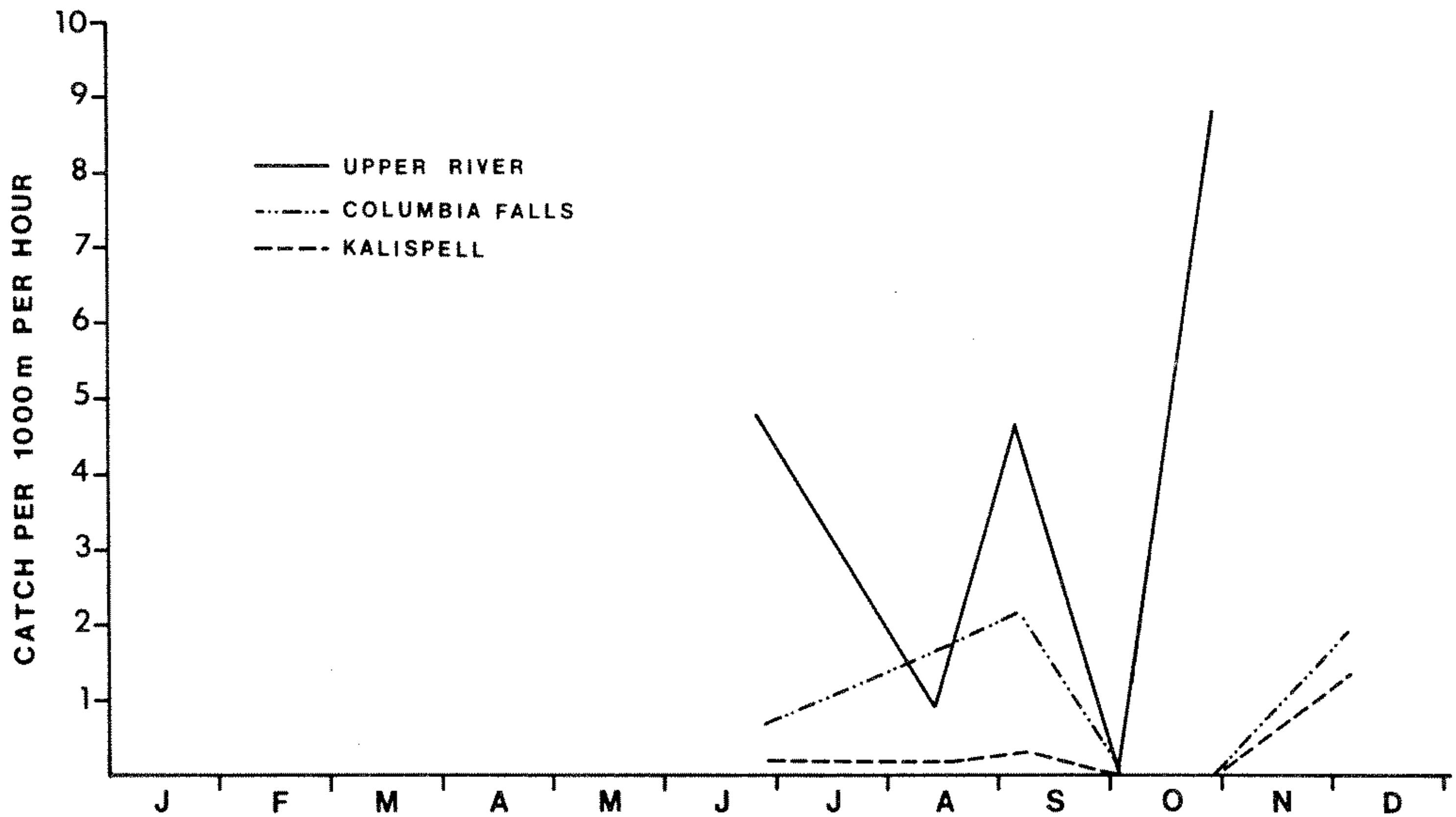

Figure 34. Rainbow trout catch per 1000 m of shoreline per hour of electrofishing effort in three sections of the Flathead River, 1979.

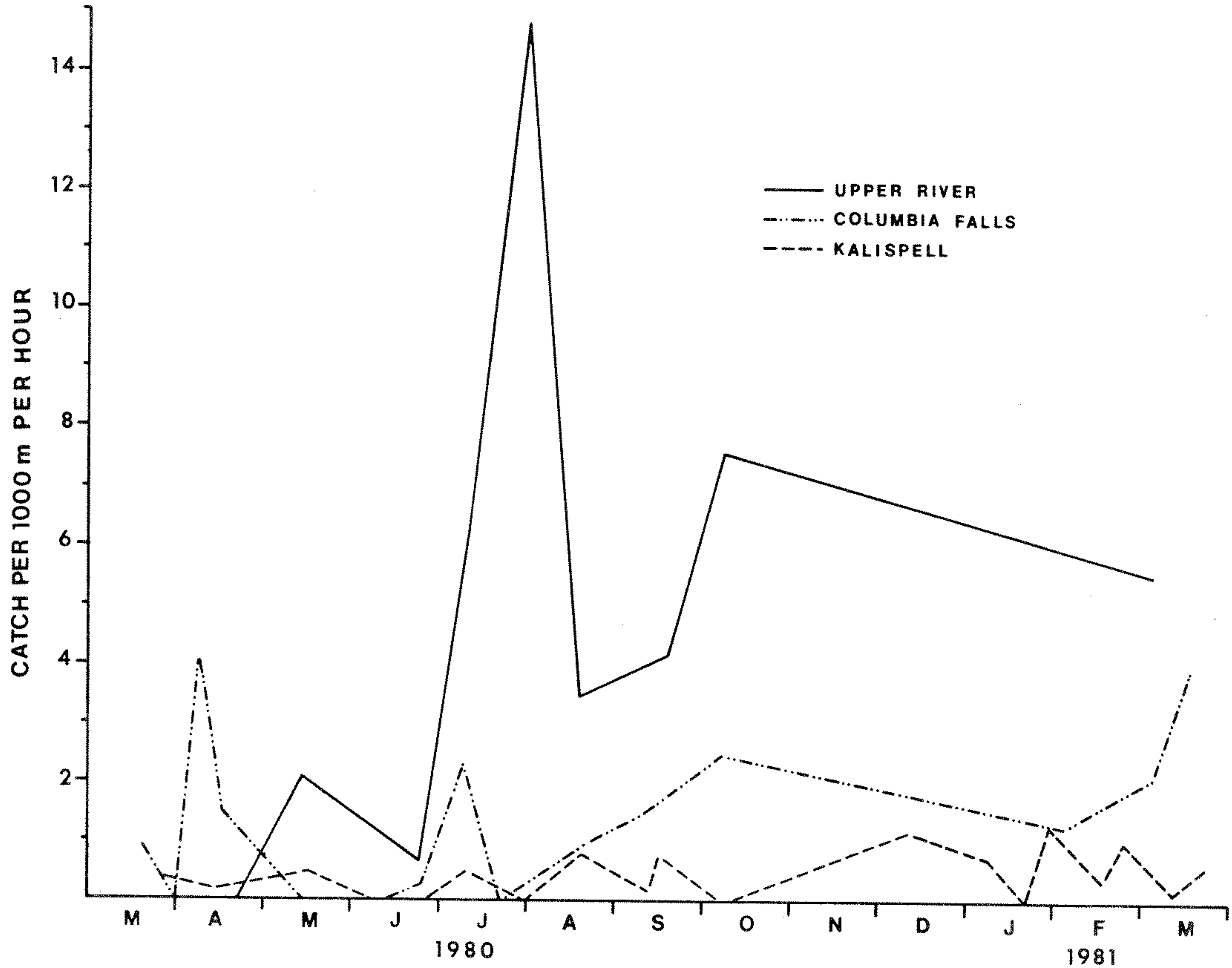

Figure 35. Rainbow trout catch per 1000 m of shoreline per hour of electrofishing effort in three sections of the Flathead River, 1980-81.

Rainbow trout averaged 77 mm total length at age I (Table 17). Growth from age I to age II was similar to growth of cutthroat trout during their first year out of the tributary streams. After age II, rainbow grew at a faster rate than cutthroat. Growth of rainbow in the Flathead River in 1980 was slightly slower than growth of rainbow in the Kootenai River between 1970 and 1977. Rainbow in the Kootenai averaged 69 mm at age I, 276 mm at age II, 376 mm at age III and 414 mm at age IV (May and Huston 1979). Growth of rainbow in the Kootenai River has been slower in recent years.

Bull trout

Relative abundance and movement

It is more difficult to assess abundance of bull trout than any other species in the Flathead River. Large adults (up to 10 kg) are powerful swimmers and more often than not escape the electric field during our electrofishing samples. Adult bull trout captured by electrofishing frequently exhibit skin burns and temporary loss of equilibrium. In addition, adult bull trout are sensitive to handling. Stress associated with shocking and handling may increase chances of mortality occurring, thereby reducing probability of gaining tag return information. Peak abundance of adult bull trout in the main stem is often associated with peak run off when electrofishing efficiency is greatly reduced.

Juvenile bull trout (<400 mm total length) are certainly more abundant than our sampling would indicate. Juvenile bull trout are usually closely associated with the river bottom in deeper runs and pools, areas where electrofishing is relatively ineffective.

We snorkeled selected areas of the main stem in 1980 in an attempt to test the effectiveness of snorkeling in a large river. Cutthroat and rainbow trout were readily observed when visibility was good, but we saw no bull trout. Fraley et al. (1981) found snorkeling to be less effective than shocking as a means of estimating abundance of juvenile bull trout populations in tributaries of the North and Middle Forks of the Flathead River.

Bull trout catches during the 1979 sampling season were too low and variable to determine patterns in abundance (Figure 36). However, peaks in abundance of juveniles in the Columbia Falls and Kalispell sections during 1979 roughly coincided with peaks during the 1980 season (Figure 37). Juvenile bull trout appeared to inhabit the partially regulated portion of the main stem throughout the year. A significant portion of the juvenile bull trout captured were subadults (nearly 400 mm total length). A few subadult bull trout were caught in the lake influenced portion of the river in March, 1981. Yearling mountain whitefish were very abundant in the area at the time. We frequently captured adult and subadult bull trout in areas of high whitefish density, suggesting whitefish may be an important food item of bull trout in the Flathead River.

Table 17. Back-calculated lengths and increments of growth for rainbow trout collected in the main stem Flathead River, 1980.

Age	Sample size	Length at annulus (mm)					
		I	II	III	IV	V	VI
1	42	77					
2	23	72	193				
3	5	68	194	286			
4	13	89	227	316	379		
5	1	93	262	381	432	462	
6	1	86	211	335	407	467	521
	Mean	77	205	314	384	465	521
	Sample size	85	43	19	15	2	1
	Growth increment		128	109	70	81	56

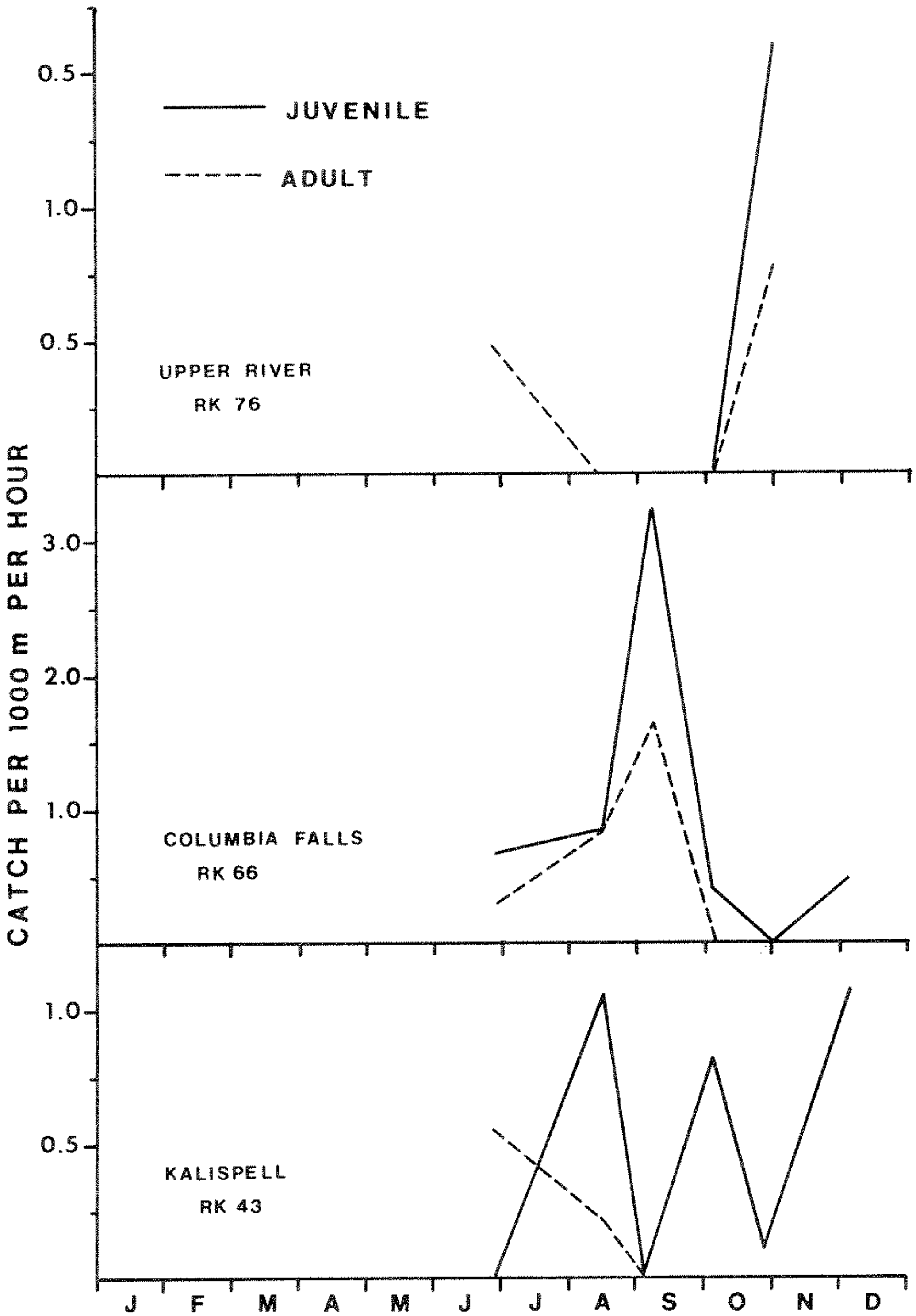

Figure 36. Bull trout catch per 1000 m of shoreline per hour of electrofishing effort in three sections of the Flathead River, 1979.

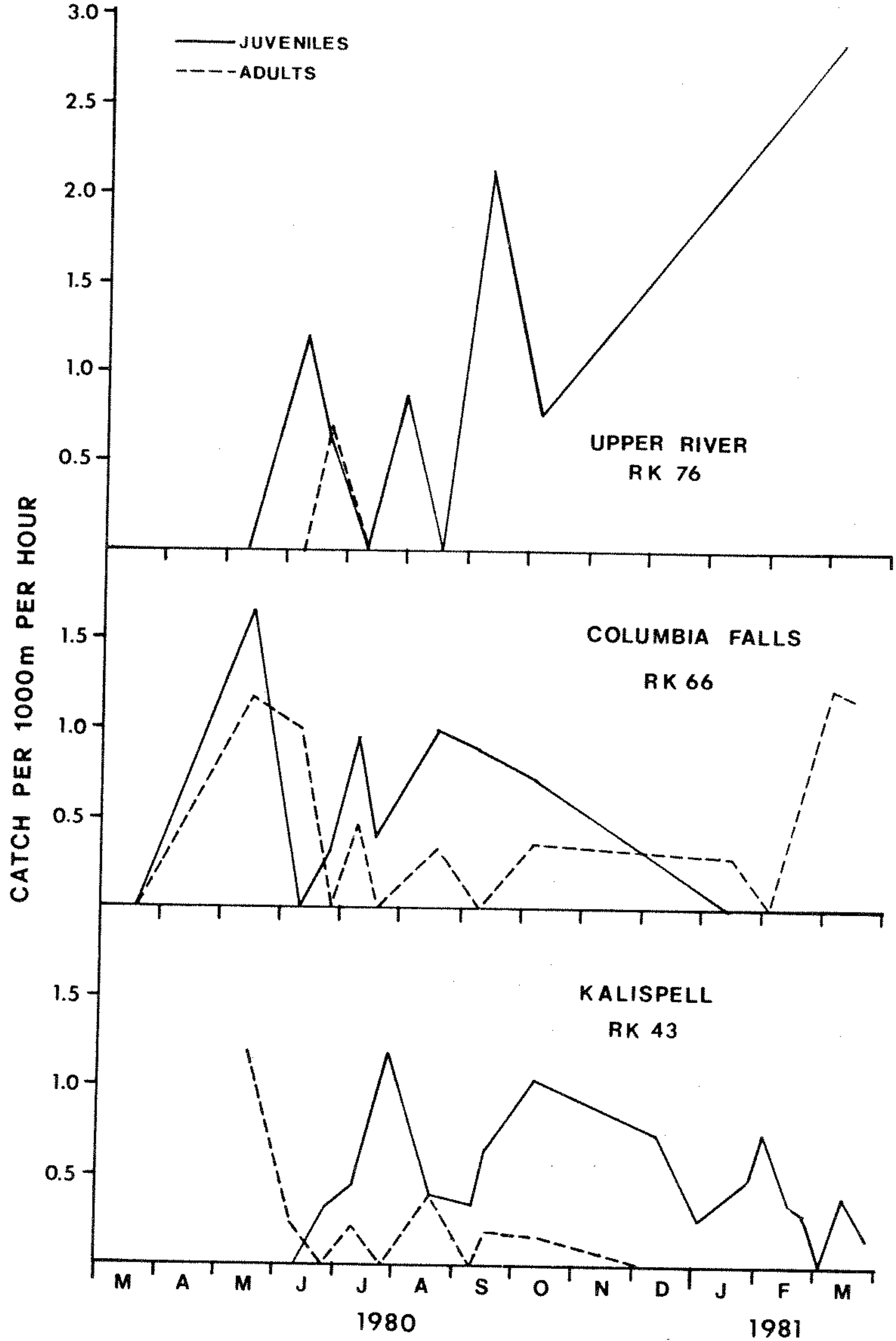

Figure 37. Bull trout catch per 1000 m of shoreline per hour of electrofishing effort in three sections of the Flathead River, 1980-81.

Peak migration of adult bull trout through the Kalispell and Columbia Falls sections normally occurred in May and June when river flow was high. Although spawning did not occur until September and October, we usually began to catch adults in the lower river in April. Spawning appeared to be nearly equally divided between the North and Middle Fork drainage (Fraley et al. 1981).

Age and growth

Scales from 59 adult and juvenile bull trout captured in the main stem in 1980 were used in age and growth analysis. The Monastyrsky body-scale relationship was Log TL - 0.733 + 1.076 SR ($r^2 = 0.92$). The body-scale relationship is similar to that of bull trout collected in the Middle Fork drainage in 1980 (Fraley et al. 1981).

Bull trout captured in the main stem averaged 57 mm total length at age I, 121 mm at age II and 198 mm at age III (Table 18). Growth rate was slightly higher than that of Middle Fork bull trout. Growth patterns in the Middle Fork and main stem were similar however. Greatest growth increment was between age III and IV, with growth slowing only slightly thereafter. Main stem bull trout averaged 131 mm growth between ages III and IV, while Middle Fork bull trout averaged 112 mm growth.

Most juvenile bull trout trapped while emigrating from North Fork tributaries in 1979 were age II or III. Accelerated growth after age III is probably due to immigration into a larger, richer environment and the ability to efficiently utilize fish as a food source at a length of approximately 200 mm.

Mountain whitefish

Relative abundance and movement

Mountain whitefish is easily the most abundant species of fish found in the Flathead River. The whitefish population represents a vastly under-utilized resource. Whitefish comprised only 3.5 percent of the total angler harvest and 25.4 percent of the harvest other than kokanee in the main stem Flathead River in 1975 (Hanzel 1977). Twice as many cutthroat trout were harvested during the same period despite the fact that whitefish were many times more abundant than cutthroat. In the North and Middle Forks, catches of cutthroat and bull trout each exceeded that of whitefish.

Due to the small harvest of whitefish, most of our information on movement is derived from recaptures made while electrofishing. Commerical fishing for whitefish was legalized in 1980 to encourage harvest.

Mountain whitefish catches during our electrofishing in 1979 (Figure 38) and 1980 (Figure 39) show similar patterns. Whitefish

Table 18. Back-calculated lengths and increments of growth for bull trout collected in the main stem Flathead River, 1980.

Age	Sample size	Length at annulus (mm)						
		I	II	III	IV	V	VI	VII
1	0	--						
2	16	55	129					
3	23	59	114	186				
4	5	59	119	207	316			
5	8	58	128	213	346	467		
6	4	65	124	220	333	440	553	
7	3	42	108	200	300	420	528	637
	Mean	57	121	198	329	450	542	637
	Sample size	59	59	43	20	15	7	3
	Growth increment		64	77	131	121	92	95

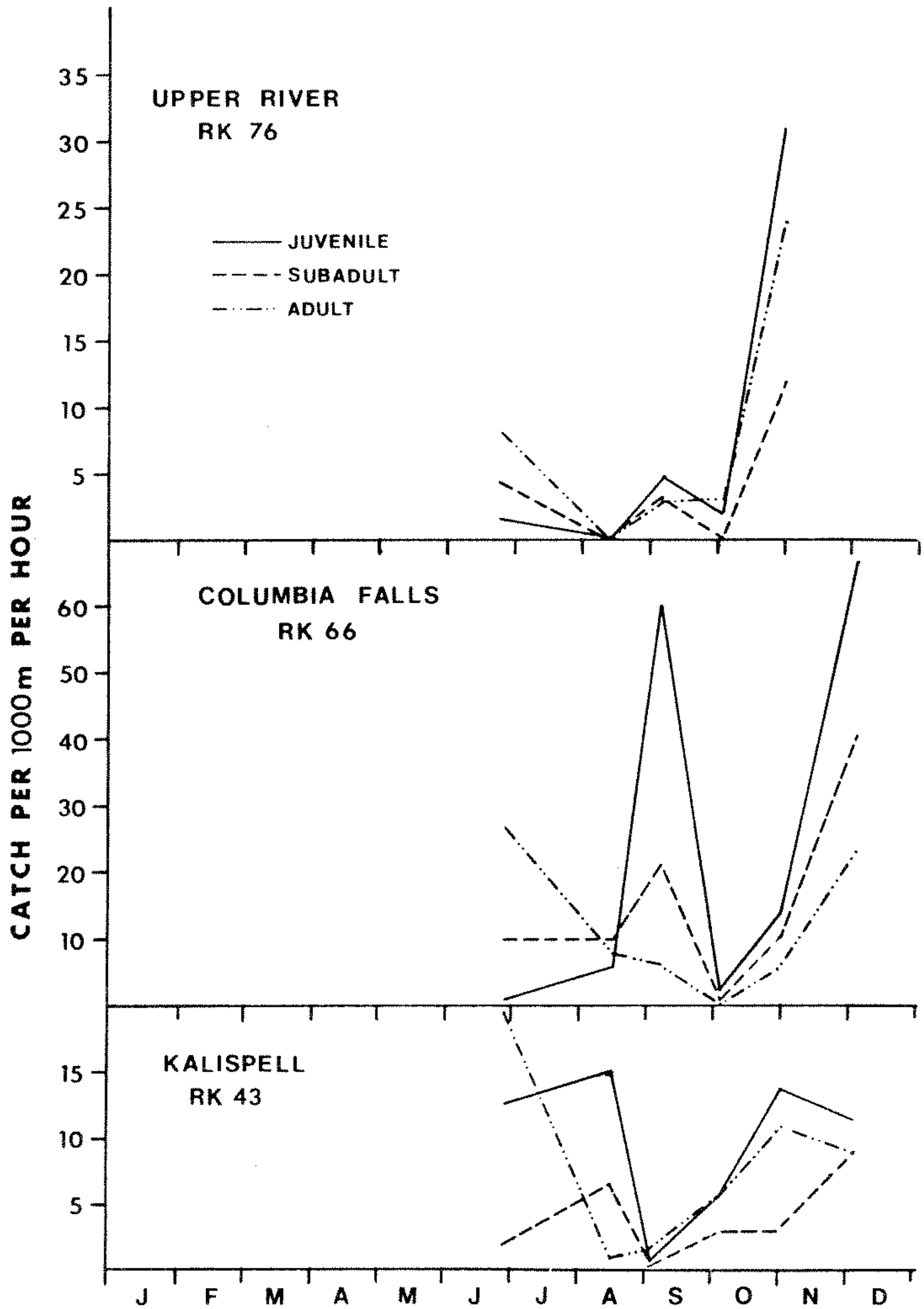

Figure 38. Mountain whitefish catch per 1000 m of shoreline per hour of electrofishing effort in three sections of the Flathead River, 1979.

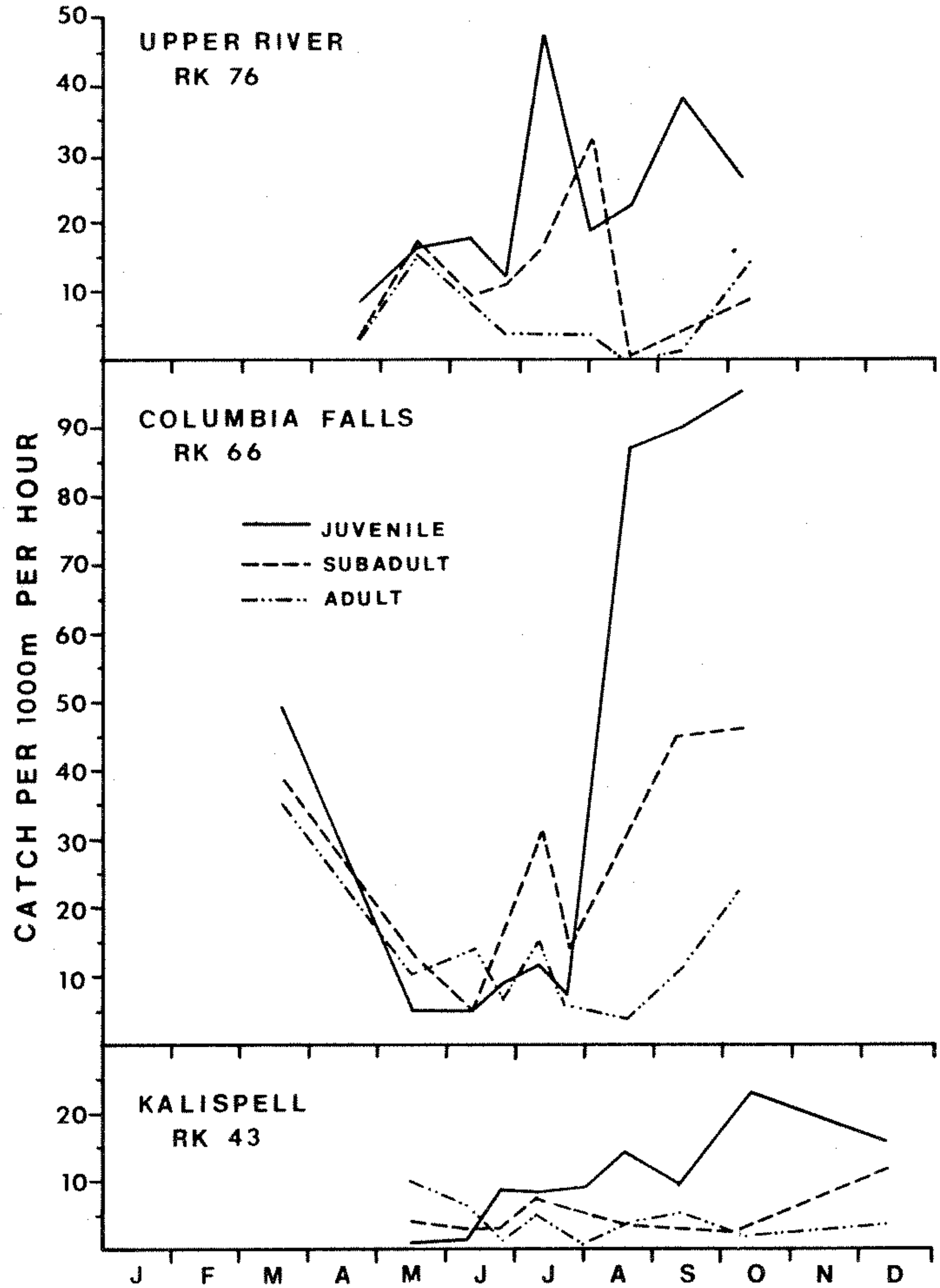

Figure 39. Mountain whitefish catch per 1000 m of shoreline per hour of electrofishing effort in three sections of the Flathead River, 1980.

were generally least abundant in summer and most abundant in late fall and winter in all three sections. In 1979, abundance was at a minimum in all three sections in early September, when kokanee were most abundant in the river.

Abundance of adults increased in all sections later in the fall. Whitefish in spawning condition were caught in October of both 1979 and 1980.

Seasonal abundance patterns and recaptures of marked fish indicate at least two different stocks of whitefish may inhabit the Flathead River. Shifts in abundance and age structure throughout the year are indicative of a mobile population. However, 83 percent of the recaptures reported thus far have been made in the areas where fish were marked. Only 14 (17 percent) whitefish were recaptured in locations other than where they were marked. Thirteen of those fish were recaptured downstream of where they were marked. Seven of the 13 were caught in Kalispell section in December or January, indicating a downstream movement in late fall or winter. Electrofishing in winter, 1981 yielded the highest whitefish catches of the entire study period (Figure 40). It is possible that whitefish migrate out of the North and Middle Forks to overwinter in the main stem. Since few whitefish have been marked in the upper drainage however, downstream migration for over-wintering cannot be documented at this time. Other researchers have documented downstream movement of whitefish related to overwintering (Pettit and Wallace 1975, Davies and Thompson 1976).

Considerable movement of whitefish in and out of the North Fork and its tributaries has been noted (Graham et al. 1980c, Fraley et al. 1981). Two whitefish caught in an upstream trap in Red Meadow Creek in summer, 1979 were recaptured in the same trap in summer, 1980. Large numbers of whitefish were caught in upstream and downstream traps during the same time period in Trail Creek.

Age and growth

Scales from 203 mountain whitefish caught in the main stem Flathead River in 1979 and 234 whitefish caught in 1980 were used in age and growth analysis. Monastyrsky body-scale relationships for the two samples were similar (Figure 41).

Whitefish caught in 1979 averaged 85 mm total length at age I, 166 mm at age II and 232 mm at age III (Table 19). Whitefish caught in 1980 grew more slowly, averaging 79 mm at age I, 156 mm at age II and 212 mm at age III.

Growth of mountain whitefish in the Flathead River in 1979-80 was much slower than that of whitefish in the Kootenai River during the period 1970-77. Whitefish in the Kootenai River averaged 120 mm total length at age I, 244 mm at age II and 300 mm at age III (May and Huston 1979). Whitefish in the North Fork Clearwater River drainage,

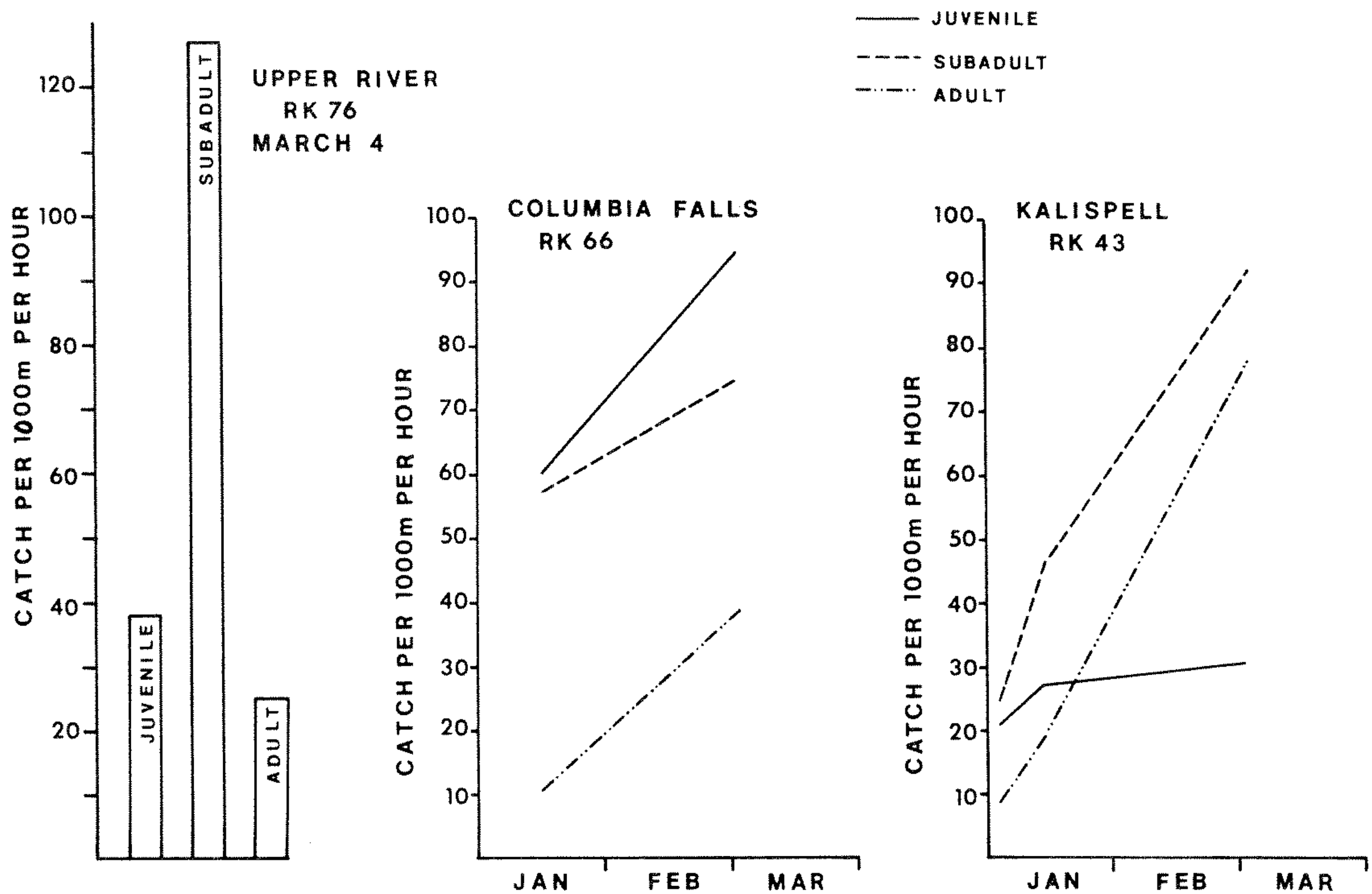

Figure 40. Mountain whitefish catch per 1000 m of shoreline per hour of electrofishing effort in three sections of the Flathead River, 1981.

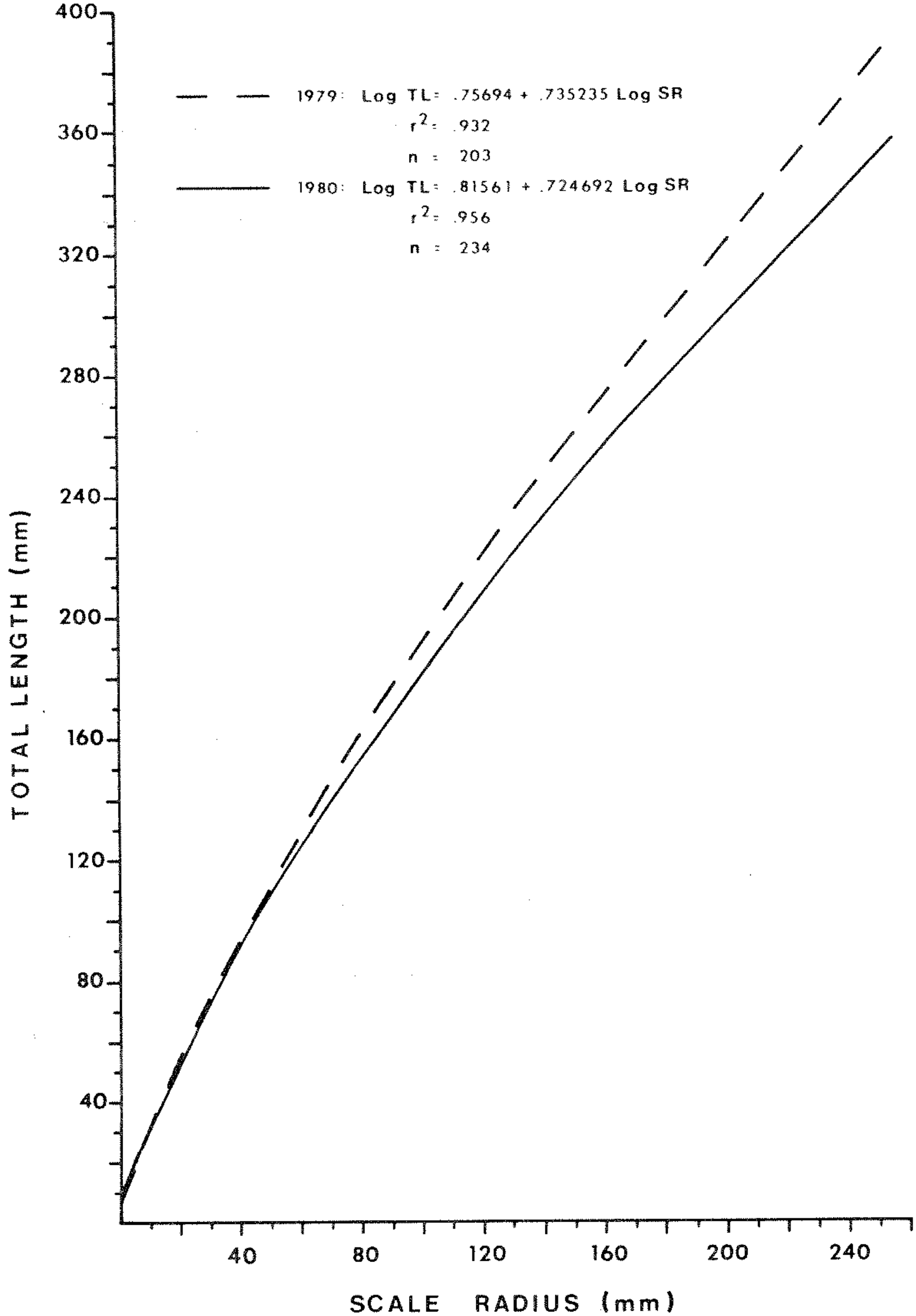

Figure 41. Monastyrsky body-scale relationships for mountain whitefish captured in the Flathead River, 1979 and 1980.

Table 19. Back-calculated lengths and growth increments of mountain whitefish captured in the main stem Flathead River in 1979 and 1980.

		Length at annulus (mm)							
Age	Sample size	I	II	III	IV	V	VI	VII	VIII
1979 Sample									
1	29	81							
2	54	86	164						
3	40	88	177	232					
4	45	85	166	241	284				
5	24	79	151	214	272	309			
6	10	88	172	237	306	350	387		
7	1	88	180	232	302	340	380	406	
8	0	--	---	---	---	---	---	---	---
Mean		85	166	232	284	322	387	406	---
Sample size		203	172	119	80	35	11	1	---
Growth increment		81	66	52	38	65	19	---	
1980 Sample									
1	60	79							
2	92	74	152						
3	35	85	154	205					
4	30	84	168	215	251				
5	4	83	161	213	267	295			
6	7	87	163	210	254	286	305		
7	4	80	160	228	272	302	329	356	
8	2	78	185	250	328	370	400	431	456
Mean		79	156	212	258	302	327	381	456
Sample size		234	174	82	47	17	13	6	2
Growth increment		77	56	46	44	25	54	75	

Idaho in 1971 grew at a slightly faster rate than Flathead River whitefish in 1979 and 1980 (Pettit and Wallace 1975).

Instream Flows

Establishment of instream flows is a widely accepted method of maintaining desirable fish population levels. The ability of a stream to support fish is dependent upon the quantity and quality of fish habitat in the stream. Fish populations are often limited by the amount of habitat available at the stream's minimum flow.

Researchers working on instream flows for large rivers in southwestern Montana have found wetted perimeter to be one of the best variables correlated to fish populations (Nelson 1980a, 1980b). Wetted perimeter is the distance along the bottom and sides of a stream channel cross-section in contact with water. As stream discharge decreases, wetted perimeter decreases, but the rate of loss of wetted perimeter is not constant throughout the entire range of discharges. Wetted perimeter increases rapidly with small increases in discharge up to the point where the stream channel nears its maximum width. Beyond that point, increases in wetted perimeter are small compared to increases in discharge. Nelson found that the inflection point in the wetted perimeter-discharge relationship for carefully selected stream cross-sections, correlated well with recommended absolute minimum flows as determined from long-term fish population data.

We applied Nelson's methodology to the main stem Flathead River in 1980. The inflection point for a cross-section located in the Kalispell electrofishing section occurred at a flow of 2,400 cfs (Figure 42). The abrupt change in wetted perimeter occurring at 6,200 cfs is probably due to an error in data collection or processing. Historical low flows, prior to impoundment of the South Fork were usually about 2,000 cfs. Thus, the inflection point in Figure 42 is probably a good indicator of a desirable minimum flow in the Flathead River.

We recommend a minimum flow of 2,500 cfs in the Flathead River at Columbia Falls between July 1 and April 30. A 2,500 cfs minimum flow would increase wetted perimeter by nearly 30 percent over present minimum flows. Insect production could be expected to increase accordingly. Increased insect production would provide more food for fish. Mean monthly flow of the Flathead River at Columbia Falls for the period 1929-1980 always exceeds 2,500 cfs (Table 20). On the average, Hungry Horse outflow would have to be approximately 1,000 cfs during winter to provide 2,500 cfs at Columbia Falls. During extreme low flow periods, Hungry Horse would have to provide approximately 1,500 cfs.

Increased Hungry Horse outflow would further alter the temperature regime of the main stem. At extreme low flows, addition of 1,500 cfs from the South Fork to near-freezing water in the main stem would result in warming of approximately 2.5° C. Winter temperature elevation would have little effect on fish growth, but increased flows would

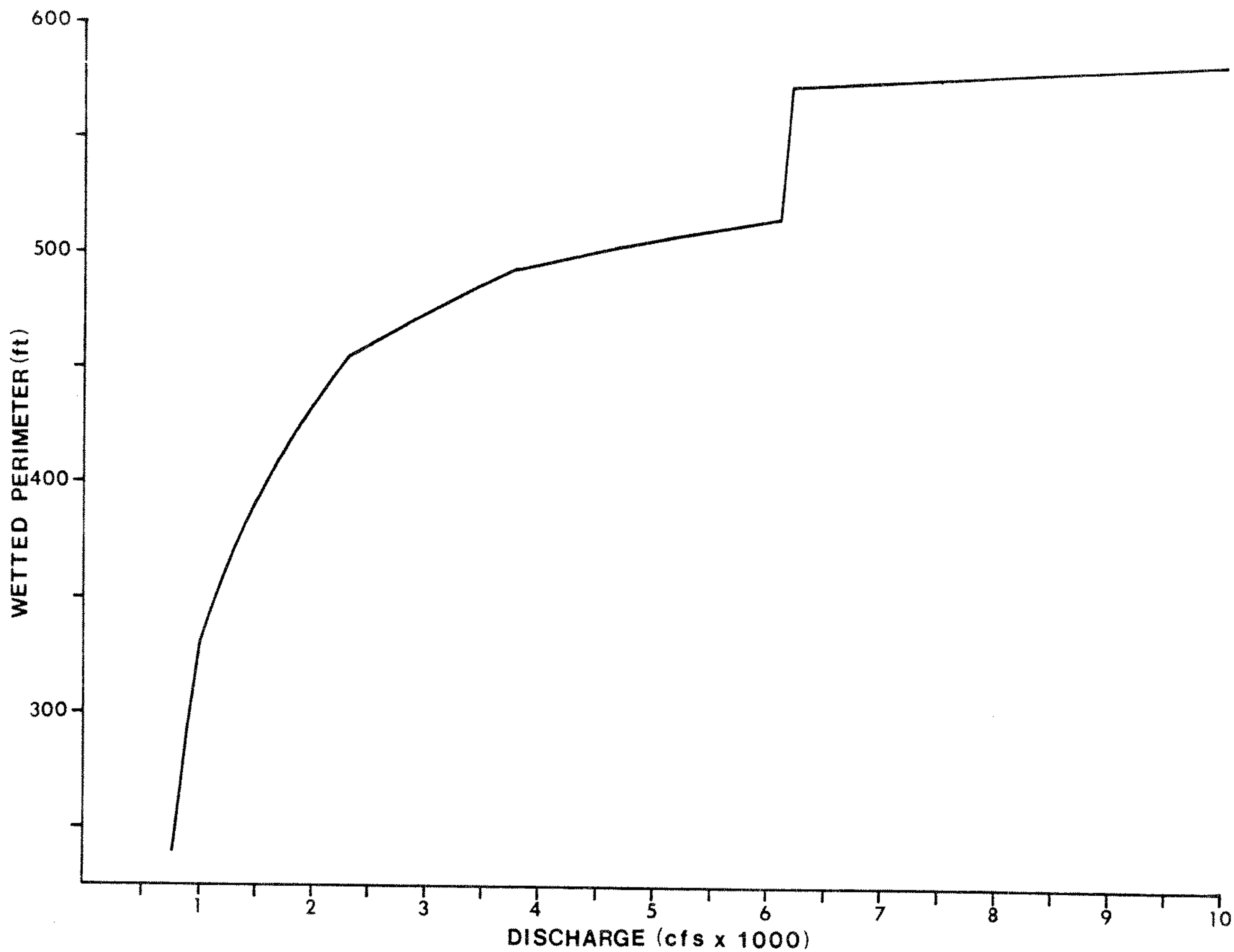

Figure 42. Wetted perimeter-discharge relationship for a stream cross-section located in the Kalispell electrofishing section.

Table 20. Mean monthly flows of the North and Middle Fork Flathead River combined and the Flathead River at Columbia Falls (theoretically unregulated). Data from water years 1929 through 1980 provided by the Bureau of Reclamation, Boise District office.

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

provide more habitat for overwintering fish. Slight changes in species composition of the benthic community could occur but total production should increase.

Selective Withdrawal Addition

Addition of a selective withdrawal system at Hungry Horse Dam would not change the dam's present effects on winter temperature in the Flathead River. The reservoir is essentially homothermous during winter. Spring water temperatures would be little affected by a selective withdrawal system as spring flows in the North and Middle Forks are high. Present effects of Hungry Horse discharge on summer and fall temperatures in the main stem would be significantly altered if a selective withdrawal system were installed. Hypolimnial water presently released by Hungry Horse lowers summer water temperatures in the main stem 6-8° C, depending on flow of the North and Middle Forks. If a selective withdrawal system was added and operated similarly to the system in operation at Libby Dam (May et al. 1979), summer temperatures would be lowered only about 3° C (Figure 43). Fall water temperatures are lowered slightly by the present withdrawal, but would be changed by a selective withdrawal.

Installation and operation of a selective withdrawal system at Hungry Horse Dam could result in significant impacts upon the Flathead River and Hungry Horse Reservoir. Further study is needed before impacts can be predicted.

CONCLUSIONS

Environmental changes in the main stem Flathead River since impoundment of the South Fork have been varied. Effects on fish populations have been beneficial and detrimental.

Construction of Hungry Horse Dam blocked spawning migrations of westslope cutthroat and bull trout into the South Fork. A significant portion of the spawning and rearing area available to Flathead Lake salmonids was lost. Releases of hypolimnial water from Hungry Horse Dam has resulted in cooler summer water temperatures in the main stem and consequently growth rates of fish have probably been slower since impoundment. Slower summer growth is partially, but not completely, offset by faster winter growth due to warmer winter temperatures.

Warmer winter temperatures in the main stem also aided in expanding the range of kokanee spawning areas in the drainage. More river spawning and less lake shore spawning occurred after impoundment of the South Fork by Hungry Horse Dam. Favorable flow and temperature conditions after impoundment resulted in increased kokanee production. Increased demand for hydroelectric energy and changes in operation of Hungry Horse Dam could result in decreased kokanee production. A reregulating

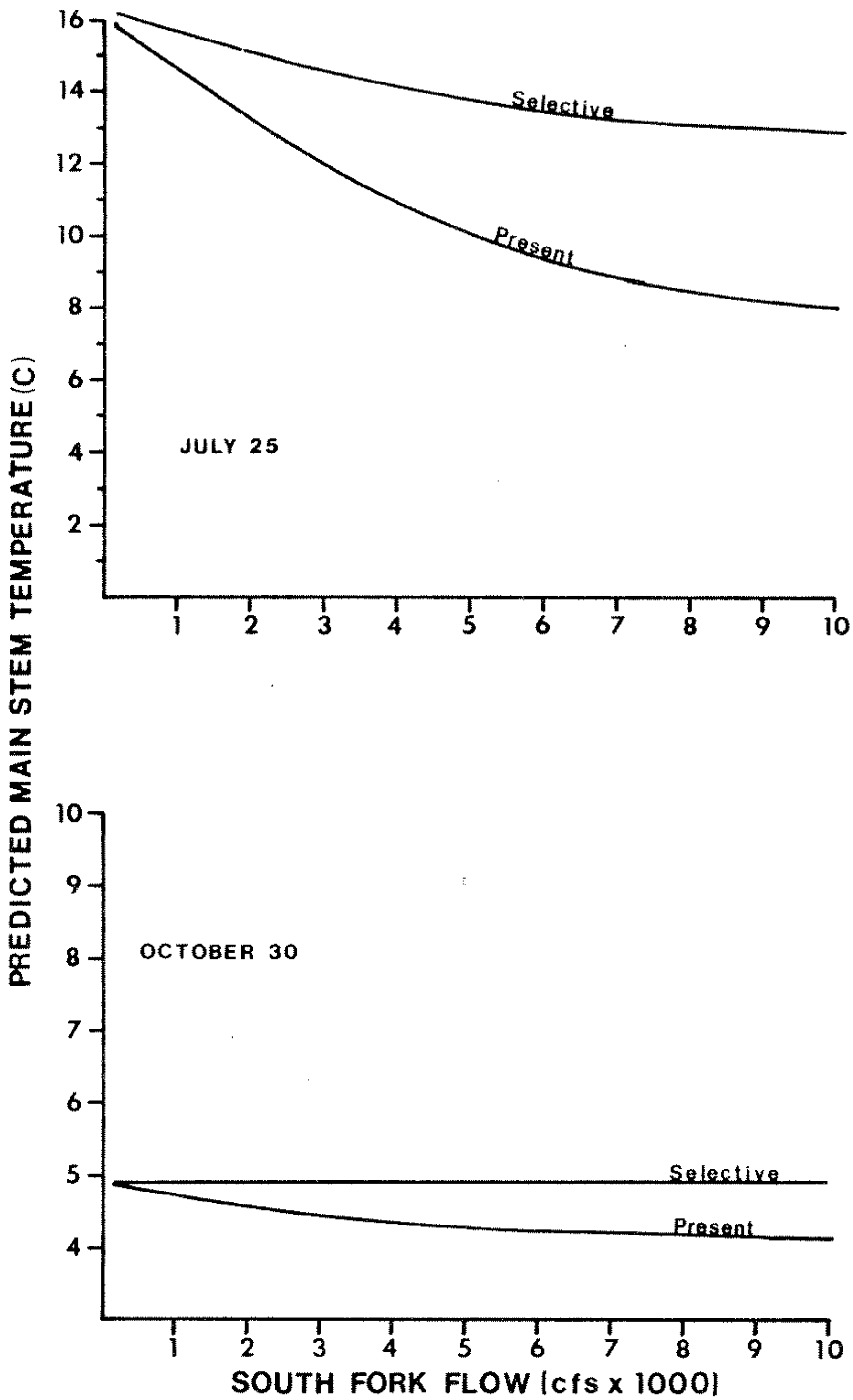

Figure 43. Estimated effects on main stem Flathead River water temperature at a range of South Fork flows with the present hypolimnial withdrawal and with a hypothetical selective withdrawal system.

dam could significantly benefit fish populations if a cyclic operating regime is adopted. Kokanee spawning and incubation flows could be managed to minimize mortality due to dewatering. Higher minimum flows generated by regulating dam storage would benefit resident fish and benthic invertebrate production.

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