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KOOTENAI RIVER WHITE STURGEON INVESTIGATIONS

ANNUAL REPORT 1993

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ABSTRACT

U.S. Army Corps of Engineers in concordance with Bonneville Power Administration provided a release of 324.3 m^3/s (400,000 acre feet) of impounded water from Lake Koocanusa, Montana from June 2 to June 16, 1993. This release of water provided approximately 566.4 m^3/s (20,000 cfs) discharge in the Kootenai River at Bonners Ferry, Idaho.

Nineteen adult white sturgeon equippedwith combinations of radio and sonic transmitters were monitored from mid-April to mid-July, 1993. Nine females and one male remained in the Kootenai River near the British Columbia/Idaho border and/or Kootenay Lake, British Columbia. One female was captured by the crew from the Kootenai Hatchery, operated by the Kootenai Tribe of Idaho, delivered to the hatchery, tagged, and released seven days later. She retreated to Kootenay Lake immediately after release.

Eight sturgeon with transmitters formed the aggregate of unknown numbers of fish in the staging area. The monitored fish were all judged late vitellogenic and were used to characterize what was assumed reproductive behavior of white sturgeon in the Kootenai River.

Four late vitellogenic females moved upriver with the lowland spring runoff (May 11), lingered around the "staging area" May 11-24, then retreated downriver May 21-24. Two fish retreated all the way to Kootenay Lake, British Columbia; the other two re-advanced upriver May 27-30 concurrentwiththe initiation of the augmented discharge on May 28. None of the monitored fish were detected beyond the U.S. Highway 95 bridge. By June 4, the remaining females began moving downriver.

Male sturgeon tended to move upriver seven days earlier than the females. They arrived in staging waters about May 11. On May 21, three male sturgeon demonstrated a slight downriver run the same time as did the females. The maximum downriver travel was 14.2 km. All four of the monitored males returned upriver just prior to and during the augmented flow period.

Crews fished a combined 14,714 hours with three types of gear designed to sample white sturgeon eggs and larvae. Three eggs (one fertilized, one dead, and one unfertilized) diagnosed as white sturgeon were collected in the vicinity of the highway bridge at Bonners Ferry. All were collected within a few days after the retreat of monitored females. The presence of unfertilized or dead eggs can not verify spawning. Thus the catch rate for one sturgeon egg from all sampling gear was 0.00002 eggs/h.

The flow test did not produce any known recruitment to the diminishing white sturgeon population.

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INTRODUCTION

Data collected during 11 years of white sturgeon _Acipenser transmontanus_ investigations on the Idaho portion of the Kootenai River (Figure 1), 5 years on the Montana portion, and 4 years in British Columbia, Canada, suggested no spring spawning was occurring. Studies of white sturgeon spawning in the Columbia River system reported water temperatures of 14 to 17°C (57.2-62.6°F), suitable water depth of at least 3 m and a discharge with velocities of at least 0.5 m/s over a substrate of bedrock, cobble, or gravel were required for successful reproduction of white sturgeon. Prior to 1972 and the operation of Libby Dam, the Kootenai River had suitable habitat ingredients for a self-sustaining population of white sturgeon.- A sample of 185 adult sturgeon examined between 1977 and 1980 revealed 79% (144) of the 185 fish were 15-27 years old. Thus, the majority of this 185 fish sample were hatched between the years 1951 and 1965. Hydrographic records indicated these were wet years with better than average runoff. Historic pre-dam flows ranged from 1,699 to 2,832 m^3/s (60,000 to 100,000 cfs) during the sturgeon spawning period. Peak flows of the Kootenai River after Libby Dam were generally in the 250 to 450 m^3/s (8,828 to 15,890 cfs) range (Apperson and Anders 1991).

The Bonneville Power Administration and United States Army Corps of Engineers used 324 m^3 (400,000 acre feet) of water in Lake Koocanusa to simulate a discharge at Bonners Ferry of 566 m^3/s (20,000 cfs) during the spring of 1993. This document summarizes the movements and apparent spawning behavior of white sturgeon in the Kootenai River prior to and during this experimental discharge period.

STUDY SITE

The Kootenai River originates in Kootenay National Park, British Columbia. The river flows south into Montana and turns northwest at Jennings, the site of Libby Dam, at river kilometer (rkm) 352.4 (Figure 1). Kootenai Falls, 50 km below Libby Dam, presents an impassable barrier to sturgeon. As the river flows through the northeast corner of Idaho, a definite reach change occurs at Bonners Ferry. Upriver from town, the river has an average gradient of 0.6 m/km, with velocities higher than 0.8 m/s. Downriver from Bonners Ferry the river slows to an average gradient of 0.02 m/km, deepens, and meanders through the Kootenai Valley back into British Columbia and into the southern arm of Kootenay Lake. The river leaves the lake through the western arm to a confluence with the Columbia River at Castlegar. A natural barrier at Bonnington Falls, and now a series of four dams, have isolated the Kootenai white sturgeon from other populations in the Columbia River basin for approximately 10,000 years (Northcote 1973). The basin drains an area of 50,000 km^2 (Bonde and Bush 1975).

OBJECTIVE

1. Determine environmental requirements for adequate spawning and recruitment of white sturgeon by 1998.

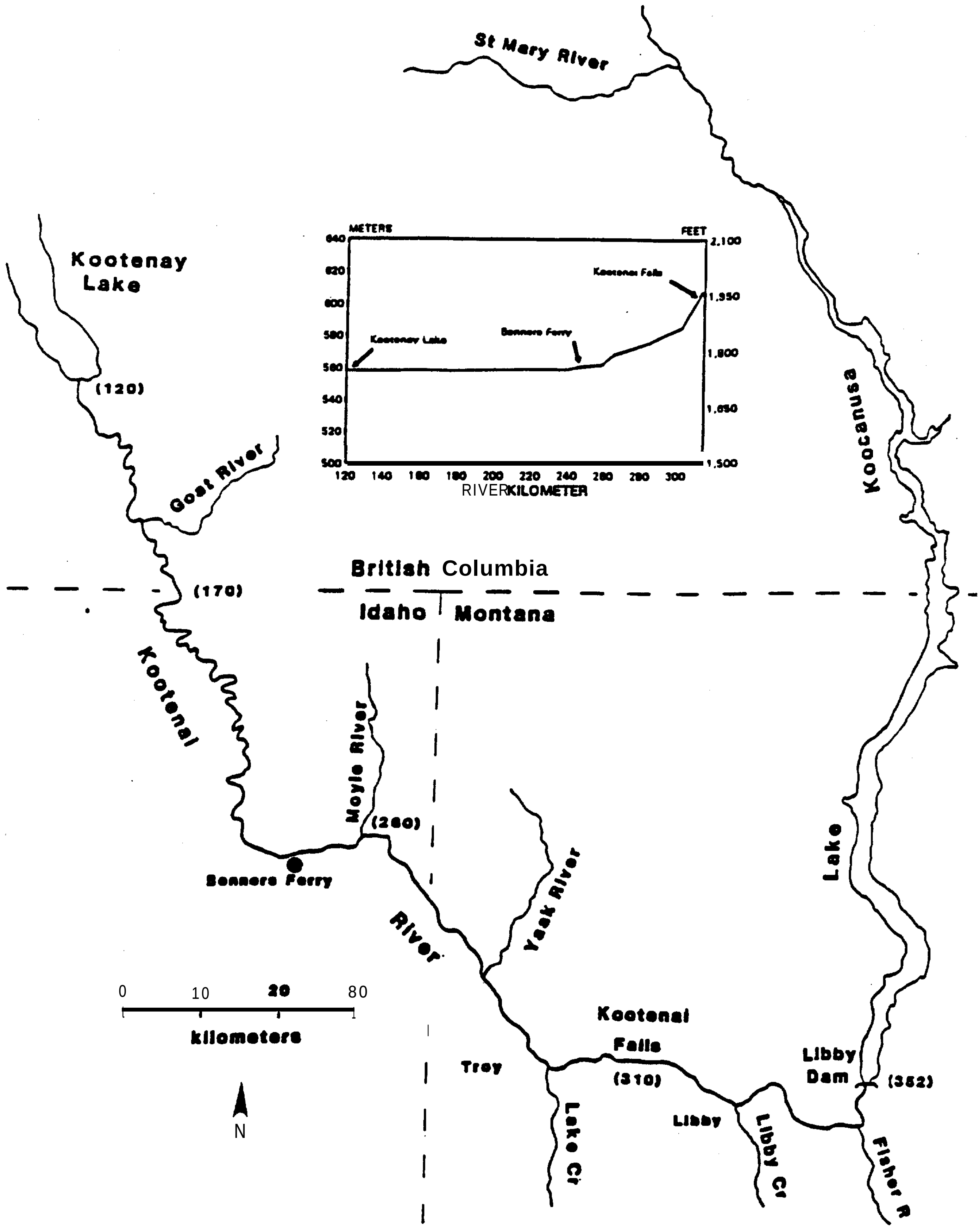

Figure 1. Map of the Kootenai River with a schematic of river gradient. Study area was from southern Kootenay Lake upriver to Kootenai Falls.

METHODS

Adult Sturseon Sampling

Adult white sturgeon were captured with rod and reel or setlines from 1991 to March 1993. Fish over 120 cm were examined surgically to determine gender and stage of sexual maturity. Fifteen females were fitted with a 50-month ultrasonic transmitters. Six of the 15 also carried 24-month radio transmitters. Four males in spawning condition received one or both types of transmitters. Ten of the 19 transmitters were attached in 1991 and 1992. Nine sonic/radio transmitters were attached from March through June 1993. All transmitters were attached with 22.7 kg test line or wire leader through the proximal portion of the dorsal fin.

Specific locations to the nearest 0.1 km were recorded for each fish. Two to three intersecting headings from different points in the river or lake were used to triangulate the fish's position. Once a fish's specific location was determined, the boat was moved to a position upriver from the fish to avoid startling it. The boat drifted over the fish's location with the motor off. The depth, water temperature, and distance to the nearest bank was measured with an echo sounder, hand-held thermometer, and a range finder.

Fork length, total length, and weight were recorded for each sturgeon. Pectoral fin rays were removed from fish <120 cm fork length and from fish previously injected with oxytetracycline identified by Passive Integrated Transponder (PIT) tags. Examinations included searching for previous tags and inserting PIT tags. Recaptured females were usually surgically re-examined for sexual development (Table 1) unless the database revealed surgery had been performed within the same year.

White Sturgeon Egg and Larvae Sampling

Artificial substrate mats of filter material (latex-coated animal hair) bolted to 62 x 75 cm angle-iron frames (McCabe and Beckman 1990) were used to document the presence of white sturgeon eggs in the Kootenai River. Mats were held in position on the substrate by bucket-shaped cement anchors and/or a 3-pronged re-bar cement anchor. An orange float with an identification number was attached to each mat. Mats were set in the river from May 18 to July 7, 1993. Mats were deployed in three river sections: Shorty's Island at rkm 227.5 to a point halfway between Myrtle Creek and Deep Creek, rkm 234.5; 2) Ambush Rock, rkm 245, to U.S. Highway 95 Bridge, rkm 245.8; and 3) upriver of U.S. Highway 95 bridge to the Moyie River, rkm 258.6. Mats were set in variable-sized groups of three to six per site.

Three criteria were used to select river locations for substrate mat sampling: water depths greater than three meters; water surface velocities greater than 0.5 m/s; and a clean gravel, cobble, or boulder substrate. Mats were positioned relative to known white sturgeon staging areas and prior egg collection areas. The time and depth of each mat was recorded. Mats were retrieved to the boat by pulling the line from an attachment point fixed to the downriver side of the mat frame to minimize flushing of contents. They were examined for the presence of eggs and larvae. Verification of any egg or possible part of an egg was handled by personnel of the Kootenai Indian Sturgeon Hatchery. All sample items collected with nets were preserved in glass quart jars containing 10% unbuffered formalin tinted with Rose Bengal stain. Samples were sorted in the laboratory. Fish eggs and larval fish were identified to family when possible. White sturgeon spawning dates and times (±4 hrs) were

Table 1. Sexual development of white sturgeon sampled in the Kootenai River, Idaho, 1989 through 1993.

Categories of sexual development			Percent (number) of sample by year				
Category	Sex	Description of development	1989	1990	1991	1992	1993
0	unknown	gonad undifferentiated or not seen	32 (58)	14 (15)	6 (3)	2 (1)	0
1	Female	Previtellogenic: no visual signs of vitellogenesis; eggs present but have average diameter <0.5 mm	14 (25)	12 (13)	8 (4)	12 (5)	0
2	Female	Early vitetlogenic: eggs are cream to gray; average diameter 0.6 to 2.1 mm	7 (12)	7 (8)	4 (2)	2 (1)	5 (1)
3	Female	Late vitellogenic: eggs are pigmented and attached to ovarian tissue; average diameter 2.2 to 2.9 mm	6 (10)	5 (5)	8 (4)	9 (4)	53 (10)
4	Female	Ripe: eggs are fully pigmented and detached from ovarian tissue; average diameter 3.0 to 3.4 mm	2 (3)	5 (5)	4 (2)	9 (4)	11 (2)
5	Female	Spent: gonads are flaccid and contain some residual fully pigmented eggs	3 (5)	1 (1)	2 (1)	0	5 (1)
6	Female	Previtellogenic with attritic oocytes: eggs present but have an average diameter <0.5 mm; dark pigmented tissue present that may be reabsorbed eggs	2 (3)	0	0	0	0
R	Female	Reabsorbing eggs	0	0	0	2 (1)	0
7	Male	Non-reproductive: testes with translucent smokey pigmentation	3 (6)	27 (30)	29 (15)	26 (11)	0
8	Male	Reproductive: testes white with folds and lobes	32 (58)	28 (31)	18 (9)	16 (7)	21 (4)
9	Male	Ripe: milt flowing; large white Lobular testes	0	3 (3)	14 (7)	21 (9)	5 (1)
S	Male	Spent: testes flaccid; some residue of milt	0	0	8 (4)	0	0

back-calculated from all collected viable white sturgeon eggs using an exponential function involving water temperature and embryonic development described by Wang et al. (1985) and Beer (1981). Embryonic stages of white sturgeon eggs were distinguished visually and with a dissection microscope using the embryological criteria.developed by Beer (1981). Color, size, and texture were evaluated on each egg and shell and compared with known white sturgeon eggs and shells hatched in 1993 at the Kootenai Indian Sturgeon Hatchery. Non-viable and unfertilized white sturgeon eggs could not be used to predict the spawning dates or times.

White sturgeon eggs and larvae were sampled with two types of trawl nets from May 26 to July 19, 1993. A beam trawl (2.7 m x 0.5 m, 1.59 mm knotlese mesh) and D-ring plankton nets (0.78 m maximum width x 0.54 m high, 1.59 mm knotless mesh) were utilized. The nets were held stationary on the substrate for 3 to 30 minutes per sample. Detailed methodology and gear specifications are given by Parsley et al. (1989). D-ring nets were fished at 19 sites on the Kootenai River between rkm 245 and 267 between June 3 and July 19, 1993. Two D-ring nets were usually fished simultaneously. A standard sample consisted of fishing nets for 5 to 30 minutes depending on the amount of organic debris in the drift. Sites chosen to sample white sturgeon eggs and larvae were immediately downstream from suspected spawning habitat and the locations of late vitellogenic white sturgeon fitted with transmitters. Site selection for trawl sampling locations used the same criteria as artificial mats.

Since water elevations at Bonnere Ferry dropped 3 to 4 feet following the 16-day augmented river discharge period, original sampling sites had to be dropped and new ones sampled. Existing sites became too shallow or out of the river channel. Priority of selecting sampling area5 was influenced by collections of sturgeon eggs with other gear. Priority of selecting sampling sites was also influenced by the lack of detection of late vitellogenic sturgeon upriver from Bonners Ferry (245.8) during 1993.

RESULTS

Discharge and Temperature

The natural spring runoff in the Kootenai River peaked at 666 m^3/s on May 15 at Bonners Ferry and tapered off steadily to 302 m^3/s by May 28 (Figure 2). On May 30, the discharge in the Kootenai River at Bonners Ferry was 404 m^3/s but was reduced to 367 m^3/s on June 1. During the augmented flow release beginning June 1 and ending June 16, flows fluctuated between 537 and 570 m^3/s. At the end of the release on June 16, flows immediately dropped to 272 m^3/s.

Water temperatures at Bonners Ferry ranged from 7.2°-12.8°C (45-55°F) during the spring freshet (Figure 2). Water temperatures approached 14°C (57.2°F) June 16 through June 22. They dropped abruptly to 12.6°C (54.7°F) June 23-25, and increased to the 15°C (59°F) range through the end of July 1993.

White Sturgeon Tracking

Tracking with telemetry gear began March 23, 1993 and concentrated in river areas typically harboring adult sturgeon. One of the purposes of initial telemetry surveys in the spring of 1993 was to locate fish carrying active transmitters installed prior to 1993, thereby providing sites for capturing new sexually ripe sturgeon for monitoring. Most of the captures of sturgeon were

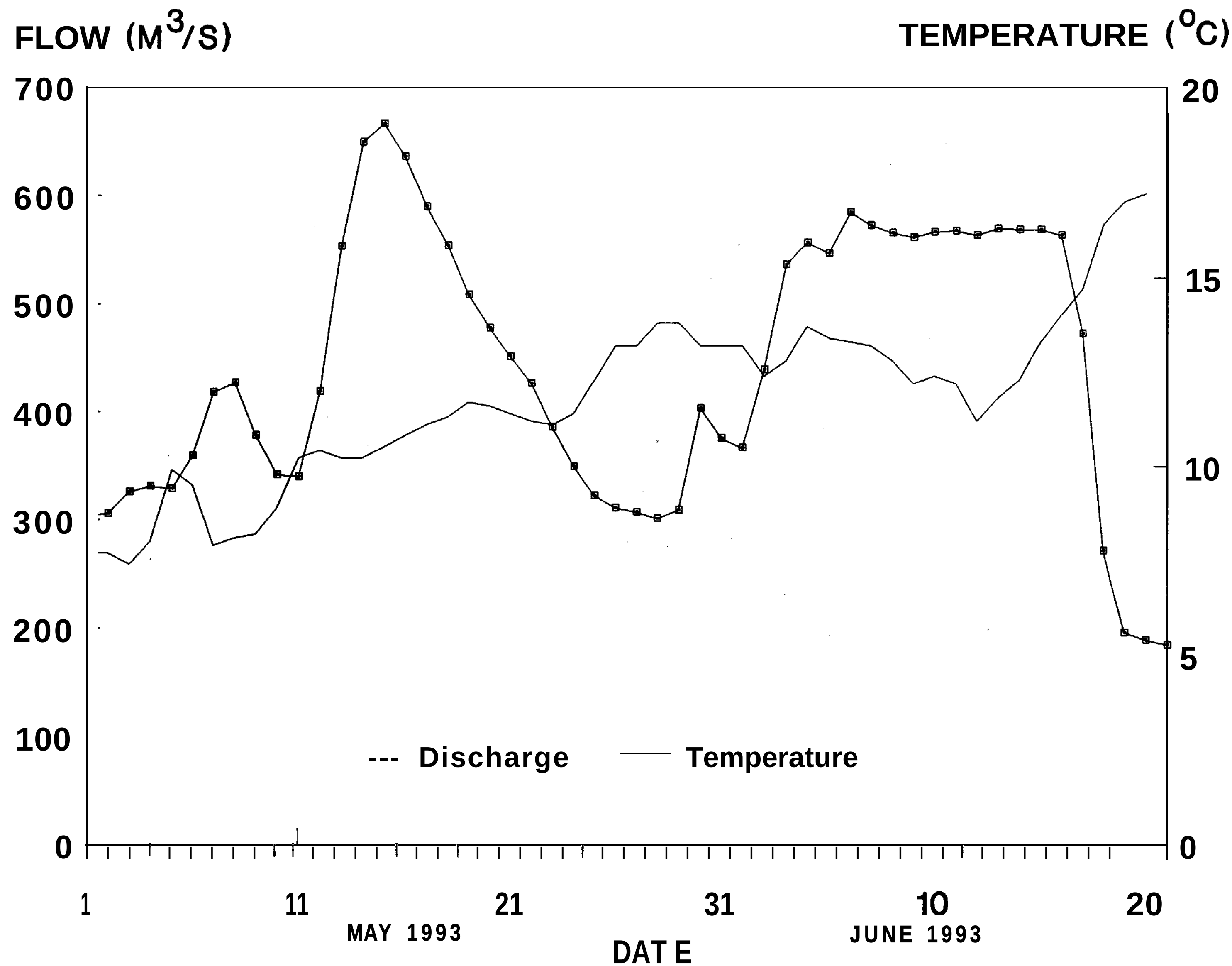

Figure 2. Temperature and calculated discharge of the Kootenai River at Bonners Ferry, Idaho for May 1 to June 21, 1993.

near the confluence of Rock Creek (rkm 215.5) and Ferry Island (rkm 207.8). Four sturgeon were fitted with transmitters near the confluence of Rock Creek and two were captured near Ferry Island between late March and mid-April 1993. On March 29, 1993, monitoring began in Kootenay Lake to relocate active transmitters. This provided additional fishing locations for continued hook and line capture of unmarked sturgeon. Weekly tracking focused on fish considered most likely to spawn in the spring of 1993. Fish were monitored in the river channel and in Kootenay Lake. On May 18, 1993, tracking efforts in the river intensified to monitoring every 2-3 days with considerable focus on fish expected to spawn.

From May 18 to June 18, daily locations on any fish from Shorty's Island (rkm 230) to Bonners Ferry (245.8 rkm) were mapped. This location was near the upper limits of slack water and was considered an important staging area for spawners moving to the suspected spawning site upriver of the U.S. Highway 95 bridge (rkm 245.8).

Telemetry from July 1 to August 10 focused on three males (#'s 430, 433, and 434). They remained between rkm 229 and 236 (near Shorty's Island) for 27 days. The other contingent of tagged sturgeon had moved back into shallow habitats on the delta of Kootenay Lake. The stationary signals of the three transmitters created suspicion radio and sonic transmitters may have been shed or fish were deceased. More detail on each of these three males is included text. Personnel using SCUBA gear located one sonic transmitter shed from fish #433 on August 18, 1993. The other two stationary sonic and radio tags from #'s 430 and 434 were not found nor were there any signs of alive or dead fish.

Behavior of Monitored Sturgeon

Of the 19 fish supporting active transmitters, 5 were males and 14 were female. Eight females (#'s 363, 345, 366, 377, 378, 403, 438, and 439) overwintered in Kootenay Lake and remained in the lake during the experimental flow release. One 211 cm female (C435) occupied the river between Ferry Island and the British Columbia/Idaho border. The above complement of fish had all been fitted with transmitters prior to 1993 and did not show any response to the increase in spring flows. The upriver movement of the remaining five females are summarized in Figure 3 and individually (Appendix 1) as follows:

Fish #387

This 187 cm female was captured April 28, 1992 near the confluence of Rock Creek. In the spring of 1992, she made an upriver run to a staging area near Shorty's Island (rkm 225.5). No effort was made to locate her from November 1992 to early April 1993. On April 13, she was relocated at the confluence of Flemming Creek (rkm 225). She moved downriver 17.7 km to a location just upriver from Ferry Island and remained until May 11. Seven days later she was located upriver at rkm 228.4 (near Shorty's Island). She and several other fish with transmitters were located in this area on seven occasions until May 28. The next two days she was 15.7 km back upriver at the confluence of Deep Creek (rkm 244.1). She was found 12.1 km downriver from Deep Creek on June 1. On June 2, she made another move upriver 4.5 km, and all subsequent locations found her moving downriver to Kootenay Lake where she remained through the report period.

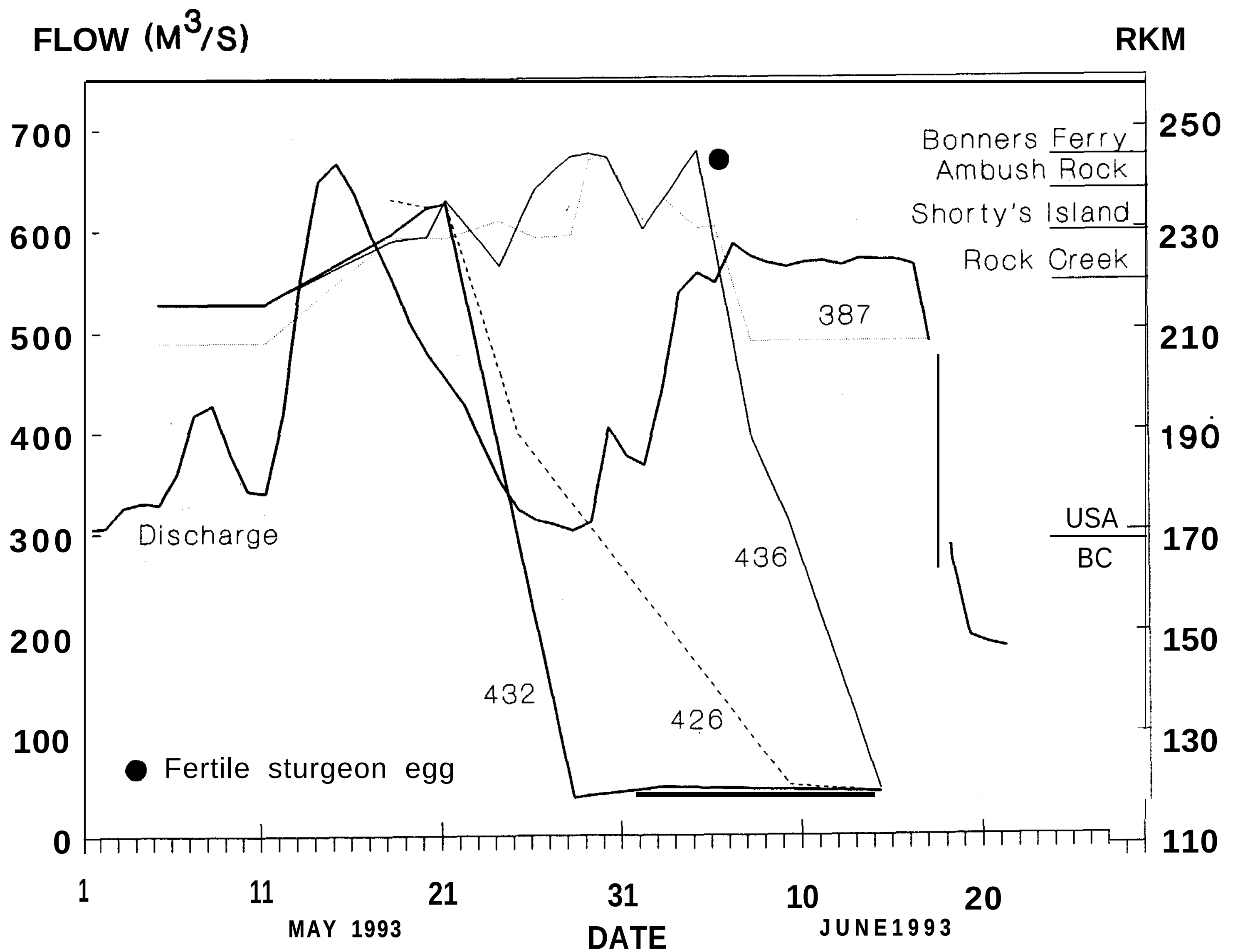

Figure 3. Movement of female white sturgeon b's 387, 426, 432, and 436 in the Kootenai River, 1993.

Fish #426

Fish #426 was captured in the fall of 1992 in the Rock Creek area. She was 179 cm total length and spent most of the fall of 1992 in the Rock Creek vicinity. She appeared on May 18, 1993 at rkm 236.1 between Myrtle and Deep creeks. She stayed in this vicinity for four days, and sometime around the May 22 she made a steady run of 115.7 km in 17 days back to Kootenay Lake. Her retreat paralleled the decreasing discharge between the lowland freshet and the augmented flow release.

Fish X432

This 202 cm, 49.5 kg female made several upriver surges in an apparent reaction to changes in river discharge. She had been captured in the 1980s during a study conducted by the British Columbia Ministry of Environment. She was recaptured March 24, 1993, and both sonic and radio equipment were attached. Sexual development indicated she was very ripe and definitely a 1993 spawner. She was in the Rock Creek area upon capture and remained there until May 11, 1993. She was detected at rkm 229.2 on May 18 and advanced farther upriver midway between Shorty's Island and the confluence of Deep Creek (rkm 235.3) by May 21, 1993. Seven days later she had retreated back 119.3 km to Kootenay Lake.

Fish #436

This was the largest (229 cm) of the ripe females supporting telemetry gear during the spring of 1993. She was captured on April 27, 1993 in the vicinity of Ferry Island and was equipped with both radio and sonic tags. This fish advanced upriver during the natural spring runoff (May 5-18) preceding the experimental discharge. She milled around the staging area near Shorty's Island through May 27. Her upriver travel placed her near Ambush Rock on May 29-30. She made a 15 km retreat May 31 to June 1 at a time discharge was fluctuating ± 57 m^3/s. June 4 found her upriver further than any detected white sturgeon (rkm 245.4; 0.4 km downriver from the U.S. Highway 95 bridge). Her last advance upriver correlated with the initial peaks of the experimental discharge from Libby Dam. On June 7 she was detected moving downriver, and by June 14 was 125.4 km downriver in Kootenay Lake. Her return to the lake took less than 10 days.

Fish X437

Fish #437 was captured May 18, 1993 in the staging area adjacent to Shorty's Island. She was taken to the Kootenai Indian Tribe's experimental culture station where she was surgically examined and found capable of spawning within a week. The crew opted to release her without taking eggs on May 5, 1993. From her release at the cultural facility, her next four locations exhibited rapid decent downriver to Kootenay Lake. It took this 199 cm, 53 kg sturgeon 12 days to find refuge 121 km from the release site. She remained in the lake through last detection on July 7, 1993.

The response of a group of five males (Figure 4) supporting active transmitters follows: Movement of these male sturgeon are individually described in Appendix 1.

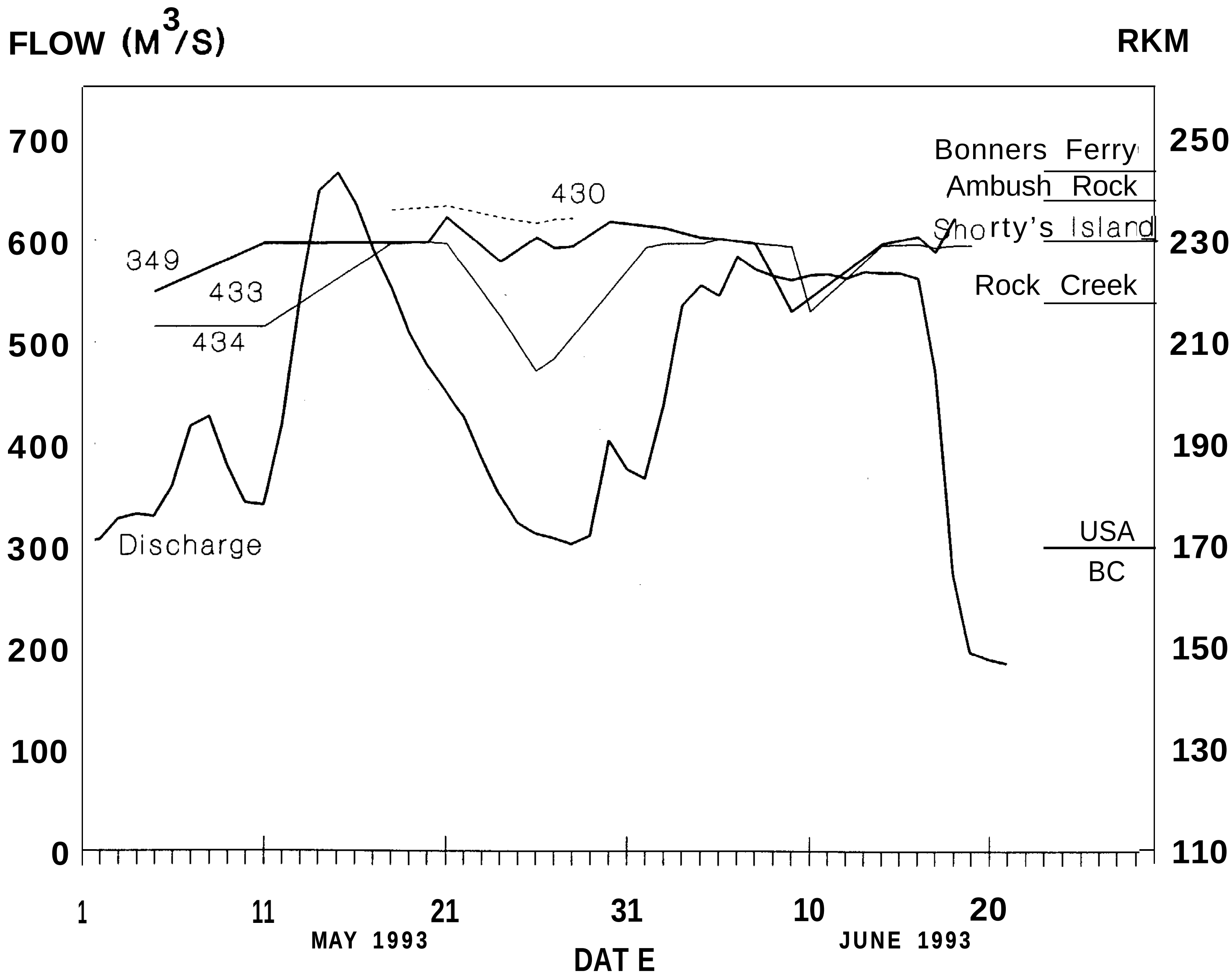

Figure 4. Movement of male white sturgeon #'s 349, 430, 433, and 434 in the Kootenai River, 1993.

Fish #335

On April 3, 1991 this 181 cm, 28.8 kg male was captured in the Shorty's Island area. He was sexually rated in stage 8 and showed movement activity typical of reproductive behavior during subsequent detections in 1991. In late June 1991, he dropped back into Kootenay Lake. This sturgeon remained in Kootenay Lake in 1992. It was assumed he would be a potential spawner in 1993; however, nine detection episodes found him or his transmitter in Kootenay Lake.

Fish #349

This 192 cm male sturgeon was found to be in advanced stages of sexual ripeness upon capture in the Deep Creek pool on June 1, 1991. By mid-June 1991, he retreated back to Kootenay Lake where all subsequent detections found him through early June 1992. He was found in the Flemming/Rock creek areas in the spring of 1993. Twenty-eix locations were plotted for this sturgeon in 1993. His movement behavior was quite active (Appendix). He was found in the Rock Creek/Kootenai pool April 13, 1993 and for three subsequent detections until April 19. By May 21, he had moved to a location midway between Shorty's Island and Deep Creek (rkm 234.6). He dropped back to the Flemming Creek area, advanced back to rkm 233.8, and dropped back on June 6 to the Rock Creek confluence at rkm 216.2. By June 16, he was back upriver near Shorty's Island, where he stayed until June 18; 11 days later he was found in Kootenay Lake.

Fish #430

On March 23, 1993, a 170 cm male wae captured at the Rock Creek confluence at rkm 215.5. He was not relocated until May 18. On this date and all subsequent days for 27 locations, he or his transmitters remained in the same hole. On August 18, SCUBA divers descended on the location of the sonic and radio transmitters, but found neither transmitter or any sign of a sturgeon living or dead. The area searched had a very irregular bottom configuration with numerous submerged trees providing surfaces capable of removing transmitters from the fish.

Fish #433

This male was a new unmarked fish captured April 20, 1993 at the confluence of Rock Creek and the Kootenai River. Upon capture, he was fitted with both sonic and radio equipment. He had moved upriver on May 5 and was relocated May 11 at rkm 230 (Shorty's Island). He was then located on May 20 at rkm 237.5. He moved back 2.2 km by May 27, and remained in the same location for 22 subsequent detections. On August 18, 1993, divers aided with SCUBA located the sonic transmitter but not the radio. The radio was still active at this location but was not recovered. The tag recovery area was thoroughly searched for evidence of sturgeon X433. Nothing was found to indicate any problem other than shedding the tracking devices. He was 24.5 kg and had a total length of 166 cm.

Fish #434

Fish f434 carried both radio and sonic transmitters and eventually shed both, but not before revealing considerable movement episodes. The fish was 162 cm at capture on April 20, 1993. From the initial tagging site at the confluence of Rock Creek, sturgeon C434 moved slightly downriver. On May 11, he advanced to Shorty's Island for the period May 18-21. He retreated back downriver 25 km to Ferry Island on May 26 and started back upriver on May 27. For six locatione, June l-9, he remained in the Shorty's Island staging area. He dropped back to the Rock Creek confluence on June 10 and advanced back to Shorty's Island on June 14. Because the next 10 sightings were in the same location, we believe this fish shed its transmitters. An underwater search did not reveal the transmitters' location, nor was there any evidence the fish perished.

White Sturgeon Recapture Effort

On June 23, 1993, rod and reel angling (17 rods) at rkm 120 in Kootenay Lake captured 17 white sturgeon. The goal was to recapture any sturgeon that had been monitored upriver to and beyond Shorty's Island staging area. Unmarked sturgeon were examined to evaluate evidence of spawning during the spring of 1993. None of the 19 radio/sonic tagged fish were recaptured. Of four female8 landed, none had spawned in 1993, and none were previously captured. Two of these females were judged in sexual development stage 3 and were fitted with radio and sonic transmitters for tracking migratory behavior in 1994. The other two were released with implanted PIT tags.

Seven male8 measuring 143 cm to 200 cm total length were captured. One was a recapture, originally caught September 26, 1990. None of the seven males showed evidence of spawning.

Six of the 17 sturgeon were not examined to identify gender. One sturgeon had no obvious reproductive organs. This sturgeon was 164 cm and had an old green anchor tag identifying it a8 a recapture from the 1979-82 study by the State of Idaho Department of Fish and Game. The body cavity contained a clear fluid, and the crew agreed it was not a spent sturgeon. One of the six sturgeon had been previously captured on August 10, 1990 and had increased 13 cm in 3 1/2 years; from 143 cm to 156 cm total length.

D-Ring Net Sampling

Two hundred and forty-five samples were collected with D-ring nets from June 6 to July 17, 1993. These 245 samples accounted for 64.78 hours of effort at 19 sites (Table 2). Crews fished 34.79 hours on the downriver side of the U.S. Highway 95 bridge. D-ring sampling targeted this section of river on days no beam trawling occurred in this reach. The remaining 29.99 hours of sampling occurred at sites upriver from Bonners Ferry.

Twenty-one fish eggs were collected with D-ring nets; only one of these 21 was a white sturgeon egg. This sturgeon egg was dead, eliminating opportunity to back-calculate the day of spawning. Fourteen egg shells were collected, and of these, five were speculated to be of white sturgeon origin. Eleven cyprinid and catastomid larvae were identified in the samples.

The total collection of one dead white sturgeon egg in 64.78 hours was a catch of 0.015 eggs/h. No white sturgeon larvae were collected.

Table 2. Distribution of D-ring effort for sampling white sturgeon eggs and larvae in the Kootenai River, Idaho, 1993.

RIVER SECTION	DOWNRIVER RKM	UPRIVER RKM	# D-RING SAMPLES	TOTAL SAMPLE HOURS	W. STURGEON # EGGS/ SHELLS/ LARVAE
BONNERS FERRY DOWNRIVER	245.6	245.8	122	34.79	1 EGG (DEAD)
BONNERS FERRY UPRIVER	246.0	267.0	123	29.99	5 SHELLS
ALL	245.6	267.0	245	64.78	6

Beam Trawl Net Sampling

Two hundred and twenty-four trawl samples (Table 3) were gathered over a 23-day interim between May 26 and June 29, 1993. The duration of individual hauls varied between 3 and 30 minutes (mean 14.2) depending on the amount of debris in the drift. The total sampling time was 3,177 minutes (53 hours). Crews concentrated their work on river sections near Shorty's Island, Ambush Rock, and the Railroad bridge.

No white sturgeon eggs were collected with the beam trawl. Depths between 1.4 and 15.2 m were sampled between rkm 227.6 near Shorty's Island and rkm 245.8 at the U.S. Highway 95 bridge adjacent to Bonnere Ferry. Thirty-six haul8 were made in 12 days near Shorty's Island (rkm 227.6 and rkm 236.5) at depths of 4 to 11.3 m. This effort targeted female white sturgeon numbered 387, 426, 432, and 436 all tracked to locations upriver of Shorty's Island.

Sampling near Ambush Rock (rkm 243.6 to rkm 244.2) at depths from 1.5 to 15.2 m involved 35 hauls in an 18-day period. The substrate was not considered suitable for sturgeon spawning, but was an assumed staging area. The crew worked this area because hatchery personnel demonstrated the presence of adult sturgeon through numerous captures of ripe male sturgeon. In addition, female #436 was detected in this area on June 4, 1993.

The area sampled near the railroad bridge produced one egg shell assumed to be of white sturgeon origin. This Shell was collected on June 9 from a depth of 3 m during a 5-minute stationary set at rkm 245.6. On June 21, 1993, another assumed white sturgeon egg shell was collected at a depth of 2.4 m during a 20-minute stationary trawl at rkm 245.8. One hundred and fifty-three hauls were conducted in 23 days. Depth8 were 1.4 to 5.5 m, surface water velocities were greater than 0.5 m/s, and substrate was composed of clean gravel and scattered boulders. This site was just downriver of suitable spawning habitat. Sampling continued in this area after the velocity and depth habitat values diminished upon cessation of the requested 566 m^3/s (19,986 cfs) flow augmentation on June 16. Sampling was not conducted upriver of this site due to inability to negotiate shallow water with a propeller driven boat.

The total collected contents of 53 hours of beam trawling was two egg Shells, assumed to be of white sturgeon origin. Eggs of suckers (catastomidae), unidentified non-sturgeon eggs, and seed-like pods were inspected among the collected trawl contents. Four fish were identified as cyprinid and catastomid larvae.

Artificial Substrate Mat Sampling

Of 354 mat samples, 86 were collected from the Shorty's Island section, 116 from the Ambush Rock reach and 152 upriver from the U.S. Highway 95 bridge to the confluence of the Moyie River (Table 4). The total sampling time was 41,597 hours between May 18 and July 7, 1993.

Two eggs (one fertilized and one unfertilized) attached to mats in the Ambush Rock to U.S. Highway 95 bridge section were identified to be of white sturgeon origin. One fertilized white sturgeon egg was recovered on June 10 and was estimated to have been 73 hours old when collected. Its age was back-calculated to arrive at a spawning day of June 7 at 1300 hours (±4 hours) (Paul Anders, personal communication, Kootenai Indian Tribe). This ovum was taken at rkm 245. The other egg identified as that of a white sturgeon was not fertilized and was assumed to be caught the same day as spawned. This mat was set on June

Table 3. Distribution of beam trawl effort for sampling white sturgeon eggs and larvae in the Kootenai River, Idaho, 1993.

RIVER SECTION	DOWN-RIVER RKM	UP-RIVER RKM	# BEAM TRAWL SAMPLES	DEPTH (M) (AVE.)	TOTAL SAMPLE HOURS (AVE. MIN.)	W. STURGEON # EGGS/ SHELLS/ LARVAE
SHORTY'S ISLAND	228.7	230.6	36	4.0-11.3 (8.2)	8.6 (14.3)	0
AMBUSH ROCK	243.6	244.2	35	1.5-15.2 (10.3)	9.0 (15.4)	0
RAILROAD BRIDGE	245.1	245.8	153	1.4-5.5 (2.9)	35.4 (13.9)	2 SHELLS
ALL	228.7	230.6	224	1.4-15.2 (4.9)	53.0 (14.2)	2

Table 4. Distribution, of artificial substrate mat effort for sampling white sturgeon eggs and larvae in the Kootenai River, Idaho, 1993.

RIVER SECTION	DOWN-RIVER RKM	UP-RIVER RKM	# MAT SAMPLES	AVERAGE DEPTH (M)	TOTAL SAMPLEH OURS	W. STURGEON # EGGS/ SHELLS/ LARVAE
SHORTY'S ISLAND UPRIVER TO WILDLIFE REFUGE	227.5	237.8	86	7.8	9,083	0
WILDLIFE REFUGE UPRIVER TO HIGHWAY 95 BRIDGE (BONNERS FERRY)	244.9	246.0	116	2.6	14,516.	2 EGGS 1 SPAWNED 6/7, 1 UN-FERTILIZED EGG CAPTURED 6/15
HIGHWAY 95 BRIDGE UPRIVER	246.2	258.0	152	3.7	17,998	0
ALL	227.5	258.0	354	4.3	41,597	2 EGGS

10 and pulled June 15, 1993. Three non-sturgeon fish eggs were captured on June 2; one near the U.S. Highway 95 bridge, the others at rkm 252.5.

Collection of two white sturgeon eggs in 41,597 hours of effort represented a catch rate of 0.00005 eggs/h. No larval fish of any species were entangled in the matting.

Summary of Reproductive Products Captured

One fertilized egg was the beet evidence of spawning by white sturgeon in 1993 (Table 5). This egg was collected within 0.8 km downriver of the U.S. Highway 95 bridge and at a date coinciding with the known presence of sexually ripe sturgeon. One unfertilized egg, one dead egg, and seven egg shells were also captured.

DISCUSSION

Five years of research on the life history of white sturgeon in the Kootenai River system answered some specific questions about this population. 1) Sexually ripe sturgeon move upriver each May in response to spawning. 2) Few, if any, white sturgeon moved up the Kootenai River past the town of Bonners Ferry, Idaho. 3) The population had not recruited any meaningful year class cohort8 since 1974.

Arguments persisted about the significance of finding an occasional post-Libby Dam white sturgeon recruit. The occasional recruit was not thought to be sufficient to continue the existence of sturgeon in the Kootenai River. Because of continued decline of the white sturgeon population, the U.S. Fish and Wildlife Service (USFWS) was petitioned to pursue listing the species as threatened or endangered. Public hearing8 on this listing status were conducted in September 1993. The USFWS proposed a threatened or endangered ruling with a final determination forthcoming.

It had been hypothesized that the depressed condition of this population was due to high copper and zinc levels, limited food resources, diminished rearing habitat for juvenile sturgeon, and seasonal alteration of flow and natural water temperature regimes. Subsequent research funded by the Bonneville Power Administration (BPA) shed light on most of the questions regarding "the cause" for this population8 persistent failure to reproduce. The contaminate issue was examined in 1991 by evaluating levels of copper, zinc, and organochloridee in oocyte samples. Little is known regarding the toxicity of zinc to white sturgeon, but concentrations in the river at Porthill were less than U.S. Environmental Protection Agency 1984 water quality criteria levels. Copper levels in the Kootenai River at Porthill ranged from 2 to 12 ug/l from 1983 through 1986 (Apperson and Anders 1991). Level8 of organochloride reeidues in oocytes of white sturgeon residing in the Kootenai River were in the range found in the lower Columbia River stock. The Northwest Power Planning Council directed the BPA to fund construction and maintenance of an experimental sturgeon hatchery near Bonners Ferry, Idaho. Upon completion, it was soon realized Kootenai River water was of a quality adequate to propagate and hold juvenile sturgeon in captivity. Contaminants in the Kootenai River water had not lessened the viability of adult sturgeon reproductive products. At issue and yet to be researched to conclusion was the influence of contaminants on in-river egg incubation and subsequent survival of. juvenile sturgeon.

The food limiting question for juvenile white sturgeon was unanswerable without a juvenile component to study. The continued existence of adult white

Table 5. Capture time and location of sturgeon reproductive products by gear type in the Kootenai River, Idaho, 1993.

PRODUCT COLLECTED	NUMBER	DATE OF CAPTURE	DATE SPAWNED	RIVER SECTION	GEAR TYPE
FERTILIZED EGG	1	6/10/93	6/7/93	245.0	MAT
UNFERTILIZED EGG	1	6/15/93	---	245.7	MAT
DEAD EGG	1	6/10/93	---	245.6	D-RING
EGG SHELLS*	7	6/9/93	---	245.7	BEAMTRAWL
		6/16/93	---	267.0	D-RING
		6/18/93	---	246.8	D-RING
		6/21/93	---	245.8	BEAM TRAWL
		6/24/93	---	246.8	D-RING
		7/1/93	---	246.8	D-RING
		7/1/93	---	246.8	D-RING

*Diagnosis Of Origin is not an exact science at this time. These determinations were based on visual examination and comparison to egg shells in the Kootenai Indian Sturgeon Hatchery. Eggs shells are not collected in the lower Columbia River while sampling for white sturgeon eggs with the gear used above.

sturgeon provided convincing evidence this segment of the population had sufficient food. The decline of historic runs of kokanee <u>Oncorhvnchus</u> <u>nerka</u> and possibly other fish and invertebrates numbers may have profoundly influenced white sturgeon diets. The assumed geographic isolation of white sturgeon since the last glacial ice age (10,000 years ago) apparently did not limit the ability of the sturgeon population to adjust and survive on the food resources the river system offered.

We Speculated that diminished rearing habitat for juvenile8 may have influenced the lack of recruitment. Much of the shallow backwater8 were eliminated by diking river banks along the Kootenai River downriver of Bonnere Ferry. Populations of white sturgeon in the lower Columbia River, however, were rarely found in shallow backwater environment8 (McCabe, personal communication). The development of a cohort of sturgeon took place in 1974 after dikes were constructed on the Kootenai River. Also, an abundance of slack water can be found below Bonners Ferry and in Kootenay Lake, which hae been described as beneficial to the early life history of white sturgeon. Thus, rearing habitat for juveniles was not thought to be limiting.

The greatest evidence "to date" attributes the white sturgeon decline and lack of recruitment to manipulated hydrology of the river for hydroelectric power production and flood control. The lower Columbia River and Snake River studies found convincing evidence sturgeon need heavy running water current to successfully spawn (Anders and Beckman 1993; McCabe and Tracy 1993; Parsley and Beckman 1993). This study was an attempt to evaluate the response of white sturgeon to an augmented discharge of water from Libby Dam.

The release of 566.4 m^3/s (20 kcfs) from June 1 to 16, 1993 left manager8 and researcher8 without convincing evidence a successful reproductive episode occurred. Only one fertilized egg was collected in 14,714.78 hours of combined sampling utilizing techniques known to be effective in the lower Columbia River and middle Snake River. We compared our catch to the collection of eggs and larvae in other white sturgeon habitats (Table 6). The 1991 collection of white sturgeon eggs on artificial substrate mats was 0.4/h in the lower Columbia (McCabe, personal communication), 0.006/h in the middle Snake River (Lepla, personal communication) compared to 0.00007 eggs/h in the Kootenai River 1993 collection.

It was suggested that adult sturgeon possibly spawned in the slow moving water downriver of the collection gear. Other studies, however, emphasized the importance of fast-flowing water over cobble and gravel (Anders and Beckman 1993; McCabe and Tracy 1993; Parsley et al. 1993). We set egg and larval collection gear in areas occupied by detected sturgeon, including the staging area near Shorty's Island. This placed gear in the slow-moving river habitat, yet no eggs or larva were collected.

The presence of a fertilized egg assumed to be of white sturgeon origin suggest some limited spawning. The presence of unfertilized eggs or egg components does not confirm a spawning episode. It is not unusual for eggs or egg components to extrude from ripe fish. The 1993 augmented flow study provided evidence sexually ripe white sturgeon moved upriver in the spring. Ripe males and females advanced upriver during lowland runoff discharges in early May. The upriver movement of tagged males started approximately May 11 with the female contingent following around May 20, 1993. Sexually ripe adults were found to congregate or stage in the Shorty's Island to Ambush Rock reach of the Kootenai River. This reach of river provided the bulk of the broodstock of white sturgeon collected for the experimental hatchery. Also reconfirmed was that sturgeon examined surgically up to a 18 months prior to active telemetry monitoring remained a reliable tool for identifying sexes and predicting an upriver reproductive behavioral response. Another reconfirmed finding was the positive downriver response of sturgeon seeking winter habitat in or near Kootenay Lake.

Table 6. Comparative catch per hour of white sturgeon eggs and larvae by gear type.

GEAR TYPE	KOOTENAI 1993	KOOTENAI 1991	MIDDLE SNAKE 1993	LOWER COLUMBIA 1991
D-RING TRAWL	0.015	0	0.08	---
BEAM TRAWL	0	0	---	---
ARTIFICIAL MATS	0.00005	0.0056	0.0054	0.395
ALL	0.00007	0.0056	0.0056	0.395

Sturgeon numbered 387, 334, 344, and 436 exhibited behavior corresponding to pulses of discharge and the water temperatures associated with releases from Libby Dam. Review of these four fish in Figures 3 and 4 display upriver advancement and retreats closely approximating increasing and decreasing flows. Another contingent of monitored fish (number8 426 and 432) moved upriver during the discharge associated with the spring freshet of 666 m^3/s, only to retreat downriver to Kootenay Lake when flows diminished in late May.

RECOMMENDATIONS

1. We recommend testing a spring flow of a magnitude of 991.2 m^3/s (35 kcfs) for a duration of 40 days. The augmented release should be contiguous to the end of the lowland runoff to simulate a natural uncontrolled river hydrograph.

2. We do not recommend stocking artificially-reared sturgeon. To date, all hatchery-produced sturgeon came from very limited parental stock. Therefore, they represent a genetic risk to the wild population.

3. We recommend evaluating development of white sturgeon eggs and young-of-the-year with river water and sediments replicating a bio-assay type of study.

4. We recommend the development of techniques aimed at sampling juvenile white sturgeon in the Kootenai River. Gear testing should be done in a closed (no outlet) environment utilizing hatchery stock and/or working with researchers in other areas known to support juvenile sturgeon.

ACKNOWLEDGEMENTS

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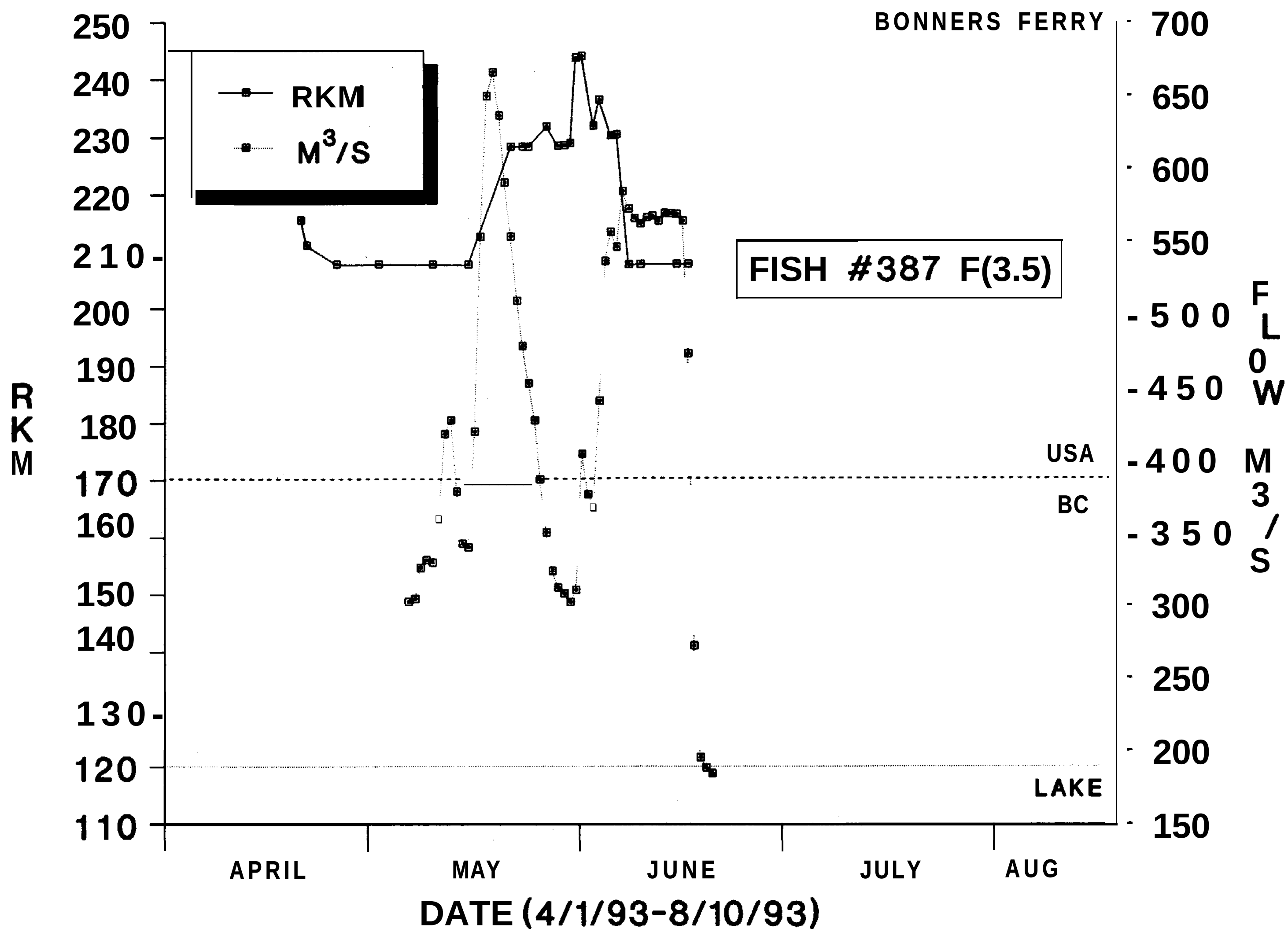
A P P E N D I C E S

Appendix A.

Description of the movement of white sturgeon tagged with transmitters in the Kootenai River in 1993. Letter and number in parentheses identifies gender and stage of sexual development. Some of the monitored fish did not respond to the 1993 flow teat and were not included in the appendix.

Appendix A. Continued.



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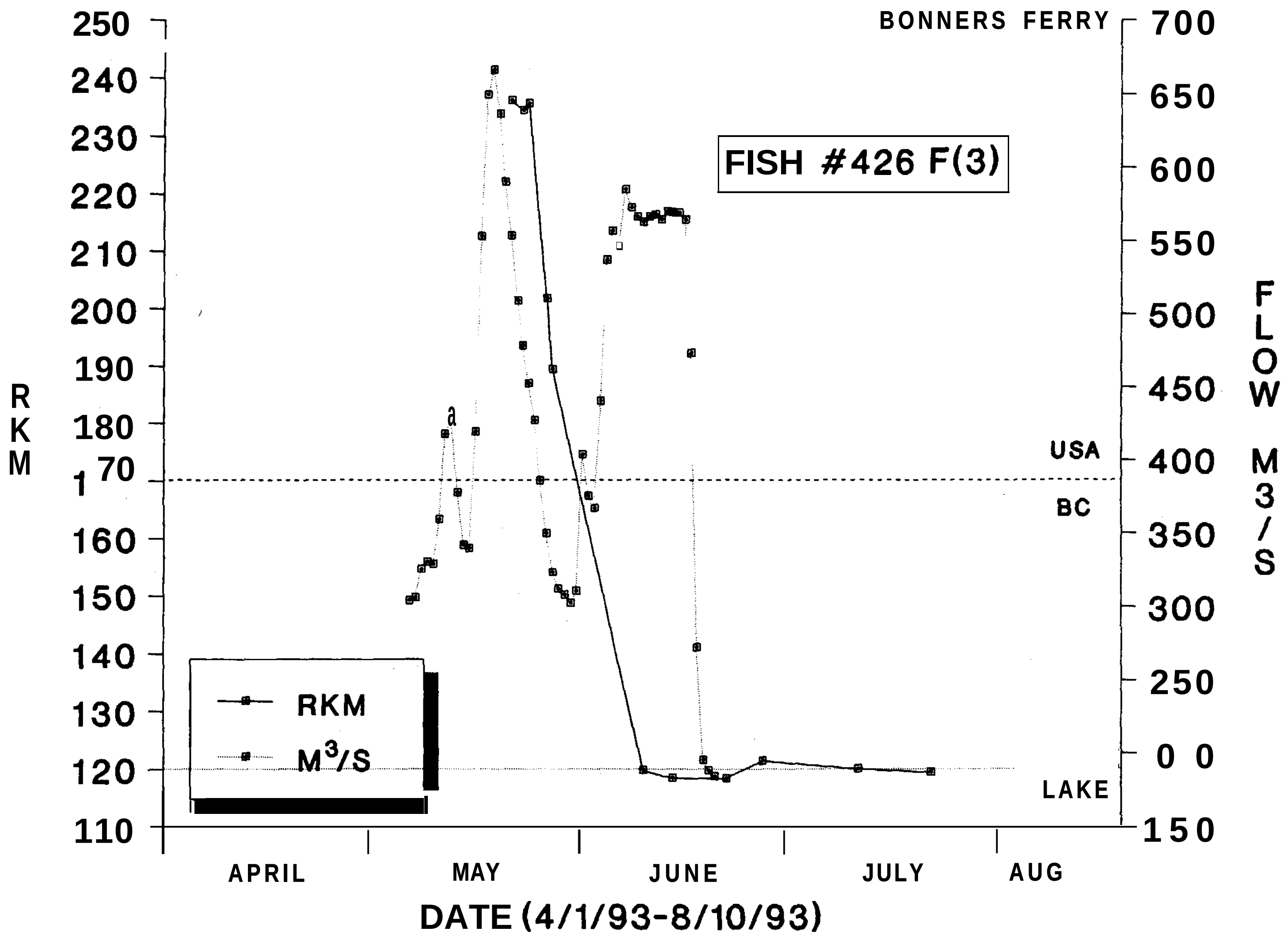

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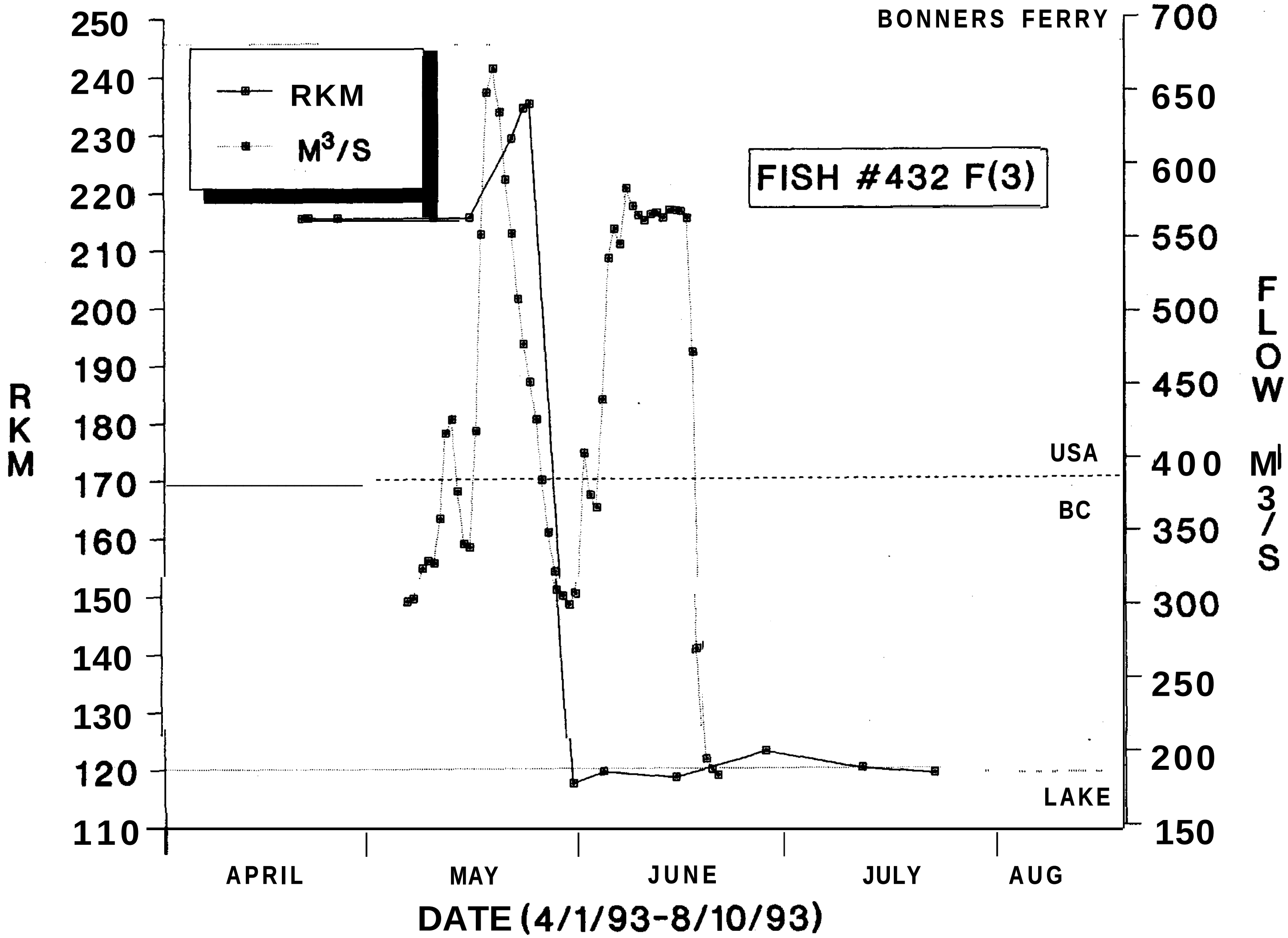

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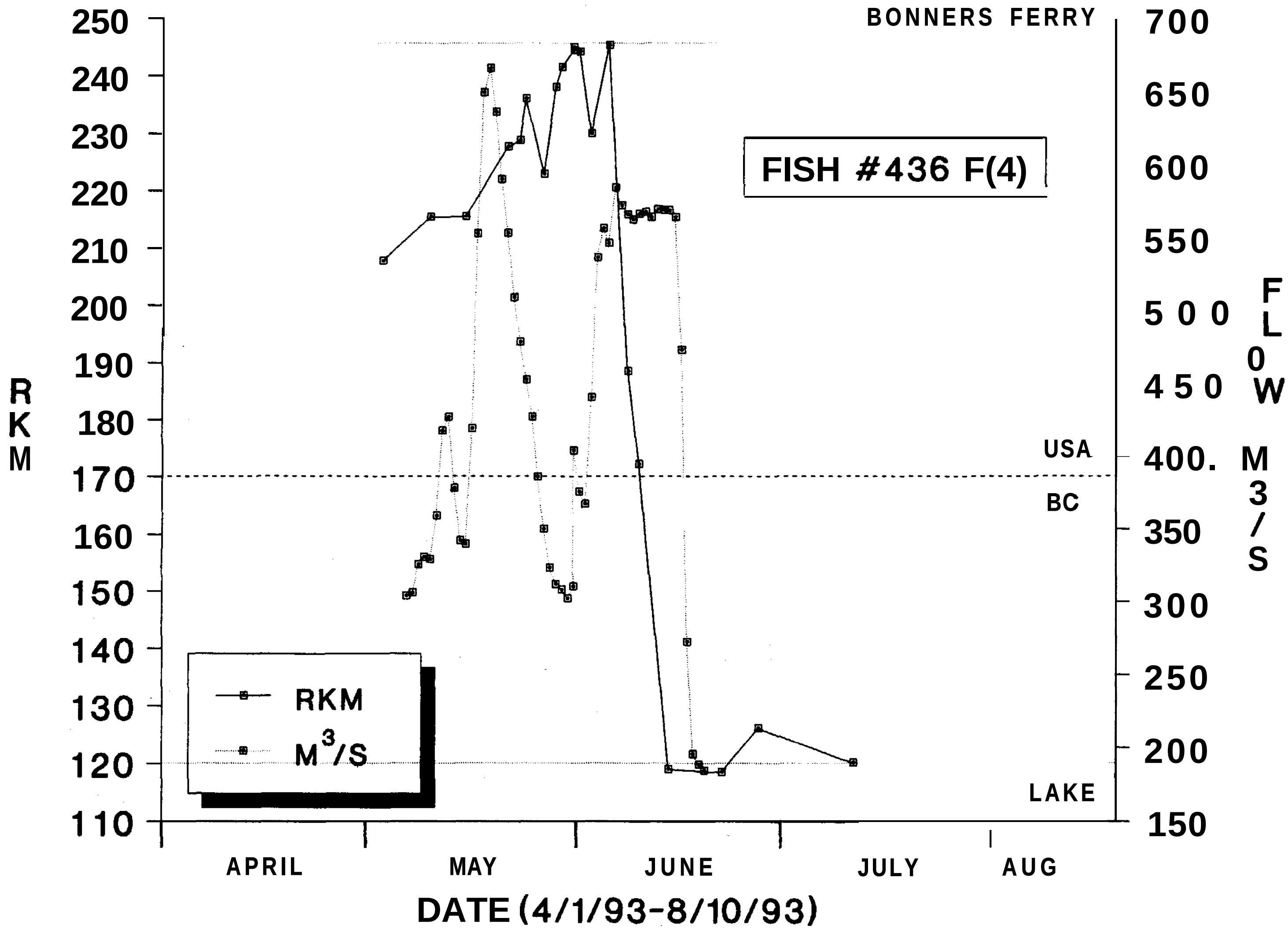

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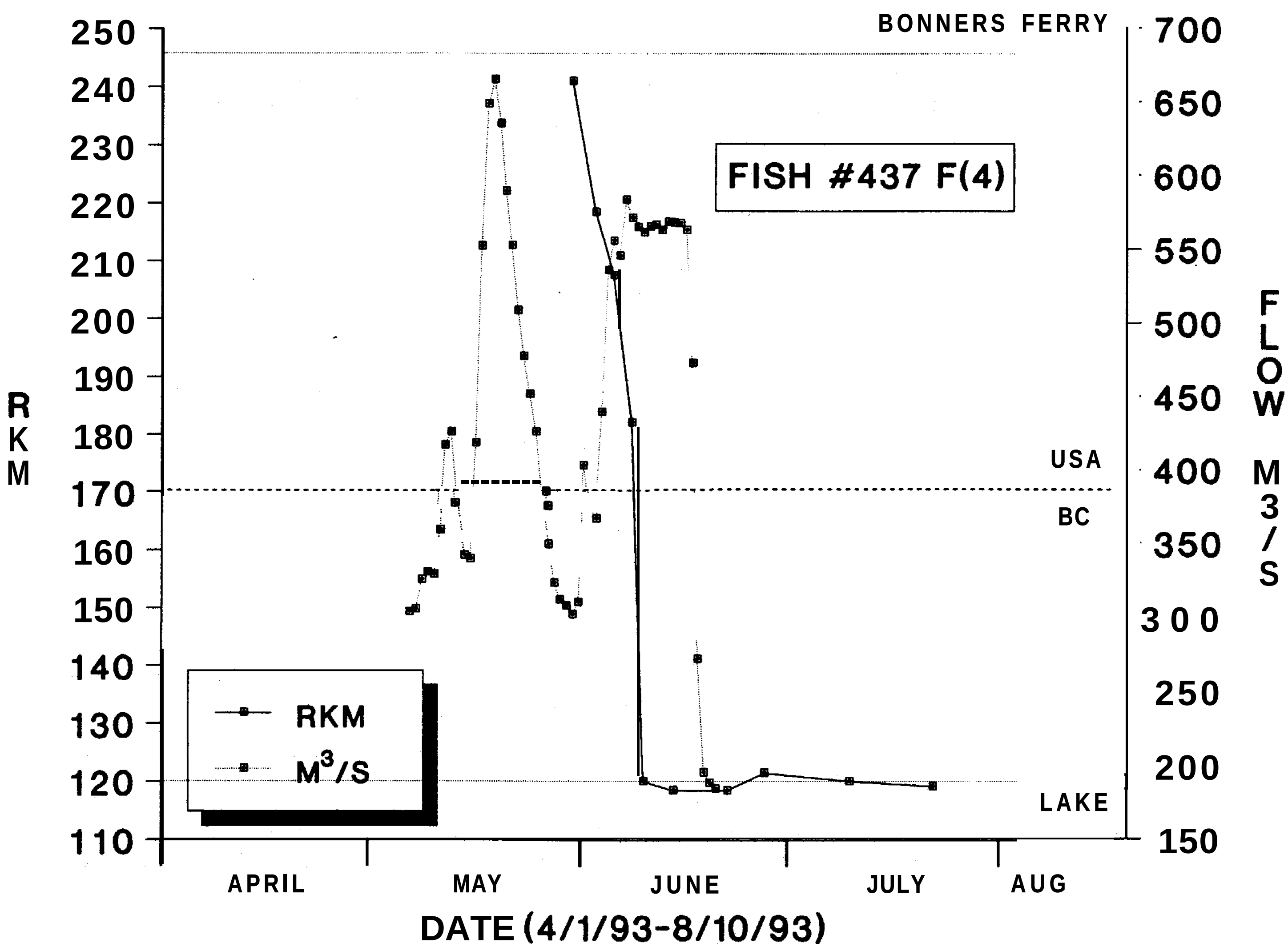

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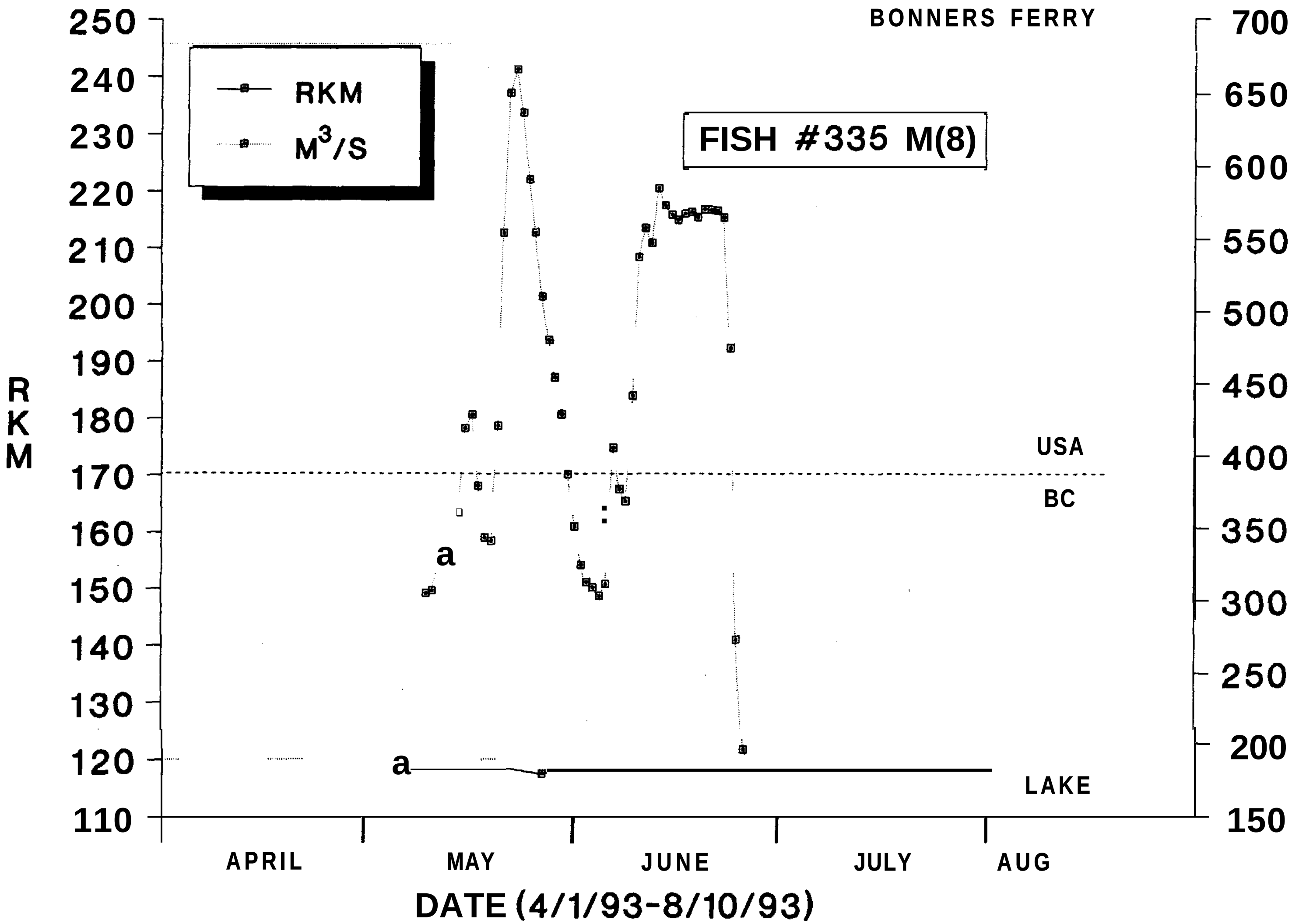

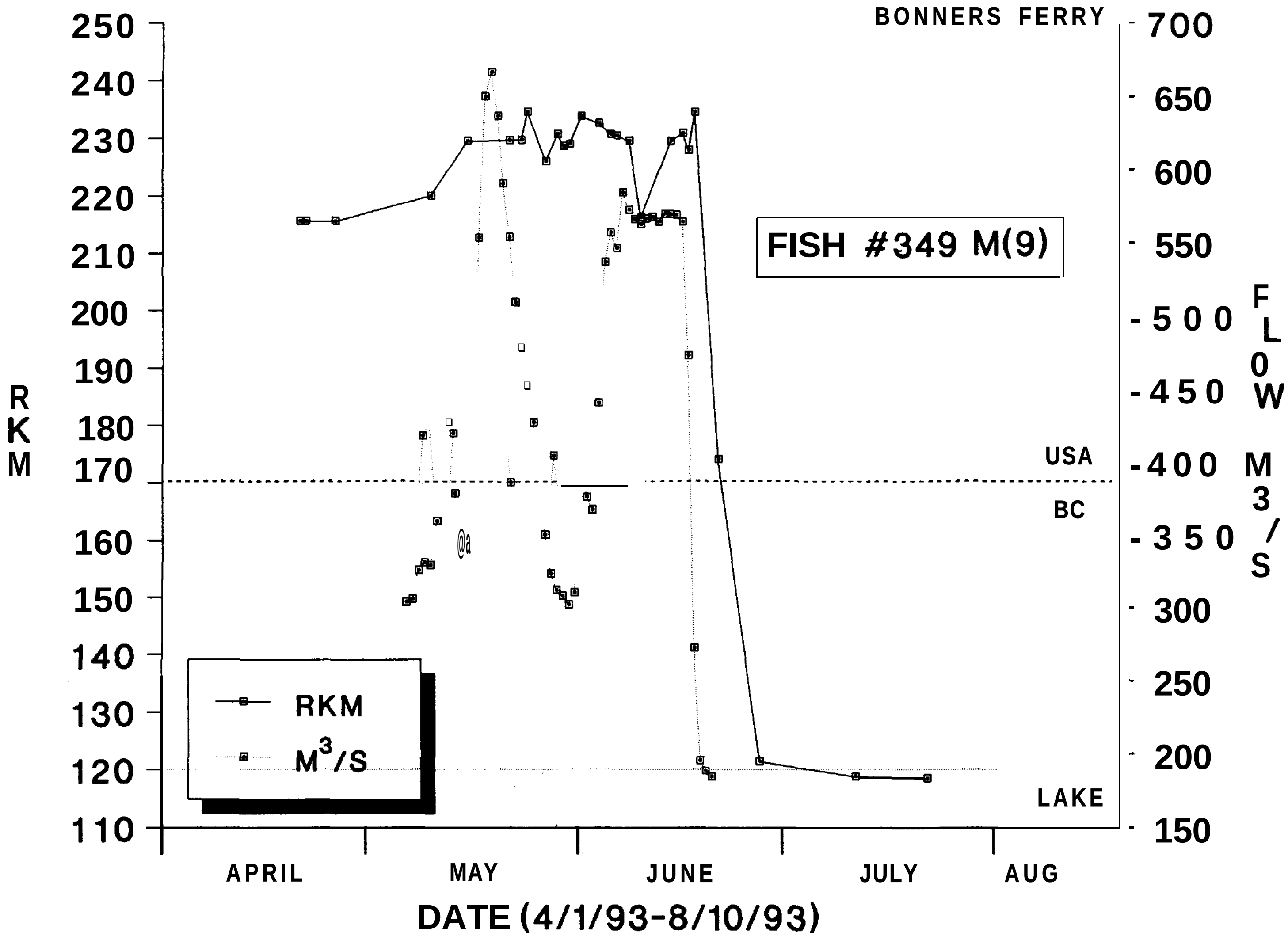

BONNERS FERRY
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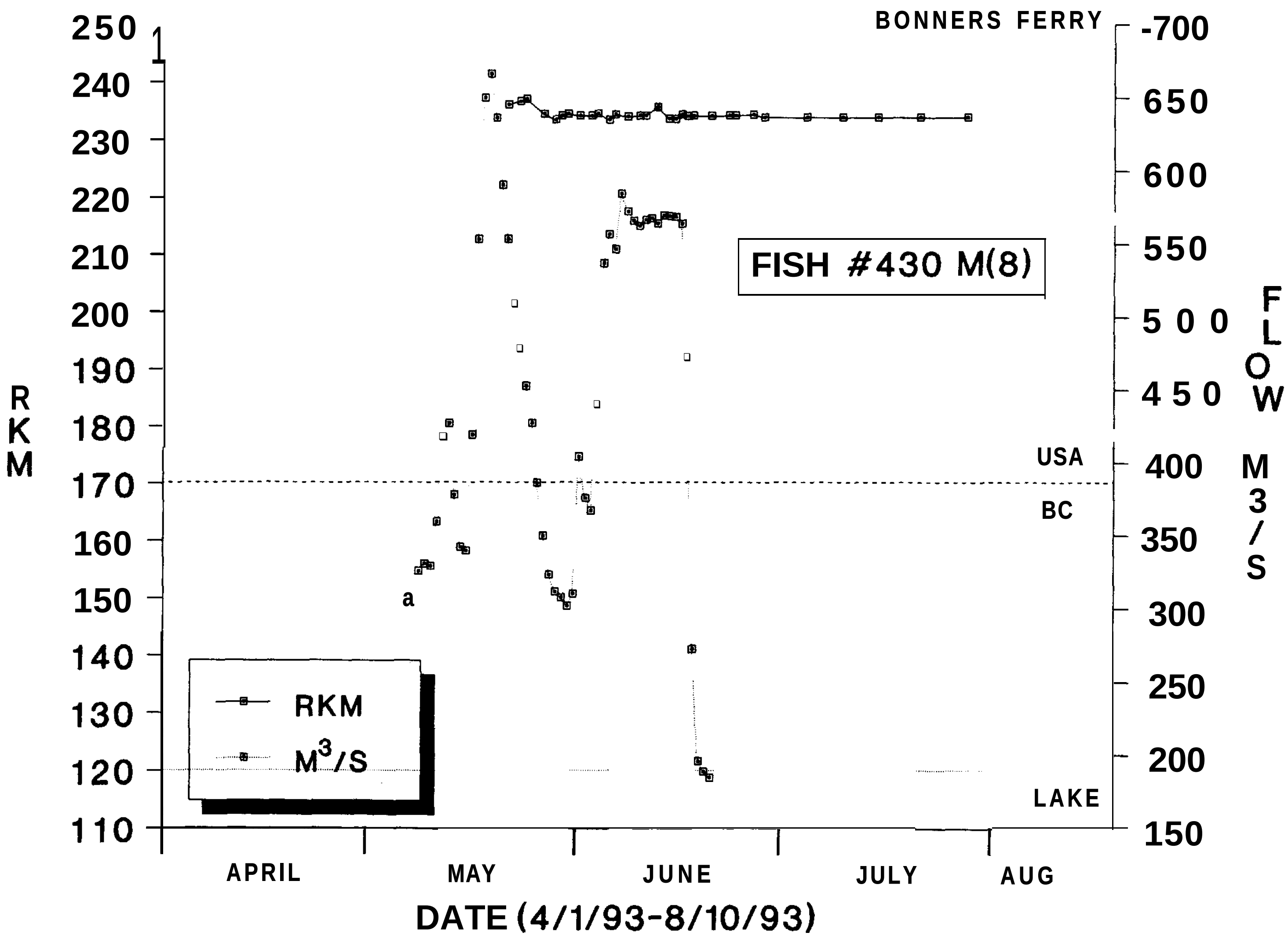
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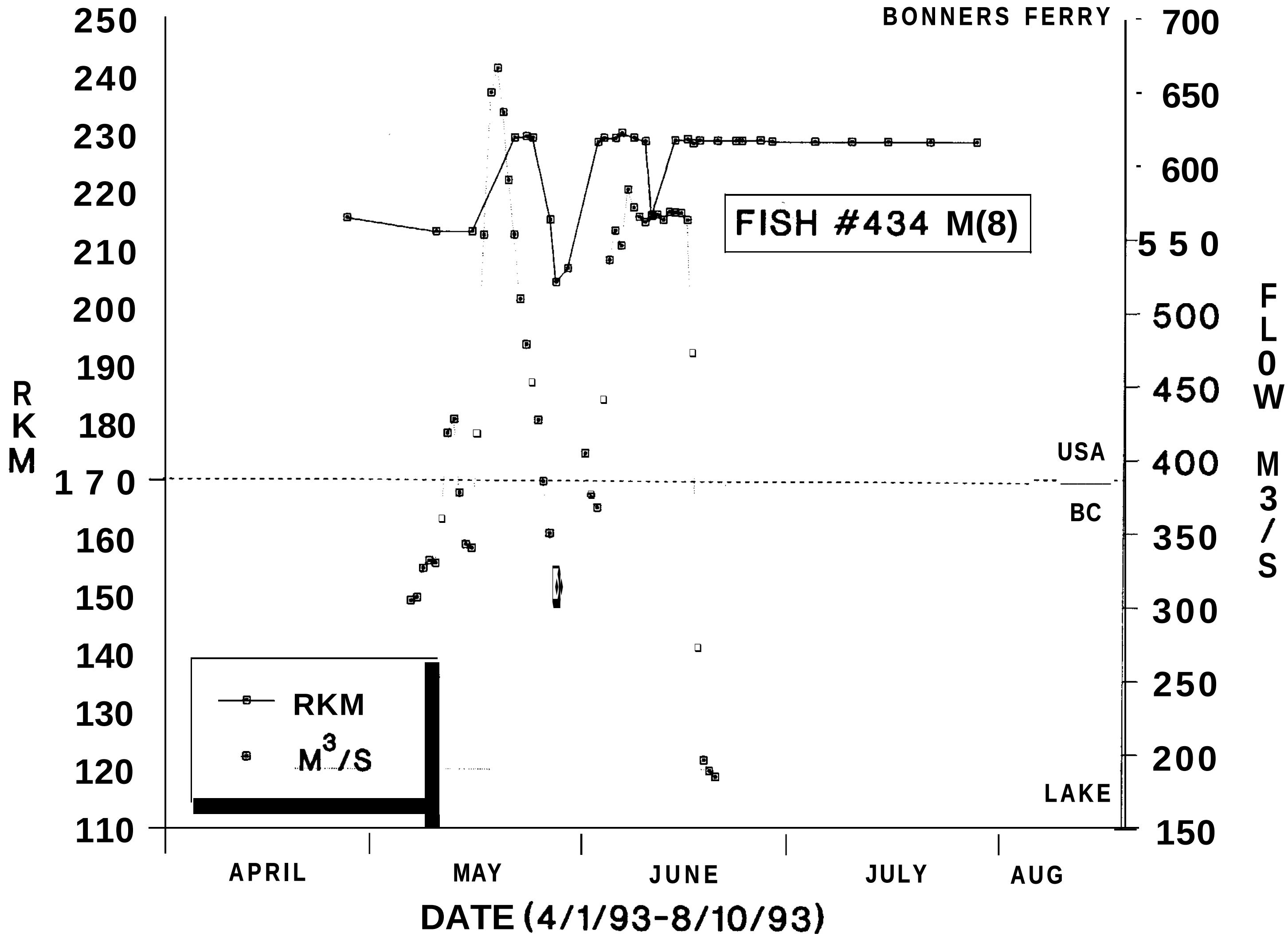
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Appendix B.

Ecosystem metabolism and nutrient dynamics in the Kootenai River in relation to impoundment and flow enhancement for fisheries management.

ECOSYSTEM METABOLISM AND NUTRIENT DYNAMICS IN THE KOOTENAI RIVER IN RELATION TO IMPOUNDMENT AND FLOW ENHANCEMENT FOR FISHERIES MANAGEMENT

PROGRESS REPORT

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SUMMARY

The purpose of this study is to evaluate the effect of Libby Dam on the Kootenai River in relation to nutrient loading and ecosystem metabolism. This report summarizes information on nutrient dynamics in the Kootenai River, as well as the distribution of nutrients in Lake Koocanusa. The results of this research are applied to the feasibility of using selective withdrawal at Libby Dam to increase downstream nutrient concentrations.

U.S.G.S. records (1984-91) show that the concentration of total phosphorus (P_T) increased in a downstream direction in the Kootenai River between Libby Dam and Kootenay Lake. This phosphorus is either (1) being supplied by major tributaries of the Kootenai River, or (2) being regenerated in the river. Contrary to these results, water samples taken in July 1993 indicated that the availability of nitrate (NO_3) and ammonia (NH,) (mg/l as N) decreased in a downstream direction. Also, a nutrient limitation experiment indicated that phosphorus and nitrogen became increasingly less available in a downstream direction and that phosphorus was the limiting nutrient in the Kootenai River. Additional measurements of nutrient dynamics in the river and sampling of nutrient concentrations inthetributaries are necessary in order to resolve this contradiction.

Results of previous studies have demonstrated that Lake Koocanusa (the reservoir formed by Libby Dam) is oligotrophic and that nutrient concentrations in the lake are low. The reservoir retains approximately 63% of its influent total phosphorus and 25% of its influent total nitrogen and has a sediment trapping efficiency which exceeds 95%. Thus the reservoir is acting as a nutrient sink, storing nutrients in the bottom sediments.

Lake Koocanusa also does not appear to have significant stratification, and concentration of phosphorus and nitrogen in the water column. Analysis of U.S.G.S. records from 1984-91 indicate that the range in concentration of total phosphorus (P,) between the surface and the bottom of the reservoir is no more than 0.015 mg/l throughout this time period. Nitrogen (nitrate + nitrite (NO_3+NO_2) and ammonia (NH,)) and ortho-phosphorus (O-PO,) concentrations follow the same trends as P_T, indicating that the reservoir is well mixed throughout most of the year and that nutrients are not significantly concentrated at any given depth or time. Given these results, selective withdrawal from areas of concentration is not possible. Furthermore, the selective withdrawal system which is currently operating at Libby Dam was installed in order to more closely approximate pre-dam temperature conditions downstream. This temperature regime could be difficult or impossible to maintain if the depth from which water is withdrawn is changed.

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INTRODUCTION

Historical background

The Kootenai River basin drains 45,584 km^2 (Knudson 1993) and flows from Mt. Assiniboine, British Columbia, south along the Rocky Mountains into Montana. There the river turns west through the Purcell, and Cabinet mountains, and eventually flows into Idaho, where it encounters the Purcell trench and turns back north toward British Columbia where it flows into Kootenay Lake (Figure 1). The drainage basin is principally underlain by folded, faulted, and metamorphosed Precambrian sedimentary rocks (Ferreira et al. 1992). The catchment is heavily forested and mountainous, and precipitation throughout the basin ranges from 500 to 3,000 mm annually (Knudson 1993). It is the second largest tributary of the Columbia River after the Snake River. The river drops in elevation from 3,618 m at the headwaters to 532 m at the confluence of Kootenay Lake (Figure 1). High channel gradients are present throughout much the system, particularly in the headwaters and in the various tributaries.

Libby Dam was completed in 1972 approximately 27 km upstream of Libby, Montana (Figure 1). The reservoir inundated 144 km of river and encompassed an area of 19.2 km^2 (4750 acres) (Knudson 1993). Since this time, the fisheries in the Kootenai River and in Kootenay Lake have steadily declined. These include the white sturgeon (Acipenser transmontanus), burbot (*Lota lota*), and Gerrard rainbow trout (Oncorhynchus *mykiss*). This decline is believed to be due to flow regulation and the entrapment of nutrients behind Libby Dam (Daley et al. 1981, Woods 1982, Ennis et al. 1983, Hamilton et al. 1990, Knudson 1993). The Kootenai white sturgeon, which is endemic to the portion of the river between Kootenai Falls, Montana, and Bonnington Falls, British Columbia, has been isolated by these natural barriers for approximately 10,000 years. Since 1972, the sturgeon population has declined 33%, and approximately 80% of the population is over 20 years old indicating that recruitment of young sturgeon is virtually nonexistent (Pacific States Marine Fisheries Commission 1992, U.S. Fish and Wildlife Service 1993). Because of this, a petition was filed in 1992 to protect the population under the Endangered Species Act.

The effect of Libby Dam on the discharge regime of the Kootenai River is evident from a comparison of historical discharge records and post Libby Dam discharge records (Figure 2). Historically, the average annual discharge in the Kootenai River was 340 m^3/s (12,000 cfs), with annual variations ranging from 57 m^3/s (2,000 cfs) in February and March, to June when spring melt yielded average discharge of 1,699 m^3/s (60,000 cfs) (May et al. 1981). Since the installation of Libby Dam, annual discharge has varied on average between 113 m^3/s (4,000 cfs) to 651 m^3/s (23,000 cfs) (May et al. 1981). Furthermore, high discharge now generally occurs only during periods of maximum power production (October through March) and low discharge occurs during reservoir refill in late March through mid-July, when sturgeon would naturally spawn (May et al. 1981).

The spring flooding and high water velocity, which occurred before Libby Dam was constructed, are necessary for successful sturgeon spawning (Pacific States Marine Fisheries Commission 1992). Since the construction of Libby Dam, these peak spring flows (1,699 m^3/s) have not occurred. Furthermore, the maximum discharge levels (651 m^3/s) which presently occur are reached in the winter when sturgeon are not spawning. In order to try and remediate this problem, a conservation agreement between the U.S. Corps of Engineers and the U.S. Fish and Wildlife Service has been implemented where water is released from Libby Dam during the spring in order to more closely approximate pre-dam spawning conditions. These timed spawning flows are to continue for four more years.

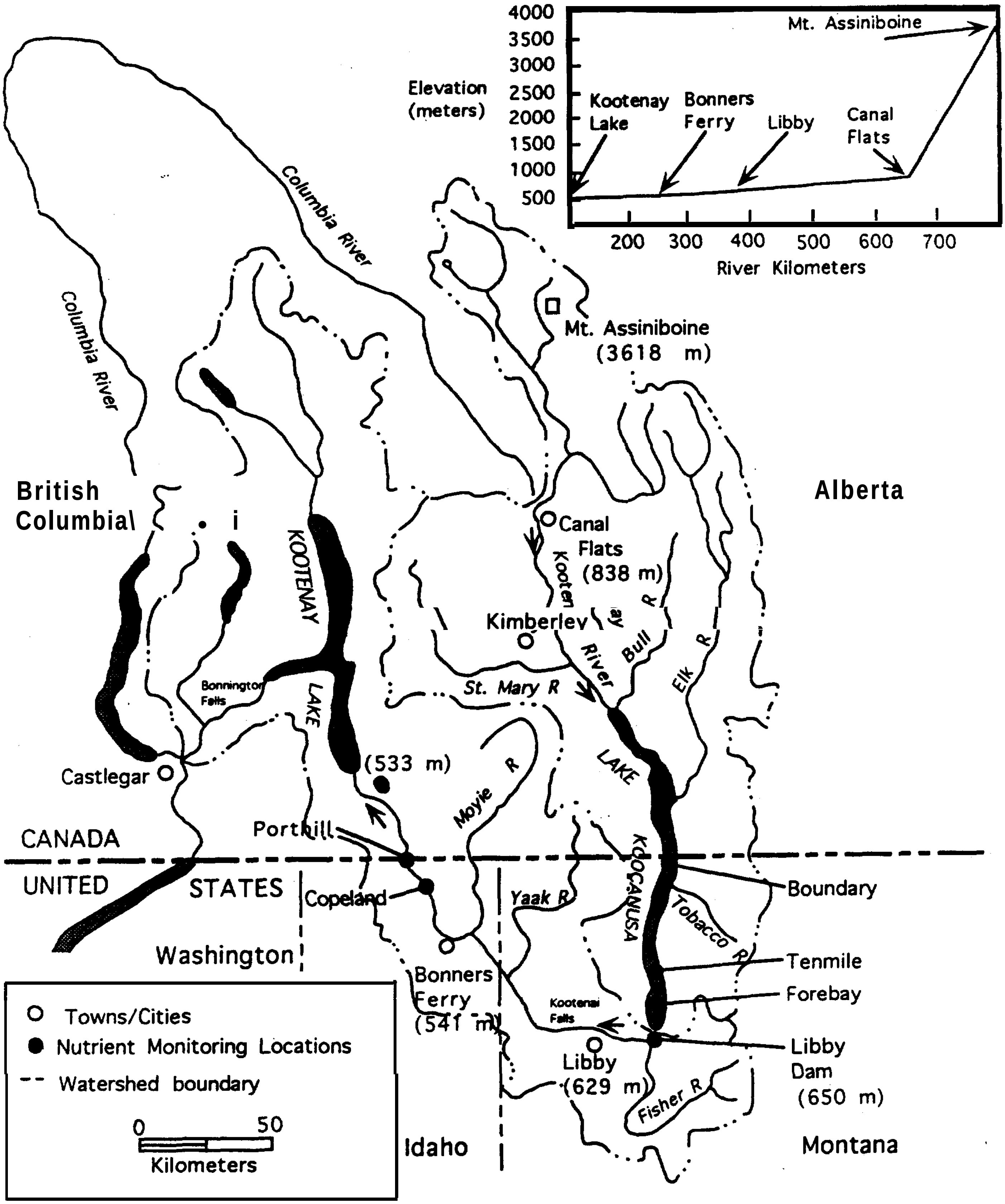

Figure 1. Kootenai River drainage showing U.S.G.S. nutrient monitoring stations on Lake Koocanusa and the Kootenai River.

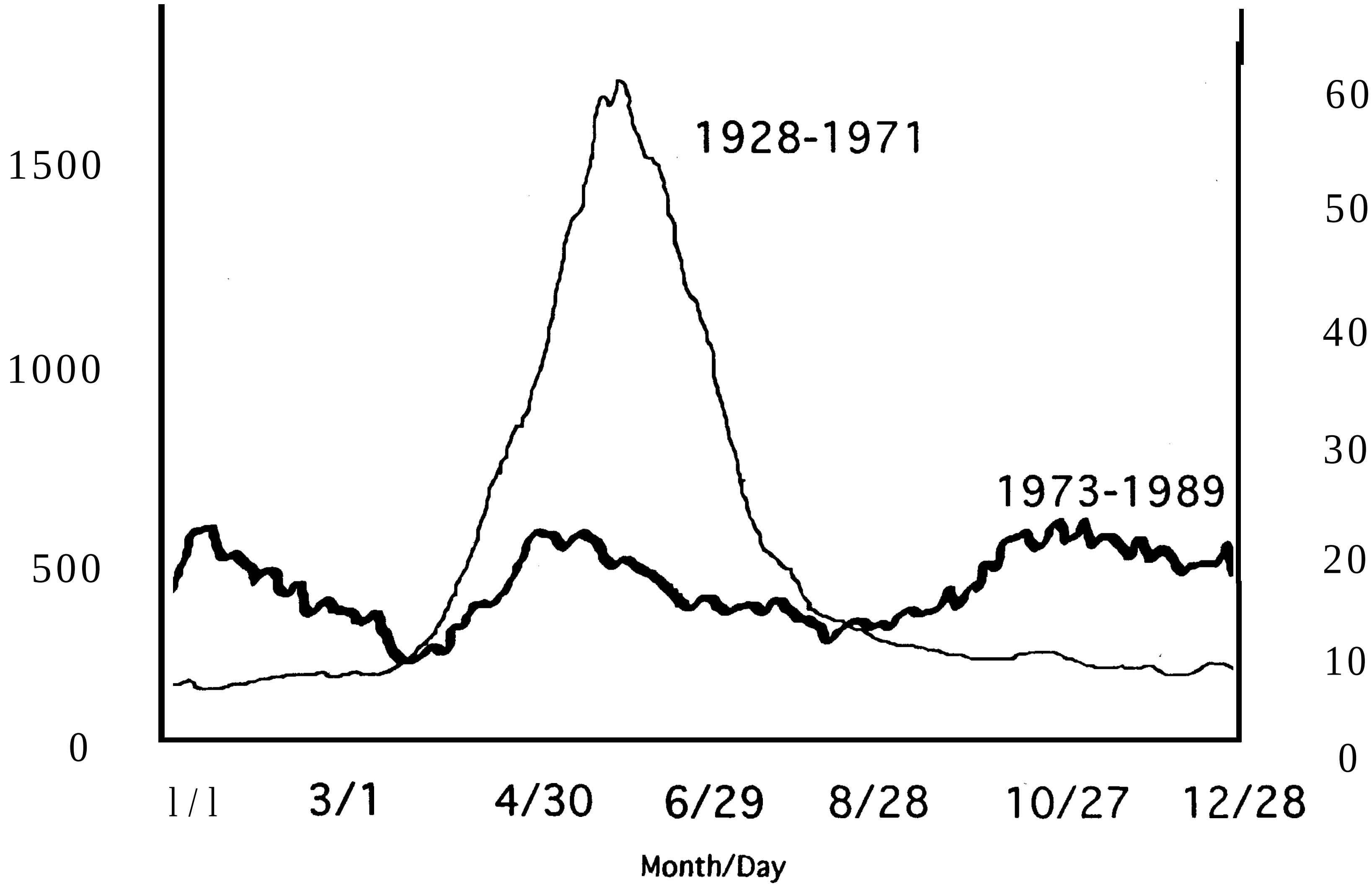

Figure 2. Average monthly discharge records from pre- (1928-1 971) and post- (1973-1 989) Libby Dam.

During the first two weeks in June 1993, 0.49 km^3 (400,000 acre feet) of water were released from Libby Dam, which provided a discharge of 566 m^3/s (20,000 cfs) at Bonners Ferry, Idaho. However, discharge historically reached 1,699 m^3/s (60,000 cfs) during this time. Monitoring of sturgeon by the Idaho Department of Fish and Game and the Kootenai Tribe of Idaho was accomplished by radio tagging adult sturgeon and sampling with a beam trawl and settling mats. Results from this monitoring showed that some sturgeon did move upstream into spawning areas. Also, two eggs were recovered in the river which originated from two females out of an estimated total of 880 sturgeon (estimate based on 1990 Idaho Fish and Game survey; personal communication). The number of females present in the population is not known, although a brood survey of potentially spawning females in 1993 yielded 61males and 4 females (Kootenai Tribe of Idaho, personal communication). It is not known if the spawning effort observed in 1993 represents natural behavior triggered by increased discharge, or if similar spawning efforts had been made in previous years. Also, that two eggs were collected is not necessarily indicative of successful recruitment. Further monitoring needs to be conducted in order to determine the realized success of the 1993 flow augmentation.

From 1972 to 1977, hypolimnetic withdrawal at Libby Dam resulted in low summer temperatures in the Kootenai River below the dam. A selective withdrawal system was installed in 1977 to more closely approximate pre-dam temperature regimes and reduce the number of fish being drawn through the power generating turbines. However, the system does not perfectly duplicate the historical regime, and average yearly temperatures just below the dam are 17% warmer than pre-dam conditions (Knudson 1993).

Libby Dam also has been linked to declining productivity in Kootenay Lake (Figure 1) and the subsequent decline of Kokanee salmon (Oncorhynchus nerka) populations (Daley et al. 1981, Ashely and Thompson 1993). The decrease in productivity is believed to be related to nutrient retention in Lake Koocanusa (Woods 1982). Nutrient stripping has been documented in other reservoir systems as well (Wetzel 1983, Soballe and Bachmann 1984, Winget 1984, Okereke et al. 1988, Galicka and Penczak 1989, Camargo and De Jalon 1990, Copper and Knight 1990). As a possible solution, fertilization experiments in Kootenay Lake were initiated in 1992 in which a total of 864 metric tons of fertilizer were applied over a 10 km section of the North Arm of the lake (Ashley and Thompson 1993). This resulted in a change in trophic status from ultra-oligotrophic to oligotrophic. An oligotrophic system is defined as having a range of P_T (mg m^3) from 3.0 to 17.7 (Wetzel 1983). P_T levels in Kootenay Lake gradually dropped from approximately 50 to 4 mg/m^3 from 1972 to 1984 (Ashley and Thompson 1993). From 1985 to 1992, P_T remained relatively stable, ranging from 2 to 6 mg/m^3. After fertilization, the concentration of P_T ranged from 5 to 10 mg/m^3 (Ashley and Thompson 1993).

Nutrient levels in the Kootenai River also have been anthropogenically influenced by factors other than the construction of Libby Dam. Beginning in 1953, a phosphate fertilizer plant was operated by Cominco, Ltd. at Kimberley, British Columbia, located on the Saint Mary River, a major tributary of the Kootenai River (Figure 1). The plant discharged more than 8,000 metric tons of phosphate annually into the river in the late 1960s (Knudson 1993). The plant installed pollution abatement measures in 1975, which decreased the annual phosphate loading, and in 1987 the plant closed (Hamilton et al. 1990). Installation of these abatement measures is evident from data compiled by Hamilton et al. (1990) in which P_T loading decreased in 1975 to 1976 from approximately 200 to 50 mg/m^3.

Objectives of Our 1993 Studies

Objectives for the 1993 research effort were to (1) analyze ecosystem metabolism within the three study reaches of the river, (2) determine which nutrients, if any, are limiting, (3) generate a nutrient budget for the Kootenai River between Libby Dam and Kootenay Lake from existing data, (4) determine the fate of nutrients in Lake Koocanusa from existing data, and (5) analyze the possibility of using selective withdrawal at Libby Dam to increase the output of nutrient concentrations.

Nutrient Limitation

By definition, nutrient limitation will occur if concentrations are too low to meet biological demand (Stream Solute Workshop 1990). Nitrogen and phosphorus play key roles in primary production and largely control periphyton and phytoplankton growth in lotic and lentic systems (Galicka 1989). An experiment was conducted in August and September to test for nitrogen and phosphorus nutrient limitation in the river reaches below Libby Dam using nutrient-diffusing artificial substrata.

Nutrient Spiraling

Spiraling can be defined as the downstream displacement in the cycling of organic matter and nutrients and is characterized by the rate of uptake, utilization, and regeneration of this material within the lotic ecosystem (Elwood et al. 1983). Nutrient spiraling, as first suggested by Webster (1975), offers an excellent basis by which the spiraling distances and transformations of organic carbon, phosphorus, and other nutrients can be determined. This spiraling process can be visualized as a helix lying longitudinally along a stream (Newbold 1982). The degree of retention of nutrients and organic matter is indicated by the tightness of the spirals. The regeneration rate is indicated by the diameter of the spiral (a large spiral represents slow regeneration and a small spiral represents rapid regeneration) (Minshall et al. 1983, Chauvet and Decamps 1989). The cycling rate is dependent on factors such as nutrient retention and processing or regenerationtime (i.e., oxidation and conditioning).

Community Metabolism

Community metabolism is an important parameter in nutrient spiraling. Determination of community metabolism values for the Kootenai River are being made because the rate of organic matter recycling can be measured by the rate of community respiration (Newbold et al. 1982, Minshall et al. 1983). In addition, measurements of primary production provides information on the rate of fixation of organic carbon, a potential food source for aquatic herbivores. Metabolism data were obtained using an open system, upstream-downstream technique. Individual metabolic pathways also can be followed by partitioning the components of the river and measuring the metabolic rates of benthic organic matter (BOM), and organic matter in transport (seston). The benthic or transported matter are placed into plexiglass chambers filled with river water. Changes in the oxygen content within the chambers are monitored and estimates of community metabolism and respiration are made.

The changes in oxygen concentration in the chambers and in the open river are driven by the same processes. In daylight, photosynthesis as well as respiration occurs, and oxygen levels increase if photosynthetic rates are higher than respiration rates. At night, photosynthesis stops and respiration continues causing oxygen levels to decrease. The organic matter content of the material inside the chambers is determined by ash-free dry mass (AFDM). Given the metabolism, AFDM, and discharge information, nutrient cycling rates can be estimated following methods described in the previous section.

Site Characterization

In order to make community metabolism and nutrient spiraling estimates, the Kootenai River was divided into three physically different reaches between Libby Dam and Kootenay Lake (Figure 3). The first reach extends from Libby Dam to the Moyie River (92 km) and is essentially unbraided, with an average depth of 7.6 m and an average channel gradient of 0.6 m/km. The substrate consists of large cobble and gravel and water velocity averaged 0.78 m/s during the 1993 summer research effort. In this reach the river flows in a north-west direction through a gap between the Purcell and Cabinet mountains, and in places is incised 50 to 100 m into the local stratigraphy. Subsequently it was labeled the canyon reach.

The second reach (Figure 3) extends from the Moyie River to the town of Bonners Ferry (7.5 km). This reach is extensively braided with depths typically less than 9 m and substrate consisting of gravel. Channel gradient and velocity (0.58 m/s) are slightly less than the canyon reach. This reach is referred to as the braided reach.

The third reach (Figure 3) extends from just below the town of Bonners Ferry to the confluence of Kootenay Lake (82.5 km). The gradient and velocity are' considerably less than the canyon and braided reaches, being only 0.02 m/km and 0.10 to 0.19 m/s, respectively. The river channel meanders over beds of compacted clay and fine sediments. Water depth in the runs range from 4.6 to 12 m deep, and from 12 to 30 m in pools. This reach is referred to as the meander reach. Metabolism measurements were made at two locations in this reach. Metabolism transects were established near Deep Creek at the upstream portion of the reach, and near Copeland at the downstream end of the meander reach.

These three reaches reflect differences in channel morphology and hydraulic slope and thus should differ markedly in ecosystem structure and function (Vannote et al. 1980). The three reaches also follow the same sequence of channel conditions (straight, braided, meandering) which are predicted to occur in an entire river system, from headwaters to ocean (Vannote et al. 1980, Minshall et al. 1985).

METHODS

United States Geological Survev Records

Nutrient Budget - Kootenai River

U.S.G.S. records were used to determine historical nutrient concentrations in the river from 1971-90. Data from Porthill and Copeland, Idaho (Figure 1), were used to estimate the quantity (as Mg/year; Mg = megagram, where 1 Mg = ca. 1 ton). U.S.G.S. data collected directly below Libby Dam were used to calculate the quantity of nutrients (nitrate + nitrite (NO_3+NO_2), ammonia (NH_4), ortho-phosphorus (O-PO_4), total phosphorus (P_T)) leaving Lake Koocanusa (Figure 1). Conversions to Mg per year were done using the formula:

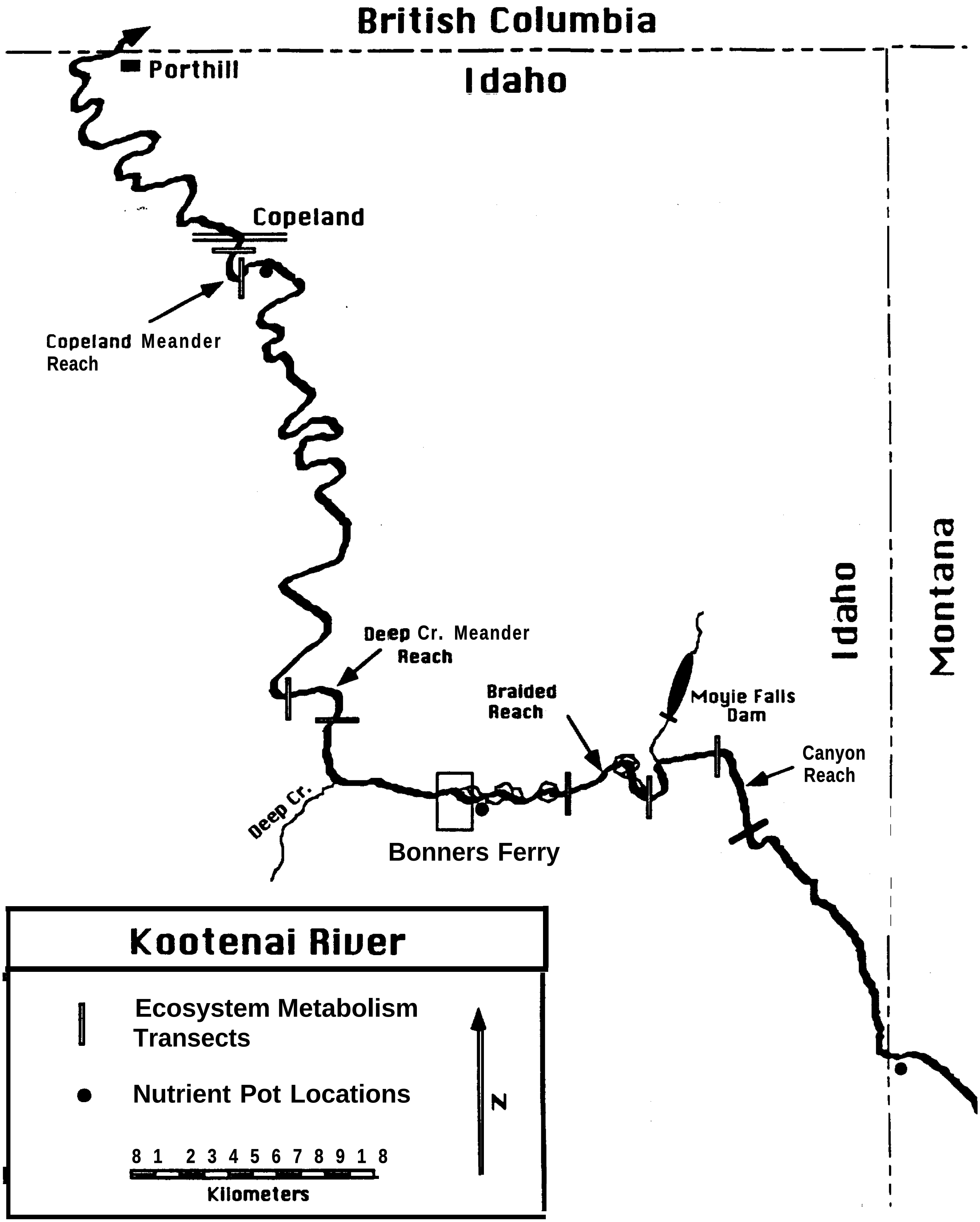

Figure 3. Location of community metabolism transects and clay pot nutrient treatment sites on the Kootenai River, Idaho.

$$\frac{\text{Ave. yearly discharge (cfs)} \times 28.321\ (l/s) \times \text{conc. of nutrients (mg/l)} \times 3.16\times10^{7}\ (s/yr)}{1.0\times10^{9}\ mg/Mg}$$

More recent data on nutrient concentrations entering Lake Koocanusa will be obtained from Les McDonald of British Columbia Ministry of Environment (pers. comm.) and this information will be included in the Annual Report.

Nutrient Distribution - Lake Koocanusa

U.S.G.S. samples weretaken at 3 locations (Figure 1) from two depths, 3.05 m from the surface and the reservoir bottom. The International Boundary site is 54 km upstream from Libby Dam, the Tenmile Creek site is 22 km from Libby Dam, and the Forebay site is nearest to Libby Dam. Nutrients in the analysis include P_T, O-PO,, NO_2+NO_3, and NH,.

Idaho State University Data

Nutrient Distridution - Kootenai River

Water samples were collected at Libby Dam, Kootenai Falls, and the four community metabolism transects (Figure 1 and 3) in July 1993 and analyzed for NO, and NH_4 using standard methods (APHA 1990). Specific conductivity (corrected for temperature at 25°C, YSI model 32) and pH (Orion model 290A) also were recorded.

Community Metabolism

Community metabolism and respiration rates were determined using two-station, upstream-downstream techniques in which diel dissolved oxygen (DO) and temperature changes were recorded. This data is being analyzed according to the open system upstream-downstream techniques outlined by Odum (1956) and Janzer (1977). Transects were established (Figure 3) within each reach such that flow time was not more than 1 to 2 hours between transects. Measurement of DO and temperature were done using an anchored-buoy system equipped with a Campbell Scientific data logger (model BDR 320) which was connected to a Royce oxygen probe (model 900). The logger recorded DO values every 10 minutes by averaging values recorded every 10 seconds. Temperature was recorded using an Aliquot temperature data logger (model aq146). Measurements of cross-sectional depth, velocity (Price meter or General Oceanic8 meter), dissolved oxygen, and temperature (Orion model 840) were made at each transect at six-tenths overall depth. Vertical profiles of the same variables were made at the monitoring buoy. Flow times were determined using fluorescein dye or floating oranges. Light was recorded using a Li-Cor PAR (photosynthetically active radiation) sensor. The same sensor was used to determine light attenuation in the water column. Data from the logger were periodically downloaded onto a laptop computer.

Coarse and fine particulate organic matter (CPOM and FPOM) in transport were collected using nested nets of two different mesh sizes (1,000 um and 53 urn). This was done three times in a 24 hour period at three locations evenly spaced across each transect. The samples were preserved with 5% formalin and returned to the laboratory for ash-free dry mass (AFDM) organic content determination.

Nutrient Limitation

Determination of possible nutrient limitation was accomplished using nutrient-diffusing substrata enriched with nitrogen (N), phosphorus (P), and N + P (Fairchild 1984, 1985, Bushong 1989). Small clay flower pots (8.8 X 8cm) were filled with enriched agar in the following concentrations similar to those in an experiment done by Tate (1990):

control	4.0% agar solution
Nitrate	0.1 mol/L $NaNO_3$-N
Phosphate	0.1 mol/L KH_2PO_4-P
N + P	0.1 mol/L $NaNO_3$ + 0.1 mol/L KH_2PO_4

Nutrients slowly diffuse through the clay flower pots (Fairchild et al. 1985, Buahong 1989) and periphyton colonizing the surface of the pots will utilize those nutrients as well as nutrients present in the surrounding river water. A river system which has low ambient nutrient concentrations such that periphyton growth is inhibited is considered nutrient limited. However, if that limiting nutrient is supplied on one of the clay pot treatments, periphyton biomass should increase on that pot as determined by chlorophyll a and AFDM.

The agar-filled pots were sealed up-side down to pine boards (Bushong 1989), which were then placed at 1 m depth in the river at a total of three locations, one each in the canyon, braided, and meander reaches (Figure 3). Replicate pots (4 per treatment) were removed at 4, 7, and 34 days, beginning on 25 August 1993. Chlorophyll a and AFDM were determined for each treatment by scraping periphyton from a known surface area on each pot. This periphyton was then filtered and frozen in liquid nitrogen for transport to the Idaho State University laboratory for spectrophotometric analysis of chlorophyll a (phaeophytin corrected)(Stockner and Armstrong 1971, Lorenzen 1966), and organic matter content (AFDM). Data were statistically analyzed using analysis of variance (Zar 1984).

RESULTS

<u>Nutrient Budcret - Kootenai River</u>

Previous research already has delineated the concentrations of nutrients entering Lake Koocanusa (Woods 1982, Hamilton et al. 1990). Loading to the reservoir as Mg/year of total phosphorus (P_T) ranged from 1,924 to 1,304 from 1970 to 1975, and values ranged from 514 to 362 from 1976 to 1980 (Woods 1982). The drop in P_T loading in 1976 is correlated with the pollution abatement measures installed by Cominco, Inc. Total nitrogen (N_T) loading to the reservoir ranged from 4,679 to 2,451 Mg/yr from 1970 to 1980 without apparent trends (Woods 1982).

Between Libby Dam and Kootenay Lake, the concentration of total phosphorus and ortho-phosphate increased slightly in a downstream direction (Figure 4). The concentration of nitrate plus nitrite fluctuated with no obvious trends after 1972 (Figure 4). A significant decrease in concentration of all nutrients examined is apparent after Libby Dam became operational in 1972 (Knudson 1993).

In contrast with this data are the results of Idaho State University (I.S.U.) July 1993 sampling effort, which showed a decrease in nitrate (NO,) and ammonia (NH,) concentration in a downstream direction from 0.106 to 0.036 and

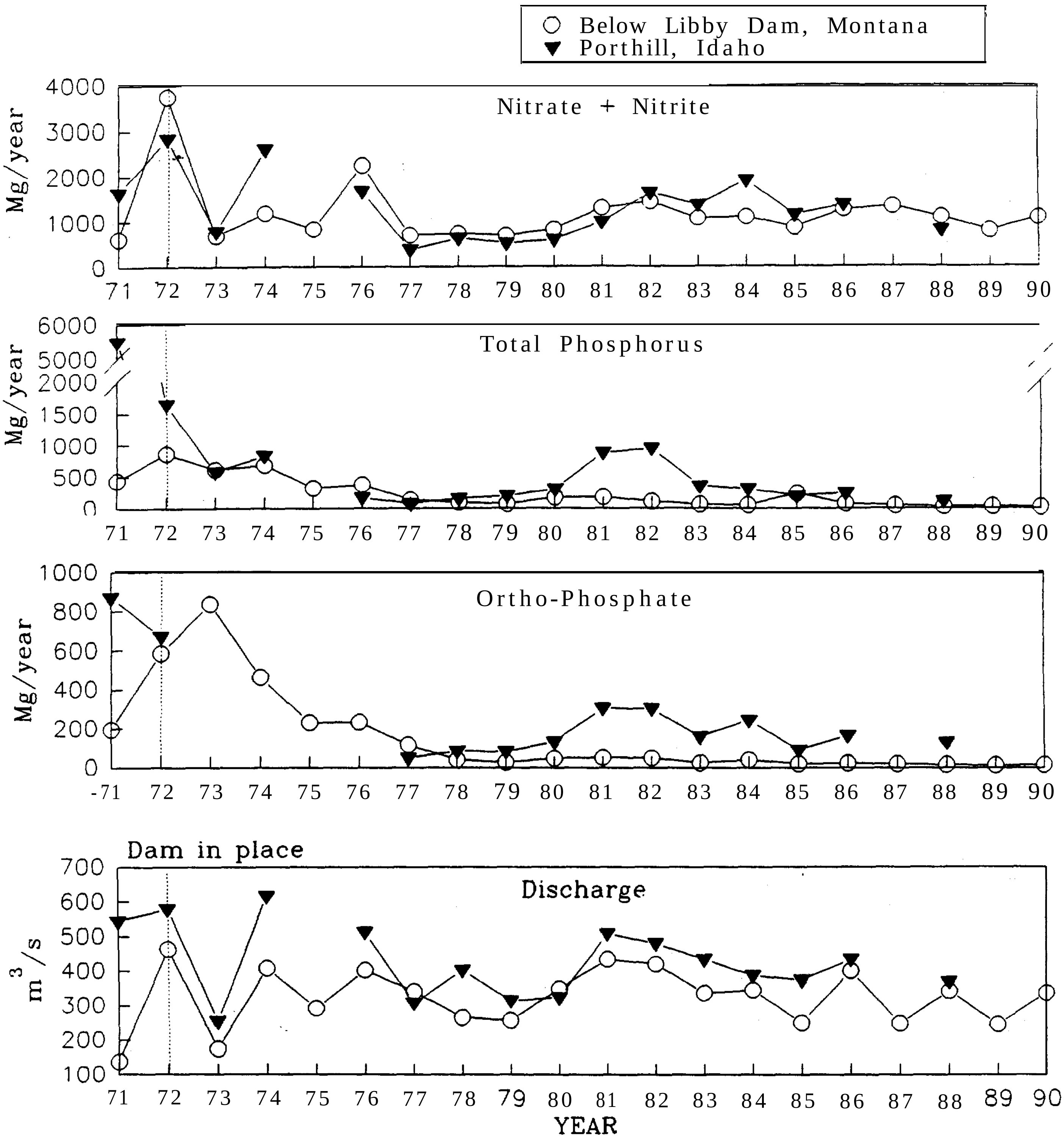

Figure 4. Nutrient analysis for the Kootenai River between Libby Dam and Porthill. Figure based on U.S.G.S. data for years of record. Note: Mg = Megagram; where 1 Mg = ca. 1 ton.

0.011 to <0.005 mg/l, respectively (Figure 5). Specific conductance decreased slightly in a downstream direction although a large spike was evident in the braided reach near the town of Bonners Ferry. A downstream increase in pH was recorded (Figure 6). Also, the results of a nutrient limitation experiment (Figure 7) performed by I.S.U. indicated that the concentration of nutrients available for periphyton growth decreased in a downstream direction. Periphyton biomass (as concentration of chlorophyll a and AFDM; average of the P and N+P treatments) decreased from the canyon, braided, and meander reaches from 266, to 92, to 52 mg/m^2 respectively for chlorophyll a; and from 17.5, to 5.6, to 1.3 g/m^2 respectively for AFDM (Figure 7). This trend was also observed for the control and N treatments (Figure 8). The autotrophic index (AFDM/chl a) was greater at the meander site (135.57) compared to the canyon site (70.45).

Nutrient Limitation

On day 4, chlorophyll a values for the N+P treatments were significantly greater ($p=0.022$) than the control treatments at the meander site (Figure 8). The same trend was evident on day 7 when N+P was significantly greater than the control or N treatments ($p=0.028$ and 0.051 respectively).

On day 34, the P and N+P treatments showed significantly greater ($p<0.05$) periphyton growth (as chlorophyll a) than the N, and control treatments in the canyon and braided reaches (Figure 8). There was no significant difference between the P and N+P treatments or the N and control treatments. In the meander reach the N+P treatments had greater periphyton growth than the N or control treatments.

Nutrient additions had the greatest effect at the canyon site. Differences in values of mean chlorophyll a between N and control treatments and the N+P and P treatments were 242 mg/m^2, while differences for site 2 and 3 were 71 and 45 mg/m^2, respectively.

Community Metabolism

Initial analyses of the community metabolism data collected during summer 1993 suggest that the Kootenai River is heterotrophic (e.g. community respiration and export exceeds total gross primary productivity (photosynthesis) and import) (Bott 1983). Determination of horizontal and vertical profiles of dissolved oxygen and temperature (Figure 9 and 10) indicated that no stratification occurred at any of the study transects. Based on this data, the future use of a single dissolved oxygen probe at six-tenths depth to monitor overall oxygen changes in the water column is justified.

Nutrient Distribution - Lake Koocanusa

Data from 1990-91 indicate that there is no more than a 0.02 mg/l difference in P_T between the surface and the bottom of the water column in the reservoir (Figure 11). The maximum difference in O-PO, is no more than 0.005 mg/l (Figure 11). At the Forebay site, which is closest to Libby Dam, the concentration differences are even less. Figure 12 shows that this trend remains relatively constant from 1984 to 1991. The range in concentration of P_T and O-PO, from 1984-91 is 0.001 to 0.03 and 0.001 to 0.02 mg/l, respectively (Figure 12).

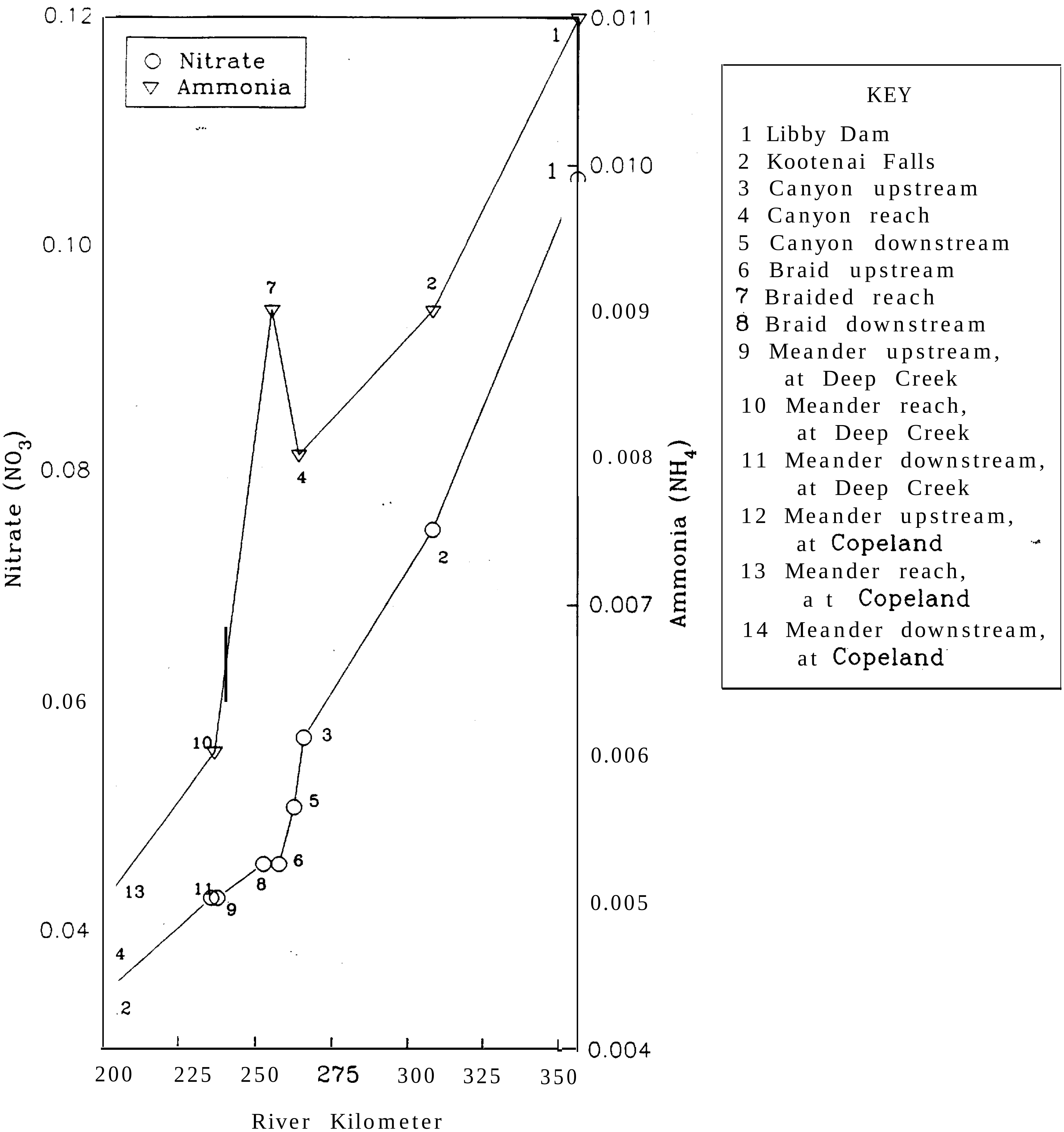

Figure 5. Nitrate (mg/l as NO_3) and ammonia (mg/l as NH_4) concentrations. Samples collected 29 July 1993. Note: X-axis arranged according to river kilometers; upstream and downstream locations correspond to ecosystem metabolism transects.

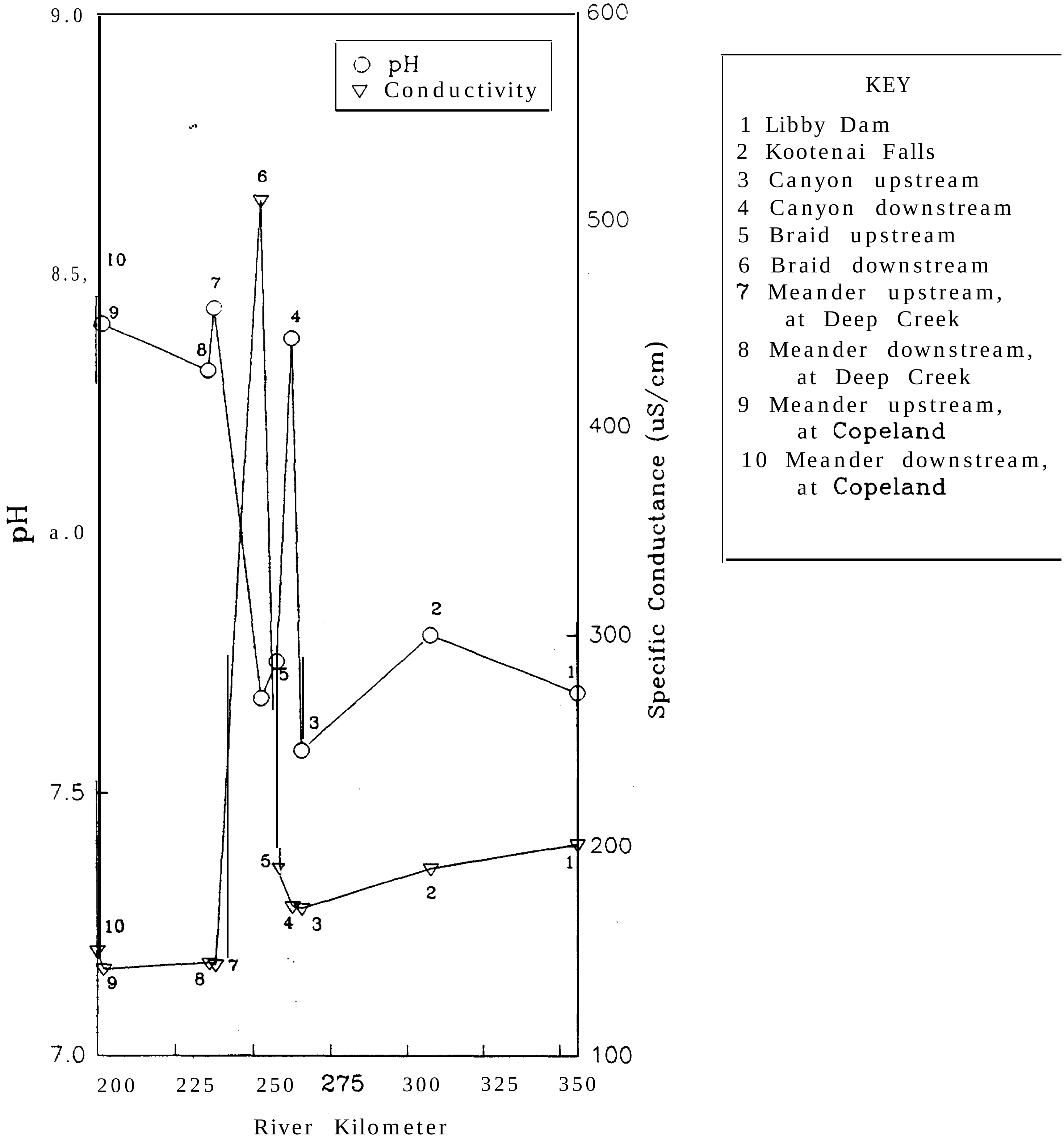

Figure 6. Specific conductance (uS/cm) and pH in the Kootenai River. Samples collected 29 July 1993. X-axis arranged according to river kilometers. Upstream, downstream locations correspond, to ecosystem metabolism transects.

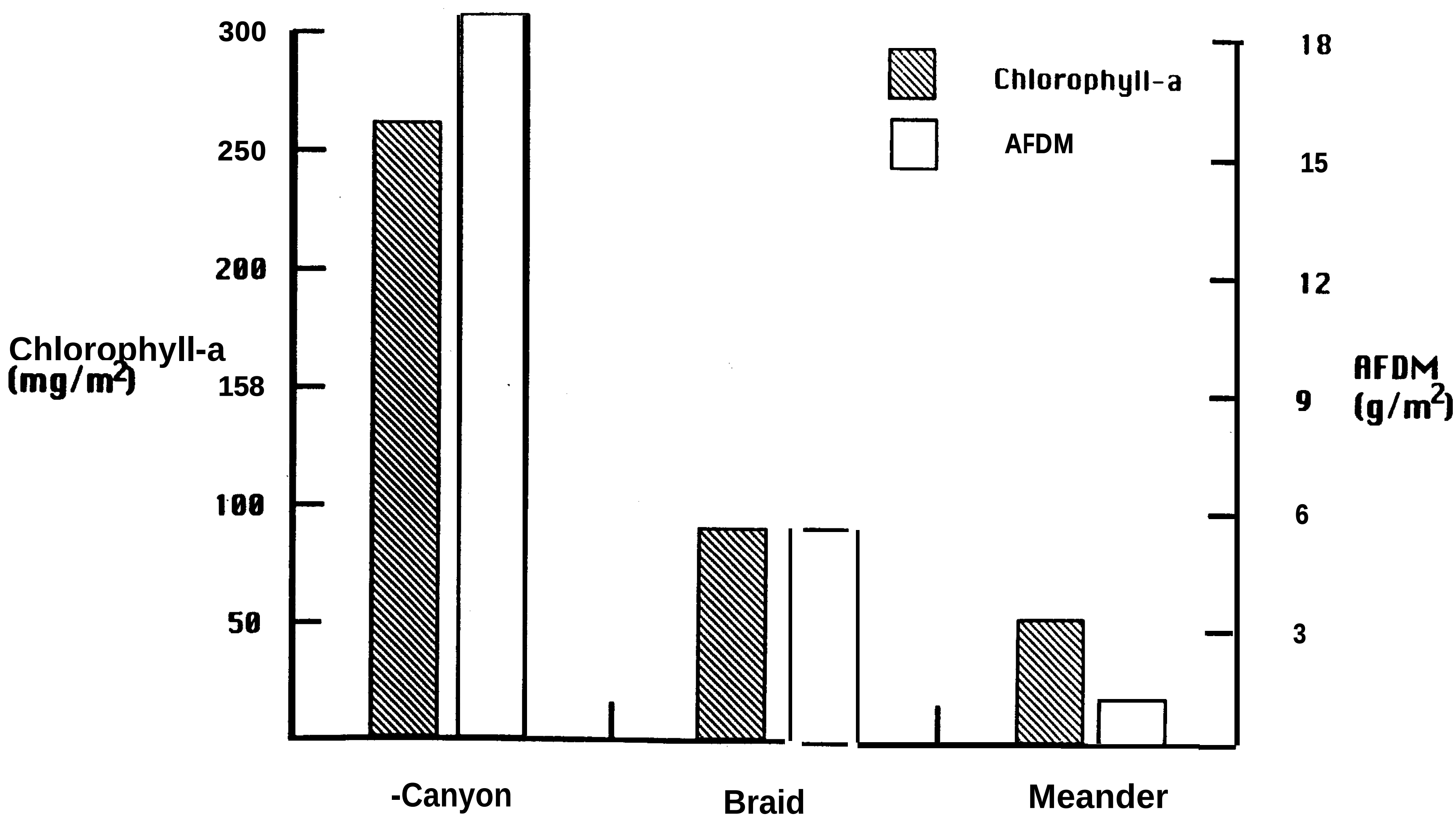

Figure 7. Mean chlorophyll-a and mean AFDM from P and N+P pots at three locations on the Kootenai River.

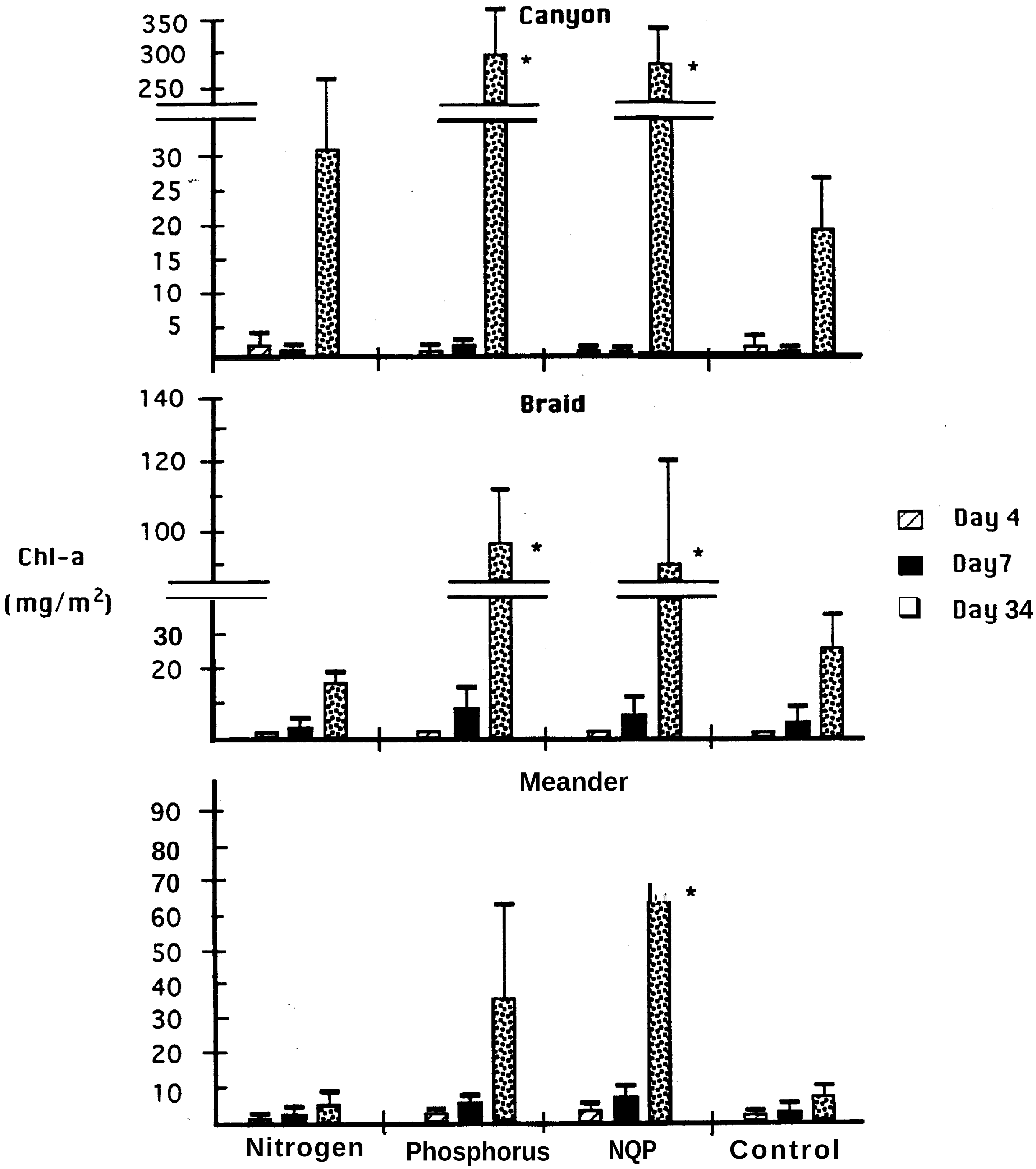

Figure 8. Clay pot nutrient addition experiment. The x-axis represents the different treatments, and the y-axes are variable. Bars represent one standard deviation. Asterisks signify significan differences.

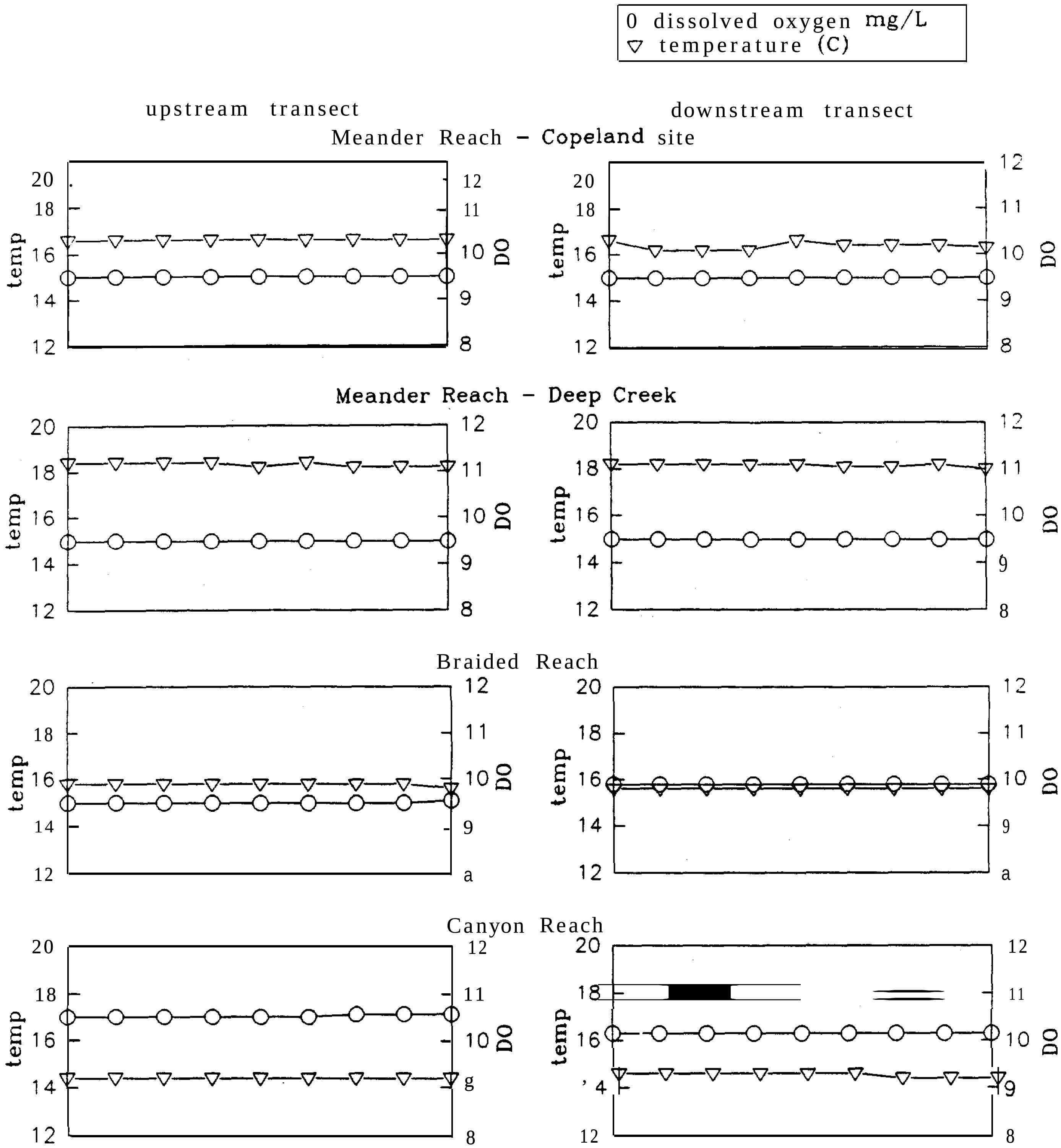

Figure 9. Horizontal profiles of temperature (C) and dissolved' oxygen (DO mg/L) at six tenths depth at 10 evenly spaced locations across each transect. Measurements made 23-30 July 1993.

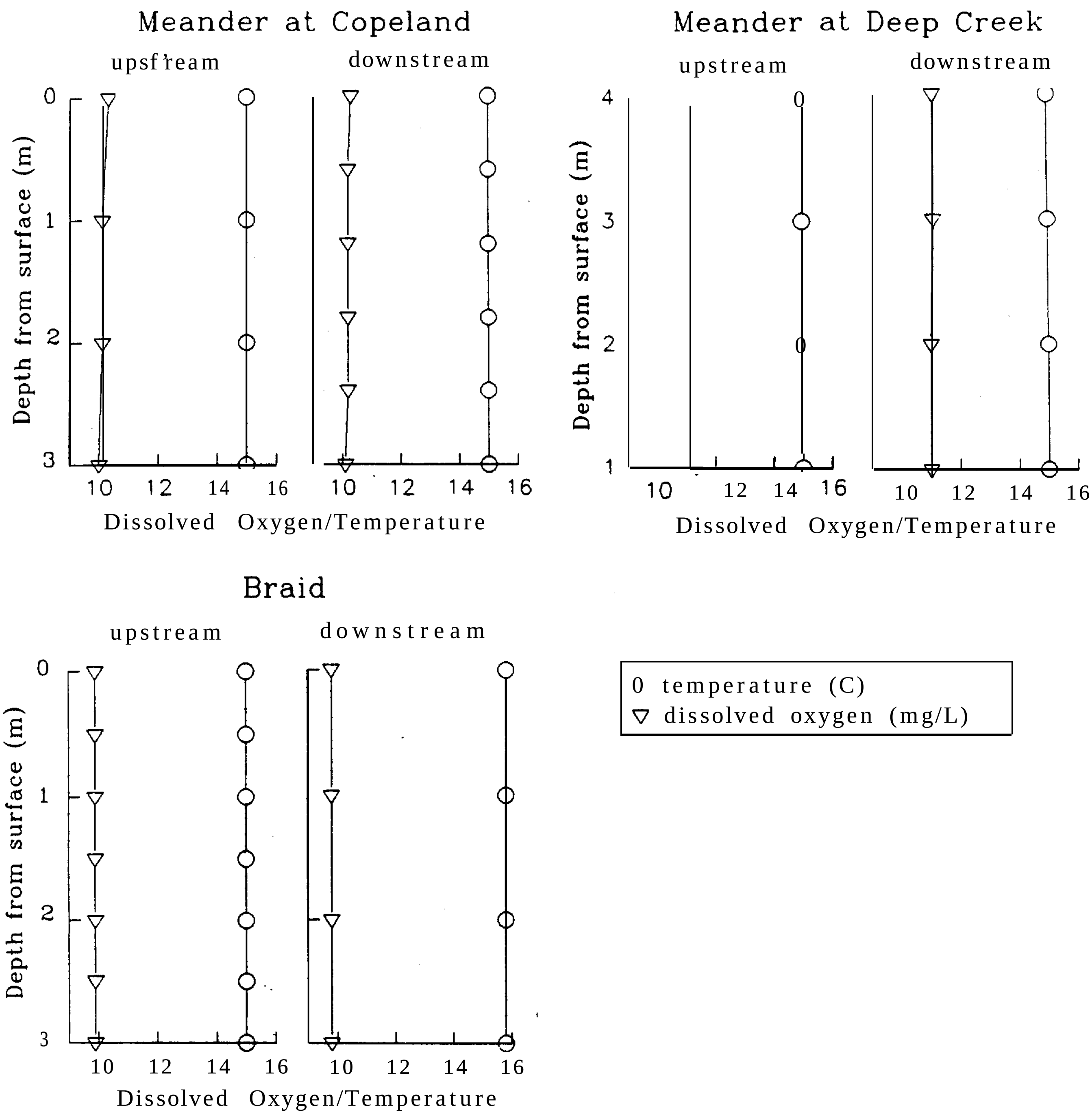

Figure 10. Vertical profiles of temperature (C) and dissolved oxygen (mg/L) taken at all transects in the Meander and Braided reaches. Due to high velocity, measurements in the canyon reach were not obtained. Note that the x axis represents both temperature and dissolved oxygen. Measurements taken 23-30 July 1993.

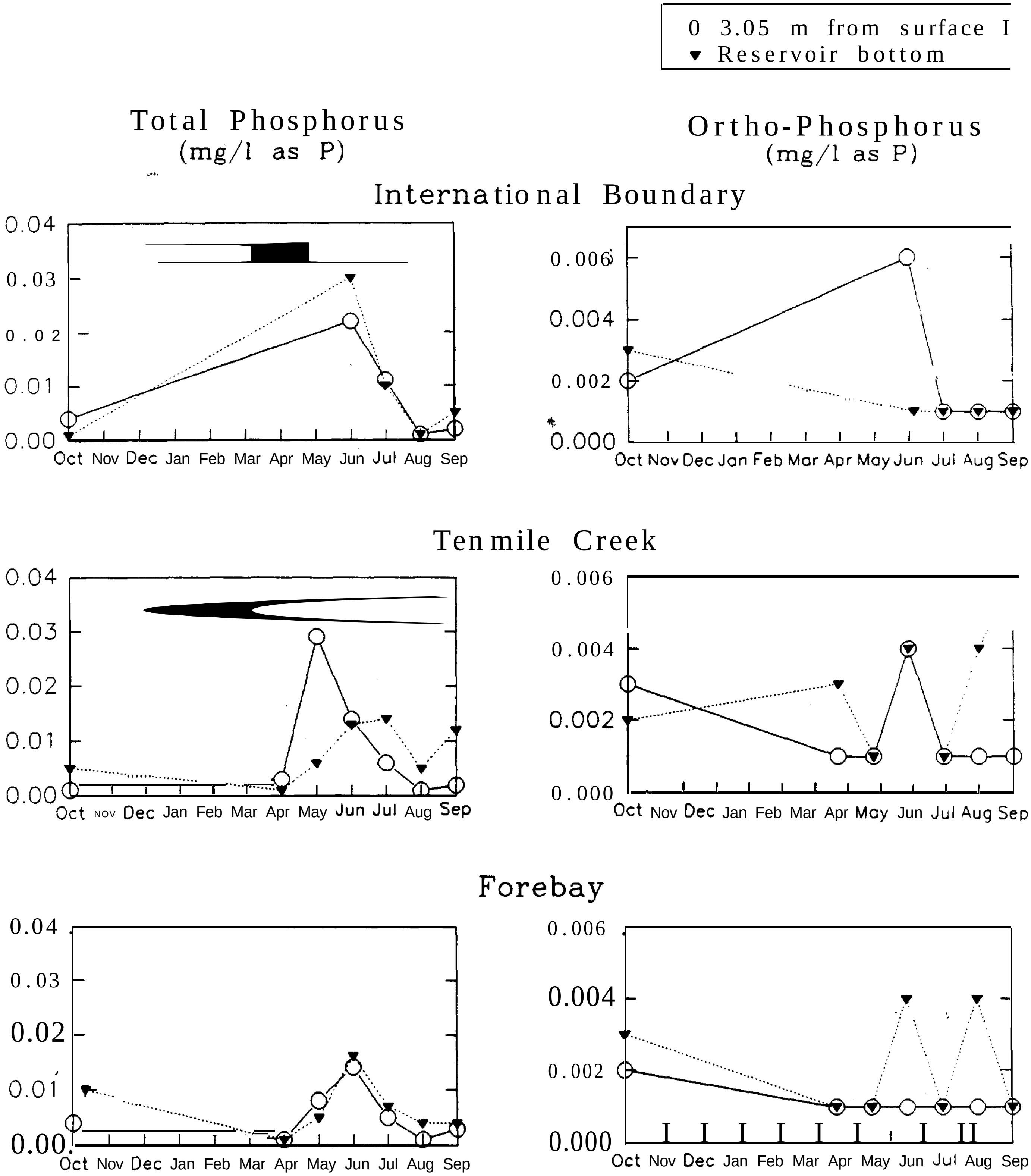

Figure 11. Phosphorus concentrations (P_T and O-PO,) from samples collected near the surface and at the bottom of Koocanusa Reservoir. Data based on U.S.G.S. records from 1990-91. International Boundary 54 km upstream from Libby Dam, Tenmile Creek 22 km upstream from Libby Dam, and Forebay nearest Libby Dam.

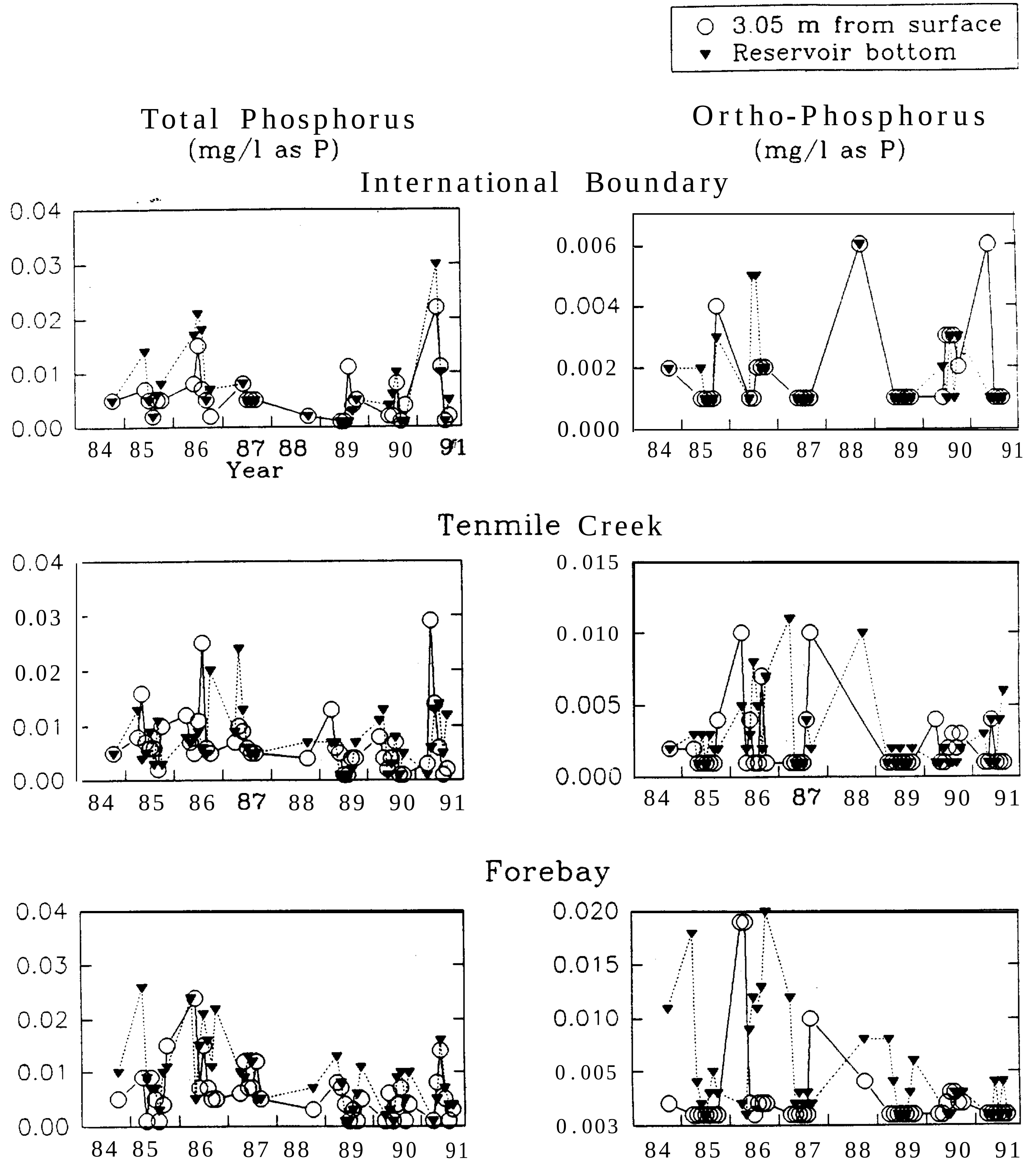

Figure 12. Phosphorus concentrations (P_T and O-PO,) from samples taken near the surface and at the bottom of Koocanusa Reservoir. Data based on U.S.G.S. records from 1984-91. International Boundary 54 km upstream from Libby Dam, Tenmile Creek 22 km upstream from Libby Dam, and Forebay nearest Libby Dam. Note that y-axes are different for O-PO,.

These same trends are evident for NO_3+NO_2, and NH, from 1984-91 (Figure 13 and 14), where vertical distribution, although varying more than P_T and $O-PO_4$, varies no more than 0.2 and 0.7 mg/l, respectively. The annual concentration of NO_3+NO_2 and NH, range from 0.02 to 0.3 and 0.01 to 3.5 mg/l, respectively (Figure 13). Seasonal variations in nutrient concentration are evident in Figures 11 and 14, which show an increase from October to a peak in May or June, and then a decrease from June to September.

DISCUSSION

Nutrient Budget - Kootenai River

It is probable that the downstream increase of P_T and O-PO, results from inputs from the Fisher River, Yaak River, Moyie River, and other tributary sources. It also is possible that nutrient regeneration and recycling are occurring. Some U.S.G.S. nutrient data are available on tributaries such as the Fisher River. However, nutrient data for the other tributaries (Yaak River, Moyie River, and Deep Creek) are lacking and need to be obtained in the upcoming research season. As with P_T and O-PO,, the concentration of NO_3+NO_2 and NH, substantially declined in 1972 after Libby Dam became operational.

Thus, the net effect of Libby Dam on the Kootenai River and Kootenay Lake has been to decrease the flux or input of nutrients from pre-dam conditions. This conclusion also is supported by work done by Daley et al. (1981), Woods (1982), and Ennis (1983). Daley et al. (1981) found that decreases in phytoplankton and zooplankton abundance are linked to the decrease in nutrient loading in Kootenay Lake. Woods (1982) was able to show that from 1972 to 1980 Lake Koocanusa retained 63% its influent loading of P_T and 25% its influent N_T. By examining the distribution of diatom frustules in the benthic layer of Kootenay Lake, Ennis (1983) was able to show that recent changes in diatom abundance were correlated with the pollution abatement measures of the Cominco fertilizer plant, and the reduction in turbidity caused by settling of particulate matter in Lake Koocanusa.

The effect that flow augmentation has on the nutrient concentrations in the Kootenai River is not known. In subsequent years, sampling before, during, and after flow augmentation should provide answers to this question. It is possible that the increase in flow actually serves to flush the river system of the nutrients that are retained during low flow periods.

Nutrient Limitation

Periphyton growth on the P and N+P treatments was greater than growth on the.control treatments at all sites after 34 days. This indicates that algal growth was limited by phosphorus. This observation is consistent with low ambient nutrient concentrations which occurred in the river near Libby Dam from 1980-90 where P_T averaged 0.007 mg/l and N_T averaged 0.155 mg/l (U.S.G.S.). Using these values, the average molar N:P ratio was 49. This value exceeds the optimal ratios of most algal species and strongly indicates phosphorus limitation (Rhee and Gotham 1980).

The results from the nutrient-limitation experiment also suggest that nutrient uptake and accumulation is occurring in a downstream direction. For example, there was a significant decrease in periphyton biomass (as chlorophyll a) from the canyon site to the meander site in the control treatments after 34 days. Further, the results from the water samples collected in July indicate

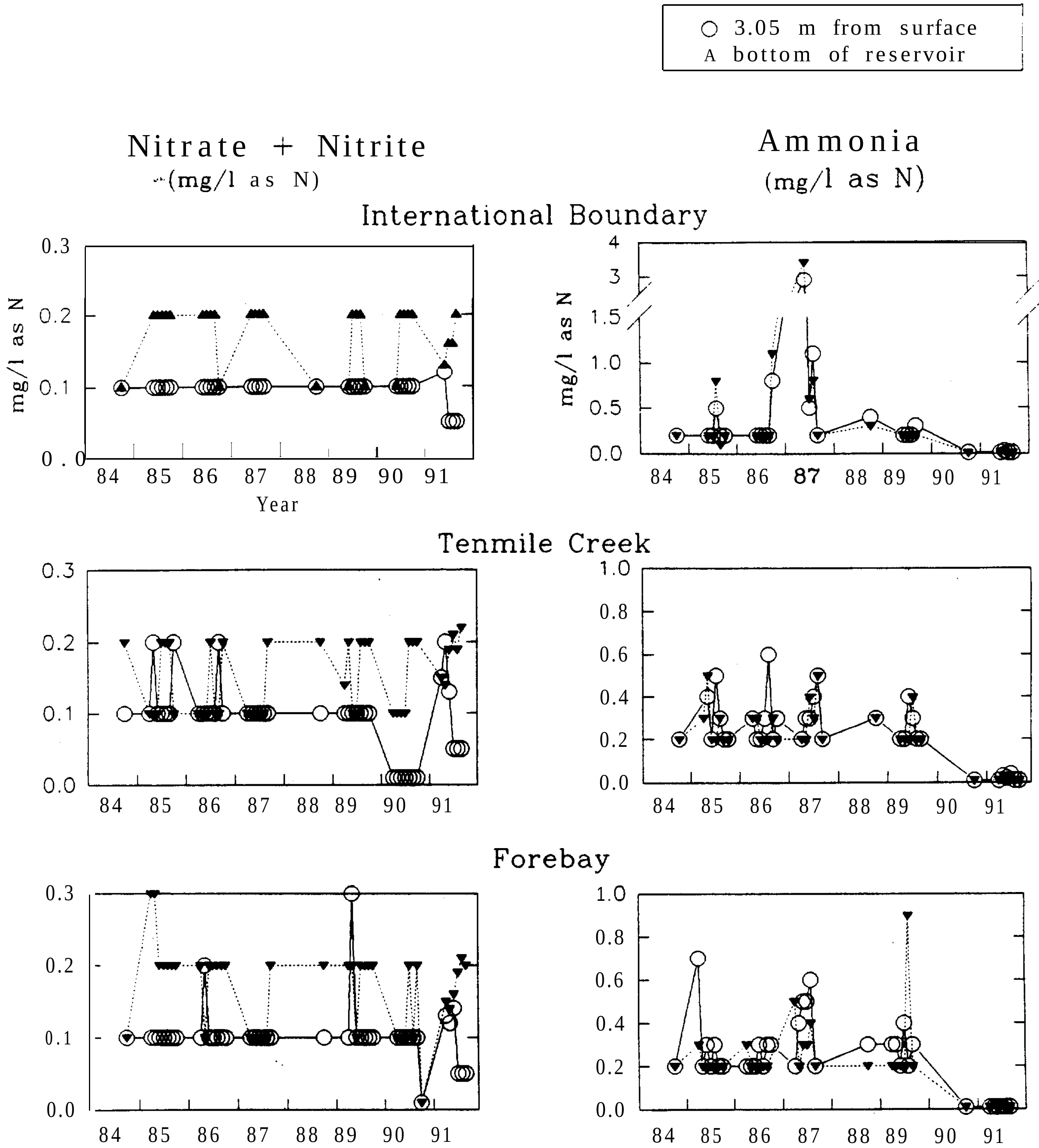

Figure 13. Nitrogen concentrations (NO_3+NO_2 and NH,) in Koocanusa Reservoir. Data based on U.S.G.S. records from 1984-91. International Boundary site is 54 km upstream from Libby Dam, Tenmile Creek is 22 km upstream from Libby Dam, and Forebay is nearest Libby Dam. Note that y-axes differ amoung sites for NH,.

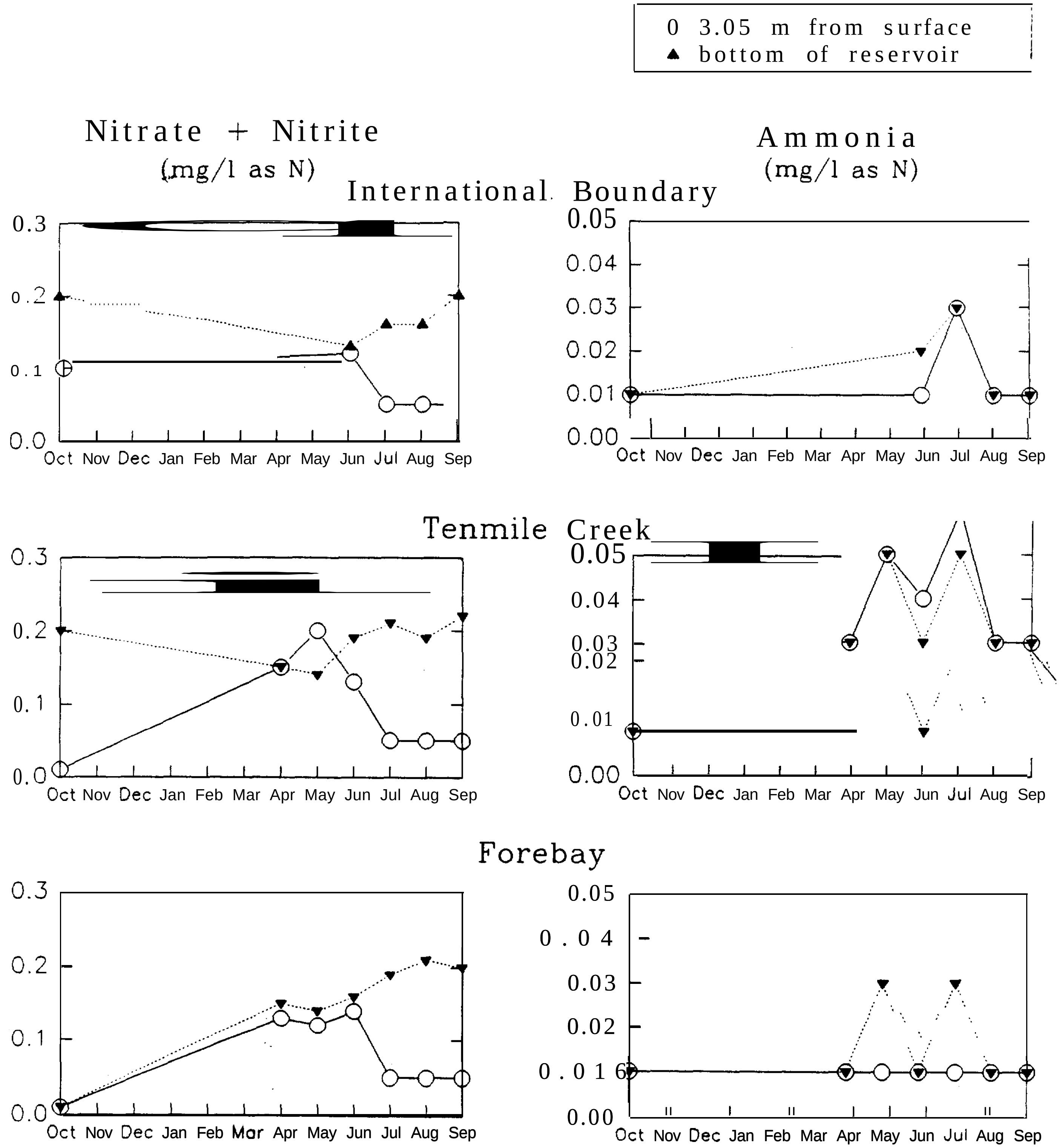

Figure 14. Nitrogen concentration (NO_3+NO_2 and NH,) in Koocanusa Reservoir. Data based on U.S.G.S. records from 1990-91. International Boundary site is 54 km upstream from Libby Dam, Tenmile Creek is 22 km upstream from Libby Dam, and Forebay is nearest Libby Dam.

that the concentration of NO, and NH, decrease in a downstream direction. These results support the well documented fact that stream biota will rapidly assimilate inorganic phosphorus and other nutrients (Wetzel 1983).

Because of the apparent downstream decrease in ambient nutrient concentrations it was hypothesized that there would be greater difference in periphyton growth between the P and control treatments at the meander site, as apposed to the canyon site. This would occur because of the relatively greater effect the P addition should have at the meander site, compared to the canyon site. Contrary to this prediction, the canyon site had the greatest difference between control and phosphorus treatments and the meander site had the least difference between these treatments. This may be due to differences in current, light or community composition.

The faster current at the canyon site could have acted to increase the rate of nutrient diffusion, or could remove detrital material in the periphyton matrix, reducing sites available for microbial activity. Also, the autotrophic index (AFDM/chl a) was greater at the meander site (135.57) compared to the canyon site (70.45). This indicates that a higher concentration of bacteria, fungi, and detritus was present at the meander site which could act to reduce the availability of nutrients for algae. It also has been shown that community composition can shift longitudinally in response to decreasing nutrient levels (Mulholland and Rosemond 1992). Therefore, algae growing at the meander site may have had low growth rates and low half-saturation constants.

The downstream increase in pH is related to the time of day when the samples were collected. Beginning at Libby Dam at 1200 hours, samples were collected in a downstream direction, finishing at 1900 hours at the meander reach at Copeland. The increase in pH is related to the concentration of respiratory CO_2. The concentration of O_2 (produced by photosynthesis) decreases at night, while concentration of CO_2 (produced by respiration) increases, which in turn increases the pH. The spike observed in conductivity could be indicative of anthropogenic influences at Bonners Ferry, the high degree of braiding present throughout the reach, or sampling error. This will be rechecked in 1994.

Nutrient Distribution - Lake Koocanusa

Historically, much data has been collected on the reservoir which has yielded information on nutrient distribution, turnover cycle, trophic status, temperature, and primary productivity (Daley et al. 1981; Woods 1982, Hamilton et al. 1990, Ferreira et al. 1992). This work has shown that Lake Koocanusa is oligotrophic (Woods 1982, Ferreira et al. 1992) and that the reservoir is acting as a nutrient sink through nutrient adsorption and interflow and underflow (Woods 1982). In this respect, the reservoir reflects nutrient dynamics of other impounded systems (Wetzel 1983, Soballe and Bachmann 1984, Winget 1984, Okereke et al. 1988, Galicka and Penczak 1989, Camargo and De Jalon 1990, Cooper and Knight 1990). The range of P_T from 1984-91 was 0.001 to 0.03 mg/l. According to Wetzel (1983) oligotrophic systems range from 0.0 to 0.01 mg/l P_T. The concentration of P_T in the reservoir is within this range much of the time. Also, the reservoir has been shown to have a weak thermal structure, to the extent that stratification is limited both spatially and temporally (Woods 1982). Typically, an oligotrophic system will not develop a concentration gradient of phosphorus in the hypolimnion (Wetzel 1983) as long as the system is aerobic. Lake Koocanusa is aerobic throughout the year (Woods 1982). From this analysis, vertical concentration gradients of phosphorous and nitrogen are not likely.

The small seasonal variation in nutrient concentrations occurs because of biotic uptake in the spring and summer via phytoplankton and zooplankton growth. During winter, influent sources of nutrients and possible regeneration internally from decomposition gradually increase the concentration of nutrients in the system. In Spring, phytoplankton and zooplankton blooms occur in the epilimnion and nutrients are taken up, decreasing ambient nutrient concentrations. Some of these nutrients are transported out of the water column and are stored in the bottom sediments when these organisms die and settle into the hypolimnion. Also, the weak thermal structure of Lake Koocanusa leads to circulation of phytoplankton out of the photic zone (Woods 1982). This would tend to increase the nutrient retention efficiency of the reservoir because of increased algal death and subsequent storage in the bottom sediments (Woods 1982).

The selective withdrawal system at Libby Dam which is presently operating was installed in 1977 to more closely approximate pre-dam temperature regimes and reduce the number of fish being drawn through the power generating turbines (Knudson 1993). Water is discharged from approximately 72 m below full pool when the reservoir is isothermal (by the end of October). When stratified (beginning in April), water is withdrawn from a higher elevation (Perry and Perry 1991). By withdrawing water from the epilimnion, the mean annual concentration of particulate organic carbon (POC) being discharged from Libby Dam was twice as high (0.15 mg/l) as that observed on a dam with only hypolimnetic withdrawal (0.07 mg/l) (Perry and Perry 1991). This provides some evidence that the selective withdrawal system is actually providing a greater quantity of nutrients (as POC) to the Kootenai River than the original hypolimnetic withdrawal system which operated from 1972-77. The selective withdrawal system must be operated to maintain the temperature regime in Kootenai River. Nutrient concentrations at specific depths in the water column do not appear to occur. Therefore, to change the selective withdrawal system to accommodate increased nutrient output to the river does not appear to be a feasible solution.

CONCLUSIONS and RECOMMENDATIONS FOR FUTURE WORK

In the present study, increased discharge, as a mechanism to promote sturgeon spawning, is being evaluated from a community metabolism and nutrient concentration standpoint. Results from research conducted during summer of 1993 indicate that nutrient transformations and stripping are occurring in the Kootenai River between Libby Dam and Kootenay Lake. However, historical data (U.S.G.S.) show that (1) nutrients (P_T and N_T) are added to the river from tributaries, or (2) that nutrients are being regenerated in the river reaches between Libby Dam and Kootenay Lake. Also, phosphorus was shown to be the limiting nutrient in the three study reaches of the Kootenai River (I.S.U. nutrient limitation experiment).

From data obtained by the U.S.G.S., it does not appear that nutrients (phosphorus in particular) in Lake Koocanusa are concentrated at a specific depth during stratification. Thus using selective withdrawal to increase nutrient concentrations below the dam does not offer a feasible solution. The nutrients entering Lake Koocanusa appear to be trapped in the sediments at the bottom of the reservoir. By aerating the sediments it might be possible to resuspend them in the water column, at which point they could be withdrawn through Libby Dam. However, this is a costly technique which is usually employed in lentic systems which become anaerobic in the hypolimnion. Lake Koocanusa does not suffer from this problem. Pneumatic circulation is another technique which might be utilized in which air is pumped into the hypolimnion to induce destratification (Brim and Beard 1980). Further research is suggested as other techniques may exist which could accomplish the resuspension of bottom sediments and increase the concentration of nutrients discharged into the Kootenai River.

Further work needs to be done in order to (1) determine the effects of flow augmentation in the Kootenai River. This can be accomplished by sampling before, during, and after increased flows using the open system metabolism procedures which were developed in summer 1993. However, this will require knowledge of when the flow augmentation will occur as well as the magnitude of increase.

Furthermore,'data from a range of annual flows, in particular from 1274 to 1841 m^3/s (45,000 to 65,000 cfs), need to be obtained as these are characteristic of spring flows recorded before Libby Dam was constructed. Given the low spring flows attained in 1993, our results thus far actually provide a measure of normal post-dam operations. Measurements at much higher flows are needed to gain an understanding of the effects of meaningful flow augmentation resembling pre-dam conditions. Also, more work is needed in order to (2) partition the nutrient changes and follow individual nutrient pathways, and (3) partition community metabolism (seatonic and benthic). This would serve to identify where in the water column and on the stream bottom the majority of the metabolic activity and nutrient uptake and regeneration take place. Finally, (4) nutrient sampling needs to be expanded to include unmonitored tributaries. By accomplishing all of the above (1-4), the relationship of community metabolism and nutrient cycling to flow augmentation can be further analyzed and applied to sturgeon fisheries in the river.

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