MONTANA DEPARTMENT OF FISH AND GAME

POWDER RIVER AQUATIC ECOLOGY PROJECT

ANNUAL REPORT

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Prepared For:

Utah International, Inc.

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INTRODUCTION

Geology-Water Chemistry

The geologic formations of a drainage basin greatly affect the chemical nature of the drainage water. The Powder River watershed drains, in part, Precambrian formations of granites and schists. However, the most obvious contribution to the drainage water chemistry is from a thick series of sedimentary strata that range in age from Cambrian to present. This sedimentary material is made up of limestones, sandstones, shales, siltstones, gypsum, shale and coal. Erosion of this substrate occurs at a moderate rate.

The chemical nature of the Powder River shown in Tables 1,2, and 3 is the result of four contributing water types. The first is granitic water coming from Clear Creek and carrying large quantities of silica and calcium. The second type is limestone water flowing from high in the Middle Fork of the Powder River and carrying large amounts of calcium, magnesium, carbonate, chlorides and nitrates. The third water type is from the lower Middle Fork of the Powder River and is best described as a gypsum water. This water holds a great deal of sodium, potassium, and sulfate. The last type is shale water coming mainly from the Little Powder River. This water carries large amounts of sodium, potassium and sulfate (Swenson 1953). The resultant water in the main stem of the Powder River has been described as a sodium, bicarbonate, sulfate water (Clark Judy, personal communication.)

Climate

The climate of the Powder River drainage is characterized as semi-arid in the non-mountainous portion. Much of the area's precipitation (78%) occurs between April and October with most of the drainage averaging less than 15 inches per year. The yearly discharge of the Powder River (Figure 1) is commonly bi-modal with a smaller March peak followed by the large June runoff and then tapering off to minimal flows for the rest of the year.

The air temperatures of this area vary from -36 to 40 C with the hot summer temperatures causing rapid evaporative losses. This no doubt impacts the adjacent prairie and is in part responsible for the somewhat sparse vegetation and the resultant erosion. The daily mean water temperatures of the Powder River for 1976 and March to mid-June 1977 are shown in Appendix Tables 3-15.

Table 1. Physical and chemical parameters of the Powder River at Moorhead, water year 1975*.

Date	Discharge (m^3/min)	ALK as. $CaCo_3$ (mg/l)	Specific Conductance (umhos/cm)	Dissolved Oxygen (ppm)	Turbidity (JTU)	pH
Oct. 16,'74	354	241	2250	10.0	390	7.9
Nov. 19,'74	371	241	1980	12.9	320	8.4
Dec. 17,'74	193	274	2150	12.8	15	8.6
Jan. 21,'75	354	299	2180	8.5	30	8.1
Feb. 19,'75	720	199	1750	11.7	50	8.1
Mar. 17,'75	1290	241	2500	11.7	240	8.2
Apr. 29,'75	959	189	1720	10.5	440	8.2

* Data from U.S.G.S.

Table 2. Physical and chemical parameters of the Powder River at Locate, water year 1975*.

Date	Discharge (m^3/min)	ALK as. $CaCo_3$ (mg/l)	Specific Conductance (umhos/cm)	Dissolved Oxygen (ppm)	Turbidity (JTU)	pH
Oct. 22'74	445	221	2180	12.4	5800	8.3
Nov. 19,'74	588	236	1700	12.4	200	8.5
Dec. 17,'74	1276	282	2400	12.5	140	8.1
Jan. 29'75	383	320	2340	7.1	40	7.8
Feb. 28,'75	840	177	1380	12.4	130	8.0
Mar. 17,'75	924	219	2030	12.8	120	8.2
Apr. 29,'75	914	216	2000	10.8	720	8.3
May 18,'75	2016	-	1090	8.4	-	8.4

* Data from U.S.G.S.

Table 3. Water quality measurements for Powder River at Locate and Moorhead, April 1977.

Water flow Rate 650. CPS(M) Gaging Station

SAMPLING SITE: Powder at Moorhead

	MG/L	MEQ/L		MG/L	MEQ/L
Calcium (CA)	122.	6.092	Bicarbonate (HCO3)	248.	4.059
Magnesium (MG)	55.	4.509	Carbonate (CO3)	0.	0.0
Sodium (NA)	250.	10.875	Chloride (CL)	105.	2.961
Potassium (K)			Sulfate (SO4)	700.	14.574
Iron (FE)			Fluoride (F)		
Manganese (MN)			Phosphate (PO4 AS P)	.0 1	0.001
Aluminum (AL)			NO3+NO2 (TOT AS N)	.39	0.028
SUM CATIONS	426.895	21.476		1053.050	21.622

Laboratory PH	7.50	Total Hardness (MG/L-CACO3)	531
Field Water Temp. (C)	12.2	Total Alkalinity (MG/L-CACO3)	203
Sum-Diss. Ions Meas. (MG/L)	1479.9	Laboratory Turbidity (JTU)	
Lab Conductivity-UMHOS-25C	1848.0	Sodium Absorption Ratio	4 7

ADDITIONAL PARAMETERS

Sediment, TOT,SUSP (MG/L)	1522.	Phosphorous, TOT (MG/L-P)	1.1

Water Flow Rate 700 CPS(M) Gaging Station

SAMPLING SITE: Powder at Locate

	MG/L	MEQ/L		MG/L	MEQ/L
Calcium (CA)	48.9	2.440	Bicarbonate (HCO3)	26 .	4.399
Magnesium (MG)	97.	7.951	Carbonate (CO3)	0.	0.
Sodium (NA)	260.	11.310	Chloride (CL)	88.	2.482
Potasium (K)			Sulfate (SO4)	715.	14.886
Iron (FE)			Floride (F)		
Manganese (MN)			Phosphate (PO4 AS P)	.013	0.001
Aluminum (AL)			NO3+NO2 (TOT AS N)	.40	0.029
SUM CATIONS	405.546	21.701	SUM ANIONS	1071.800	21.795

Laboratory PH	8.20	Total Hardness (MG/L-CACO3)	520
Field Water Temp (C)	6.7	TOT Alkalinity (MG/L-CACO3)	220
SUM-DISS. IONS MEAS..UMG/L)	1477.3	Laboratory Tubidity (JTU)	
Lab Conductivity-UMHOS-25C	1881.0	Sodium Absorption Ratio	5.0

ADDITIONAL PARAMETERS

Sediment, TOT, SUSP (MG/L)	3000.	Phosphorous, TOT (MG/L-P)	1.6

*Samples taken by: Montana Department of Fish & Game Personnel.
Analysis by: Montana Department of Health & Environmental Sciences; Chemistry Lab. in Helena, Montana

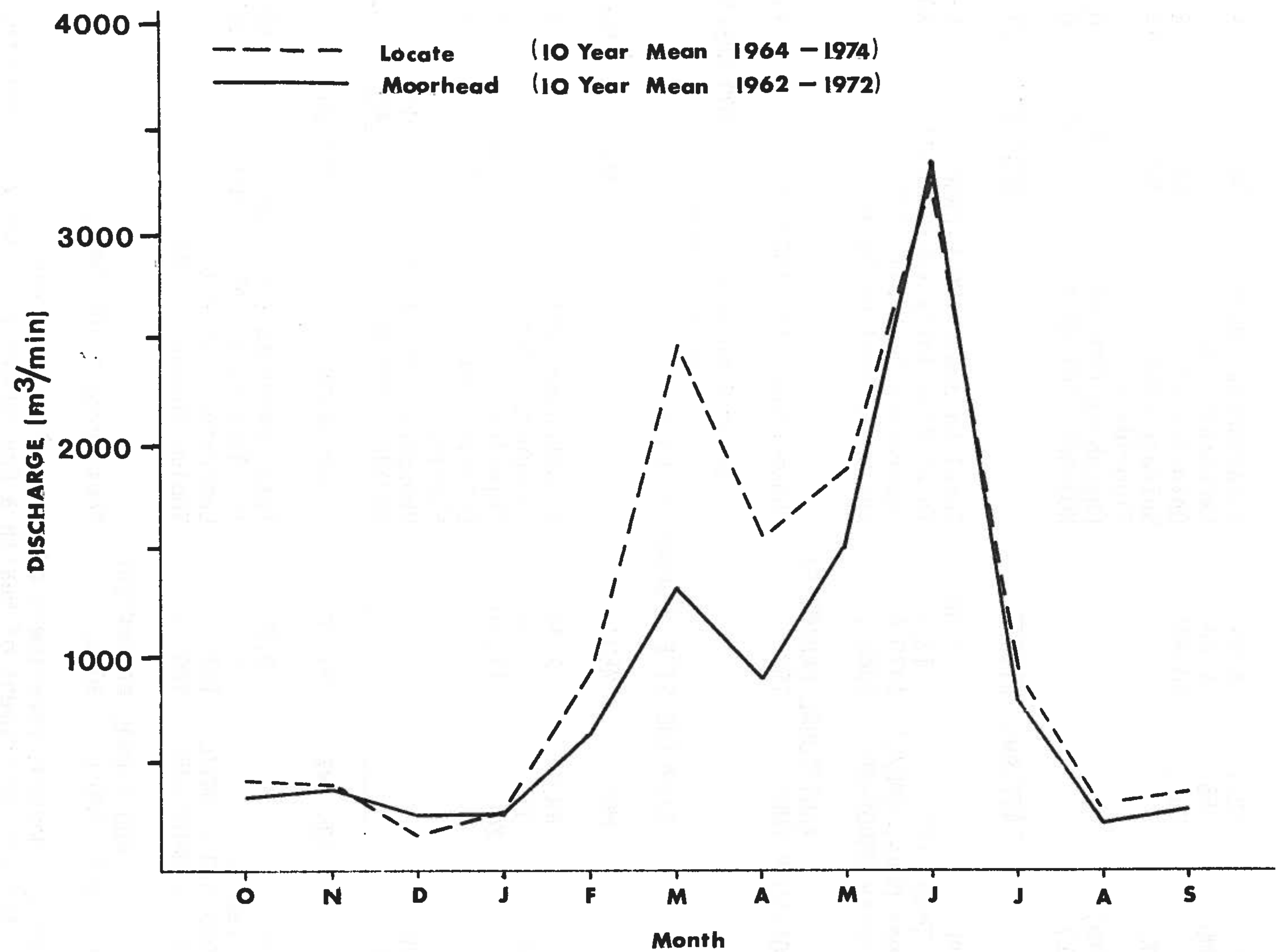

Figure 1. Summary of monthly mean discharges on the Powder River at Moorhead and Locate.

River-Habitat

The river habitat is typical of a prairie stream. The Powder River is silt laden and subject to eratic fluctuations in flow with much of its substrate constantly shifting as bed load. The river develops only shallow pools and lacks aquatic vegetation. The extreme turbidity of the Powder River severely reduces primary productivity due to lack of light penetration resulting in low numbers of aquatic invertebrates.

A map of the study area is shown in Figure 2. The river gradient and area land marks are shown in Figure 3.

Scope of the Study

The Powder River provides water for man and his livestock and for irrigating croplands. Energy development in the Fort Union area has created a new potential demand for Powder River water. The lack of information concerning the aquatic resource of the Powder River coupled with this potential new demand for its water created the need for this study which is financed by Utah International, Inc.

The objective of the study is to collect baseline data of the Powder River to determine the effects of an impoundment and largescale water withdrawals. This report includes an inventory of fish populations and distribution, aquatic invertebrate distribution and relative abundance, and selected physical and chemical characteristics of the Powder River.

Description of Sampling Sites

Permanent fish sampling sections have been established as follows:

Section Number	Location
1	Above Interstate Bridge to Burlington Northern Bridge near confluence with the Yellowstone River
2	Near Locate on the A. Young ranch
3	At Mizpah on the C. Balsam ranch
3T	Mizpah Creek on the Scott ranch
4	At Powderville on the Preston ranch
5	At Broadus on the Perry ranch
5T	Little Powder River on the Turnbough ranch
6	At Moorhead on the G. Fulton ranch
7	At the Wyoming line on the L. Sam's ranch

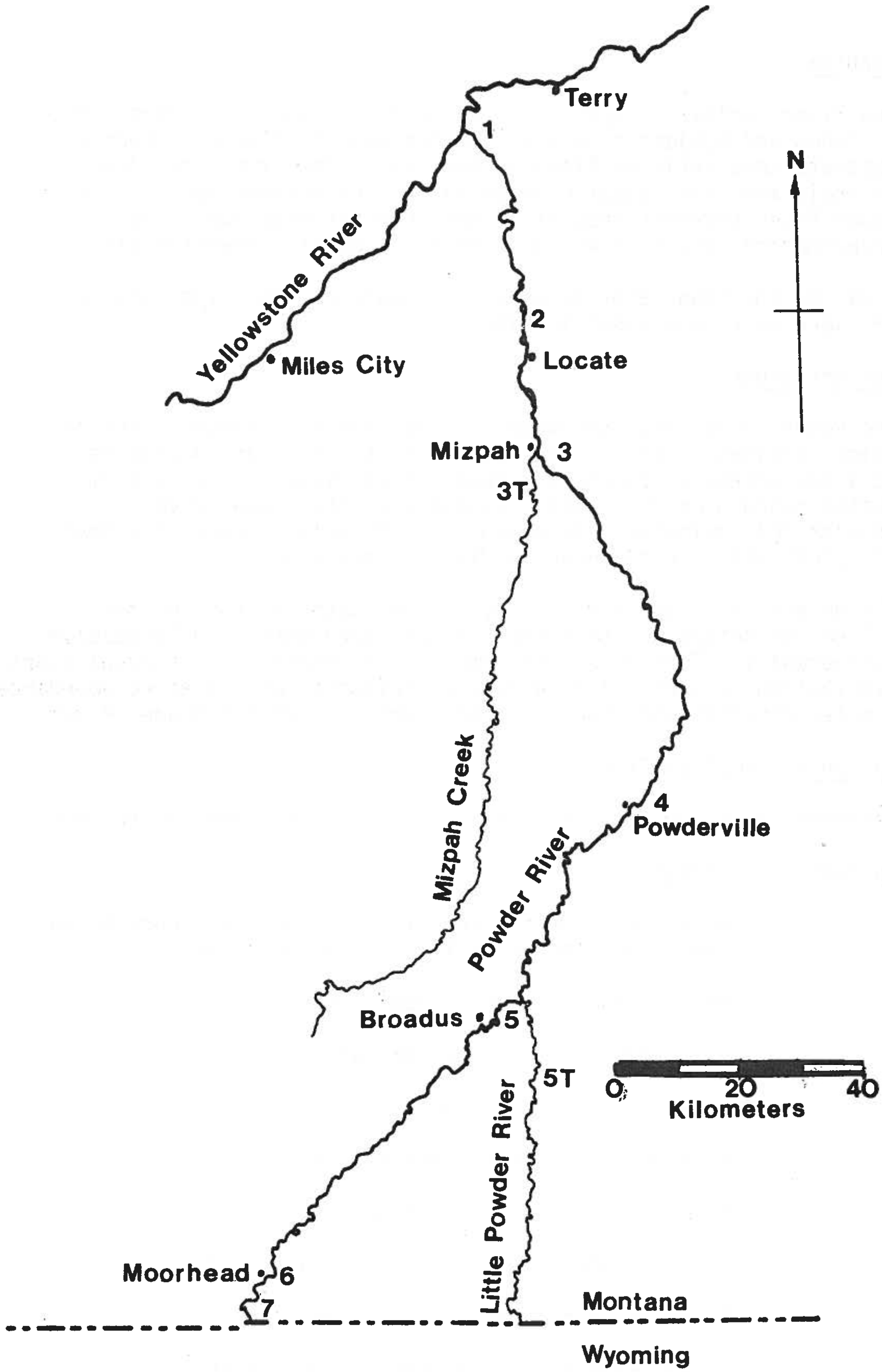

Figure 2. Map of Powder River showing sampling sites.

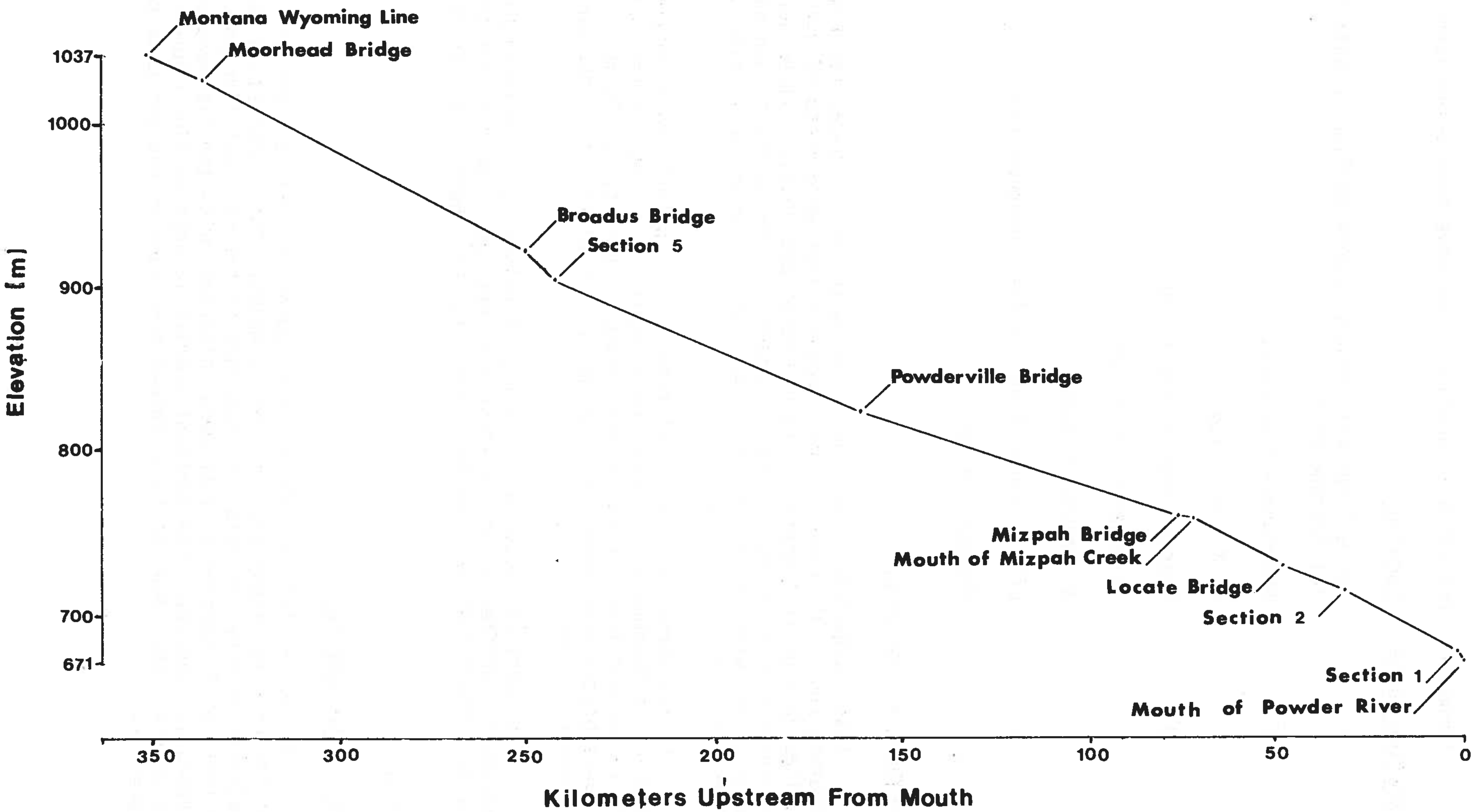

Figure 3 Longitudinal profile of Powder River.

Permanent invertebrate sampling sites have been established as follows:

Station Number	Location
1	Above Interstate Bridge, above confluence with the Yellowstone River
2	Downstream from Locate
3	At Mizpah Bridge
3T	Mizpah Creek at the bridge
4	At Powderville Bridge
5	At Broadus Bridge
5T	Little Powder River on the Turnbough ranch
6	Moorhead Bridge

METHODS AND MATERIALS

River temperatures were monitored with Taylor 30-day recording thermographs. Dissolved oxygen concentrations were measured with a Yellow Springs Instrument Co. oxygen meter and conductivities were measured with a Yellow Springs Instrument Co. conductivity and salinity meter. An Owens-Corning pH meter was used to record pH in situ. Turbidity data is from the U.S.G.S.

Macroinvertebrates were collected with a Water's round square foot sampler, a Needham kick screen and an adult net. Samples were preserved in 10 percent formalin and washed through a U.S. series 30 mesh screen. Invertebrates were separated from debris and stored in 75 percent isopropyl alcohol.

Fish were collected with the aid of pulsed D.C. electrofishing equipment, drifted 3-inch bar-mesh gill nets and a 50 foot 1/4-inch bag seine. Sport fish were weighed, measured, and tagged prior to release.

RESULTS

Fall Fish Sampling

During the fall of 1975 and the summer and fall of 1976 all seven of the original study sections were sampled. This information was gathered to show the relative abundance of the resident fish populations. A total of 17 species of fish were collected, with the flathead chub (*Hypospsis gracilis*) the dominant species in each section (Tables 4 & 5). In general, the lower sections showed more species present than the upper ones.

Table 4. Species composition in each of the Powder River sample areas, fall, 1975.

Species	1	2	3	4	5	6	7
Flathead chub	106 89.2%	266 90.9%	108 100%	192 81.5%	250 79.6%	965 91.0%	346 87.8%
Hybognathus		3 0.9%		19 8.0%	22 7.0%	33 3.1%	11 2.8%
Sturgeon chub	6 5.1%	5 1.7%		17 7.2%	27 8.6%	28 2.6%	12 3.0%
Goldeye	3 2.5%	2 0.7%				10 3.5%	14 0.9%
River carpsucker	1 0.8%	2 0.7%		1 0.4%	2 0.6%	3 0.3%	5 1.3%
Shorthead redhorse						7 0.7%	3 0.3%
Stonecat		1 0.3%					2 0.5%
Carp					1 0.3%	4 0.4%	1 0.3%
Longnose dace		2 0.7%		2 0.8%	9 2.9%	3 0.3%	
Channel catfish	1 0.8%	7 2.5%		5 2.1%	3 1.0%	1 0.1%	
Sauger						1 0.1%	
Burbot	1 0.8%	1 0.3%					
Brassy minnow		1 0.3%					
Green sunfish		1 0.3%					
Sandshiner						5 0.5%	
Creek chub		2 0.7%					
Total	119	292	108	236	314	1060	394

Table 5. Species composition expressed as numbers caught and percent of total sample, in each of Powder River sample sections, summer 1976.

	SECTION						
Species	1	2	3	4	5	6	7
Flathead chub	88 87.1%	126 79.2%	39 63.9%	47 77.0%	57 90.4%	233 67.1%	21 35.6%
Sturgeon chub	6 5.9%	2 1.3%	1 1.6%			2 0.6%	
Channel catfish	2 2.0%	3 1.9%	2 3.3%			1 0.3%	
River carpsucker	1 1.0%						1 1.7%
Hybognathus	1 1.0%	11 6.9%	13 21.4%	14 23.0%	5 7.9%	110 31.7%	34 57.6%
Goldeye	3 3.0%	15 9.4%				1 0.3%	3 5.1%
Stonecat		2 1.3%					
Longnose dace			5 8.2%				
Green sunfish			1 1.6%				
Carp					1 1.7%		

The species composition of the samples show only rare occurrences of game fish. Length information is presented in tables 6 & 7. Weight information is not included in the 1975 sample.

Length frequency distributions were compared for the flathead chub in two sections (1 and 7). These two areas showed close agreement with three definite modes occurring. The first mode was between 25 mm and 56 mm, the second between 56 mm and 97 mm and the third occurring between 91 mm and 122 mm. These modes closely agree with age groups zero, one and two according to Brown (1971). The scale method of aging flathead chubs was attempted but annuli could not be detected.

Fall 1975 sampling showed that high turbidities and low water temperatures made electrofishing quite impractical, therefore, most of the sampling was accomplished with a 50-foot, 1/4-inch mesh bag seine. Study sections 2 and 6 were ideal for this technique and the fish samples shown in Table 8 reflect this with high diversities. However, section 3 was very difficult to seine successfully and the fish samples were all of one species; flathead chubs. Sampling during 1976 was accomplished under better conditions and shows other species to be present (Table 5).

With the completion of two seasons of resident fish work, the diversity indices were calculated and are shown in table 8. The seven indexes were calculated as follows:

Shannon-Weaver function (d)= $- (N_i/N) \log_2 (N_i.N)$

Theo. Max. diversity (d max)= $(1/N) \log_2 N\text{-}S \log_2$

Theo. Min. diversity (d min.)= $(^1/N) \log_2 N - \log_2 N\text{-}(S-1)$

Redundancy (R) = $\frac{d\ max - d}{d\ max - d\ min.}$

Evenness (J^1)= $d/\log_2 S$

Equitability (E_m)= d/d max -

Species richness (SR)= $d\text{-}^d/\log_2 N$

where S = number of species

N_i= number of individuals in the ith species

N = total number of individuals

The meaning of these values is best summarized by Newell (1976) as follows:

A high (3.0) Shannon-Weaver index generally means a healthy community while a low index (1.0) generally means the community is under some type of stress (Wilhm 1970 abc).

Table 6. Fish length (mean and range in mm) by species and study sections, Powder River, 1975.

	7	6	5	4	3	2	1
Flathead chub	73.66 (20-160)	80 (41-178)				73 (23-259)	
Lake Chub	67 (41-99)	72 (38-132)	74 (46-112)	69 (48-89)		104	
Sturgeon chub	74 (41-79)	71 (66-76)	74 (38-89)	70 (43-79)		58 (28-79)	
Goldeye	301 (284-325)	301 (287-343)				303 (295-312)	86 (71-102)
River carpsucker	110 (38-325)	68 (36-124)	42 (38-46)	28		30 (28-33)	97
Shorthead redhorse	218 (135-264)	285 (201-345)					224
Stonecat	94 (89-99)					180	
Carp	462	97 (81-122)	81				
Longnose dace		74 (66-81)	69 (56-79)	67 (64-71_		58 (53-64)	
Channel cat		58	49 (46-53)	54 (43-64)		58 (51-64)	66
Sauger		523					
Burbot						490	305
Bassy minnow						124	
Green sunfish						38	

Table 7. Mean length (mm) and weight (g) of fish species by study sections, Powder River 1976.

Section	1		2		3		4		5		6		7	
Species	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight
Flathead chub	77.44	4.95	88.90	7.58	67.92	3.15	73.32	4.28	75.89	5.76	88.64	7.70	75.67	4.38
Sturgeon chub	78.16	3.16	77.50	3.00	60.00	1.50								
Channel catfish	47.50	1.00	89.00	7.67	86.00	6.00								
River carpsucker	47.00	1.00											112.00	16.00
Hybognathus	59.00	1.00	65.00	3.00			66.64	3.29						
Goldeye	314	-	320.40	-									310.30	-
Stonecat			205.50	77.00										
Longnose dace					60.40	2.20								
Green sunfish					55.00	3.00								
Carp									440.00	-				

Table 8. Shannon-Weaver diversity indexes for resident fish population in Powder River by section.

		1	2	3	4	5	6	7
1975	Diversity $\bar{d}$	0.7315	0.7477	0.0	1.0177	1.1187	0.6626	0.8273
	$\bar{d}$ Max.	2.8073	3.8073	0.0	2.5849	2.8073	3.4594	2.9999
	$\bar{d}$ Min.	0.4185	0.4261	0.0	0.1972	0.1857	0.1083	0.1785
	Redundancy	0.8689	0.9048	-	0.6563	0.6441	0.8345	0.7700
	Evenness	0.2605	0.1964	-	0.3937	0.3985	0.1915	0.2757
	Equitability	0.1061	0.0912	-	0.1291	0.1348	0.0659	0.0959
	Species Richness	0.6254	0.6565	-	0.8886	0.9838	0.5967	0.7313
1976	Diversity $\bar{d}$	0.8097	1.1511	1.7059	0.9491	0.5156	1.2792	1.4368
	$\bar{d}$ Max.	2.5849	2.8073	2.8073	1.5849	1.5849	2.5849	2.3219
	$\bar{d}$ Min.	0.3992	0.3293	0.7180	0.2409	0.2348	0.2038	0.5069
	Redundacy	0.8121	0.6683	0.5271	0.4730	0.7920	0.5483	0.4876
	Evenness	0.3132	0.4100	0.6076	0.5988	0.3253	0.4948	0.6188
	Equitability	0.1216	0.1574	0.2876	0.1600	0.0862	0.1634	0.2463
	Species Richness	0.6881	0.9937	1.4182	0.7891	0.4293	1.1150	1.1905

Equitability has been found to very sensitive to even slight levels of degradation. Healthy communities have values of 0.0 to 0.3 (E.P.A. 1973).

Redundancy is a measure of the repetition of information within a community and thereby expresses the dominance of one or more species and is inversely proportional to the wealth of species. Redundancy is maximal when no choice of species exists and minimal when there is a large choice of species.

Community distribution has maximum evenness if all the species abundances are equal and the greater the disparities among the different species abundances, the smaller the evenness.

Species richness is a little used index that shows maximal values with large numbers of species. Care should be exerted when using these values considering the variability between the 1975 and the 1976 results.

Spring Fish Sampling

Field work to determine the species composition and magnitude of game fish migration into the Powder River from the Yellowstone River was begun on April 5, 1976 and again on March 14, 1977. Fish were captured using pulsed D.C. electrofishing gear, floating gill nets and seines. Captured game fish were measured, weighed and individually numbered tags affixed. In an effort to tag as many migrating game fish as possible, section 1 (near the confluence with the Yellowstone River) was intensively sampled. During the spring of 1976 Sections 2-8 were also sampled to monitor upstream movement of tagged and untagged fish. During the spring sampling of 1977, only Sections 1 and 5T were monitored.

Prior to this study the importance of Yellowstone River game fish movements into the Powder River had not been assessed in terms of the potential or realized fishery of the Powder River or to the reproduction of the Yellowstone River game fish.

Sauger

Sauger (*Stizostedion canadense*) are native to Montana and are one of the most important game fish of the lower Yellowstone River. During the 1976 season (April 6 to May 18) 178 sauger averaging 381 mm in length and 464 grams in weight were captured, marked with individually numbered Floy tags and released. The 1977 season began March 18 and ran until April 28. During the latter season, 292 sauger averaging 381 mm in length and 482 grams in weight were captured, tagged and released.

In general both years sauger "runs" occurred during a discharge pattern of decreasing flows early, increasing flows late, with a mode appearing at mid-season (Figures 4 and 5). The mean daily temperature was low initially, gradually increased, then decreased with the mid-run discharge mode, then again increased through the remainder of the period. (Figures 6 and 7). The 1976 sauger collection period had a mean discharge of 867 cfs (partially estimated due to 7 days of missing provisional records from U.S.G.S) with a range of 697 to 1380 cfs. The mean temperature was 11.2 C (range 6.1 - 16.4) in 1976. The 1977 "run" occurred during a period with a mean discharge of 720 cfs (range 490 - 1100) and a mean temperature of 8.7 C (range 1.4 - 16.4). Actual discharge figures are shown in appendix tables 1 and 2.

The captured sauger were presumably on a spawning migration as indicated by their age structure (Tables 9 and 10) and gonadal development, with males representing 97 and 93 percent of the captured fish in 1976 and 1977, respectively. The first ripe females were taken on May 3, 1976 (mean daily water temperature was 10.0 C) and April 14, 1977 (mean daily water temperature was 13.6 C). This period of capture corresponds to the spawning period of sauger in the lower Yellowstone River as reported by Peterman and Haddix (1975).

Scale samples from 113 (1976) and 174 (1977) sauger captured in the Powder River were used for age and growth determinations (Tables 9 and 10). Captured sauger ranged from 230 - 583 mm and represented age classes II-VIII. Age IV sauger were the most commonly captured age class in 1976 while age V were the most common in 1977. The second and third most abundant age classes were V and III in 1976 and VI and IV in 1977. This suggests that several strong year classes are being followed through this work.

It should be emphasized that this age and growth does not represent a discrete population of sauger but rather a grouping of sexually mature sauger, mostly males, from various habitats of the lower Yellowstone River. The growth rates of sauger captured in the Powder River are roughly similar to those reported in the lower Yellowstone (Peterman and Haddix, 1975).

Of the 178 sauger captured and tagged in 1976, 174 were captured in Section 1, one in Section 2 and 3 in Section 8. If the 3 sauger captured in Section 8 are Yellowstone River fish, they migrated over 324 km up the Powder River to a point above the proposed construction of the Moorhead dam. All 292 sauger captured and tagged in 1977 were collected in Section 1.

The relatively few fish tagged (178 and 292) compared with the length of the river sampled (360 km) and the apparent minimal fishing pressure on the Powder River made upstream recaptures of tagged fish improbable. No tagged sauger were recaptured in the Powder River upstream from the point of tagging. Of the fish tagged in 1976, two sauger were recaptured in the Tongue River, a tributary which enters the Yellowstone River 57.0 km upstream from the mouth of the

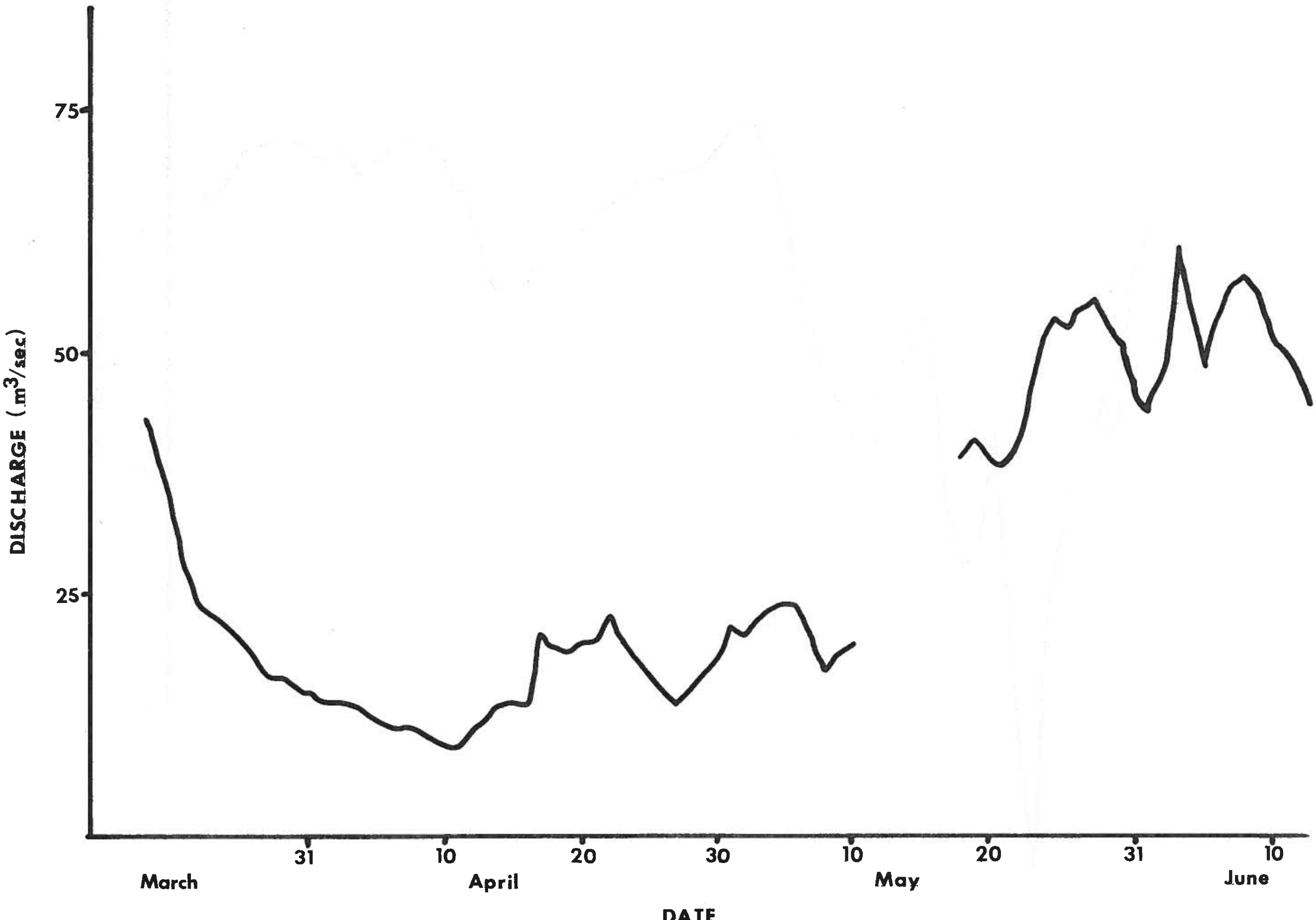

Figure 4. Discharge of Powder River at Locate, Spring 1976.

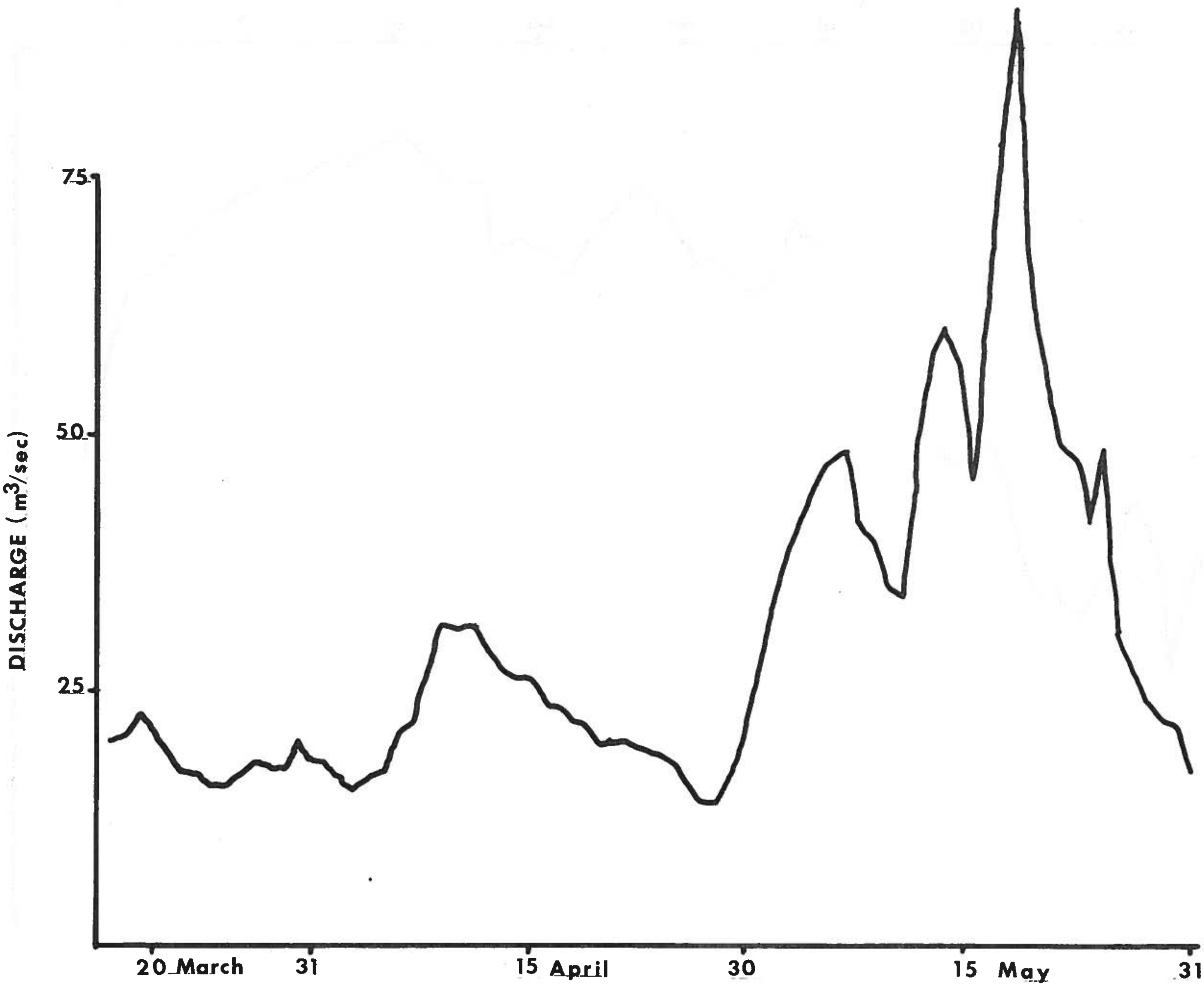

Figure 5. Discharge of Powder River at Locate, Spring 1977.

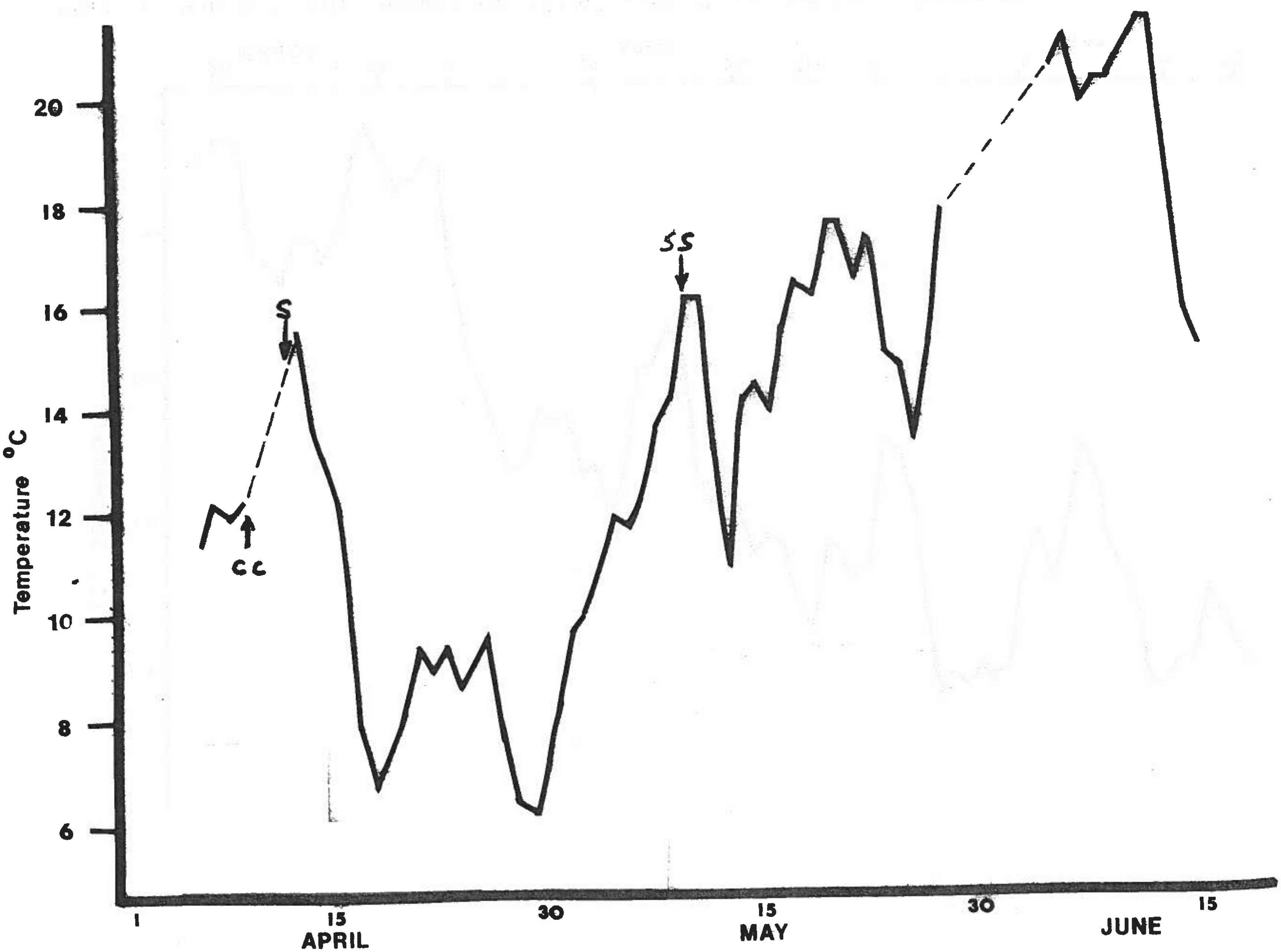

Figure 6. Mean daily temperatures at Section 1, 1976.

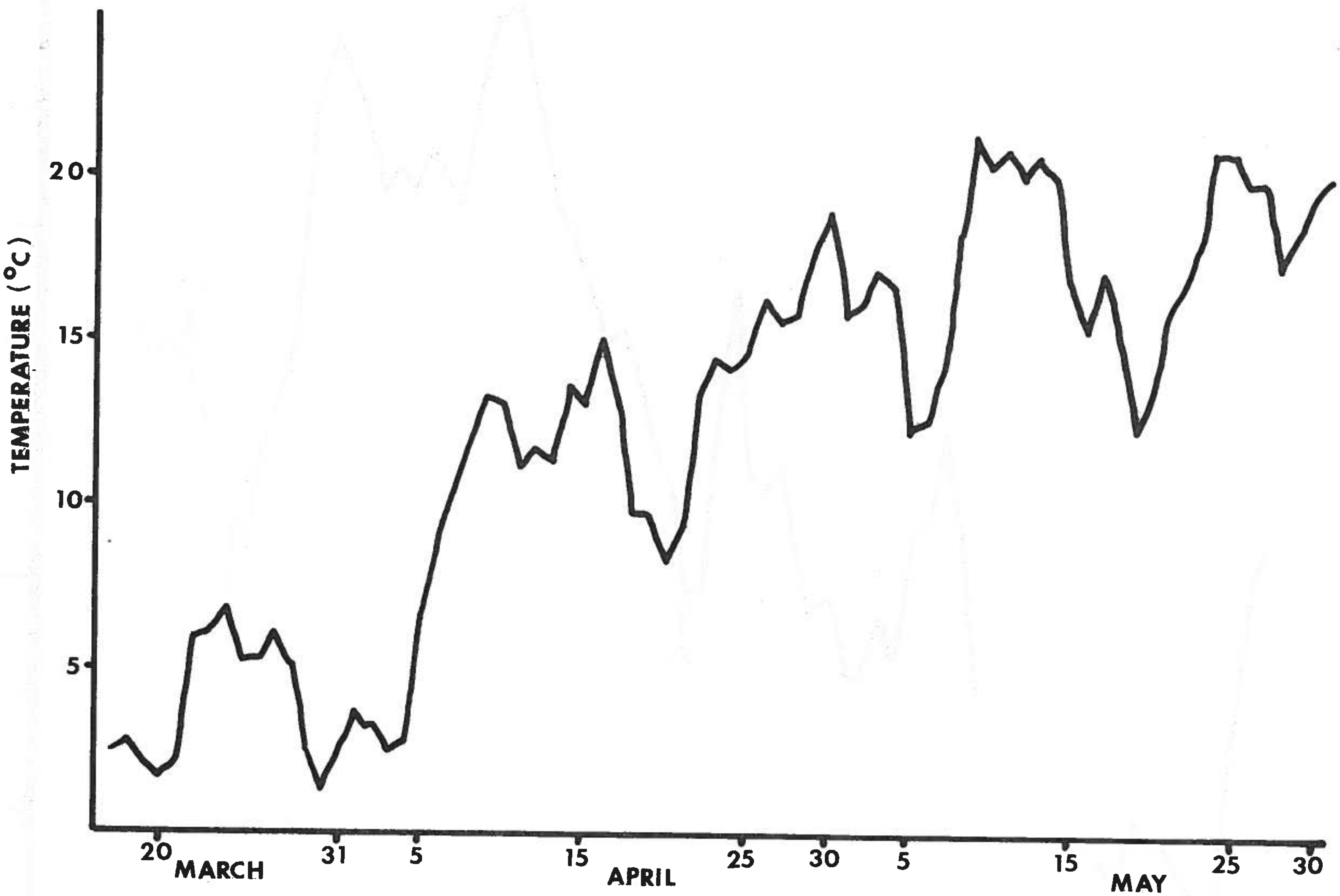

Figure 7. Mean daily water temperature (C^o) of Powder River near Terry, Spring 1977.

Table 9. Sauger age-growth from spring sample 1976.

Age Group	Number of Fish	Length Range (mm)	Mean Length (mm)	Average Annual Growth (mm)
II	4	282-322	305.5	
III	20	230-387	317.5 (12.5)	12.0
IV	45	300-402	356.9 (14.0)	39.40
V	22	359-473	415.2 (16.3)	58.30
VI	15	349-498	421.3 (16.6)	6.10
VII	5	373-500	425.4 (16.8)	4.10
VIII	2	421-535	478.0	
	113			

Table 10. Sauger age-growth from spring sample 1977.

Age Group	Number of Fish	Length Range (mm)	Mean Length (mm)	Average Annual Growth (mm)
II	4	278-296	288.3	
III	15	287-343	314.4 (12.4)	26.10
IV	37	311-394	349.1 (13.7)	34.70
V	60	340-435	378.7 (14.9)	29.60
VI	45	355-490	414.7 (16.3)	36.00
VII	12	395-530	463.4 (18.3)	48.70
VIII	1	462	462	

Powder River. Another sauger, tagged in Section 1 of the Powder River was recaptured in the Yellowstone River near the mouth of Sand Creek (371 km) upstream from the mouth of the Powder.

A fourth sauger tagged in 1976 was recaptured at Forsyth (142 km) in June 1977. A sauger which was tagged and released in the Yellowstone at Miles City on April 21, 1976 was recaptured in Section 1 of the Powder River on May 4, 1976. This is a movement of 55 km in 13 days. During the spring of 1977, 2 sauger tagged in Section 1 were recaptured by fishermen at Forsyth. In addition, 3 fish tagged in the Yellowstone (1 at Forsyth and 2 at Miles City) during 1976 were recaptured in Section 1 of the Powder River. Two sauger tagged in section 1 last year were also recaptured there this year.

In an attempt to explain the sauger movements into the Powder River, daily catch rates were calculated per kilometer of river. These catch rates (Figures 8 and 9) were correlated with discharge of the Powder River, mean daily water temperature of the Powder River, maximum daily water temperature of the Powder River, and difference in mean daily water temperature with the Yellowstone River. The independent variables of temperature appeared to follow a quadratic regression. These were computed and no significant percent of variation could be accounted for by this. A linear regression was also calculated and found to be of no significant value. The catch rate versus discharge plot appeared to be a Poisonn distribution. However, this type of program is presently unavailable. The linear and quadratic regression were calculated and found to account for no significant amount of the variation.

Channel Catfish

Classified as a game fish by the Montana Legislature in 1975, the channel catfish (*Ictalurus punctatus*) is a popular sport fish in the lower Yellowstone drainage system. Adult channel catfish are evidently highly migratory and may ascend tributary streams to spawn (Trautman 1957). Fishermen interviews indicated that channel catfish provided the major contribution to the Powder River sport fishery and suggested that Yellowstone River channel catfish migrating up the Powder River may provide this fishery since catfish are only caught in the late spring and early summer. Channel catfish are caught seasonally by fishermen as far upstream as Arvada, Wyoming (Fred Dabny, personal communication), 434 km upstream from the mouth of the Powder River.

From April 5, 1976 to May 21, 1976, 95 channel catfish averaging 614 mm in length and 2660 gr in weight were captured in the Powder River and its tributaries using pulsed D.C. electrofishing gear, floating gill nets and seines.

During the 1977 season a total of 174 channel catfish were sampled in two study sections. Section 1 was the source of 118 catfish

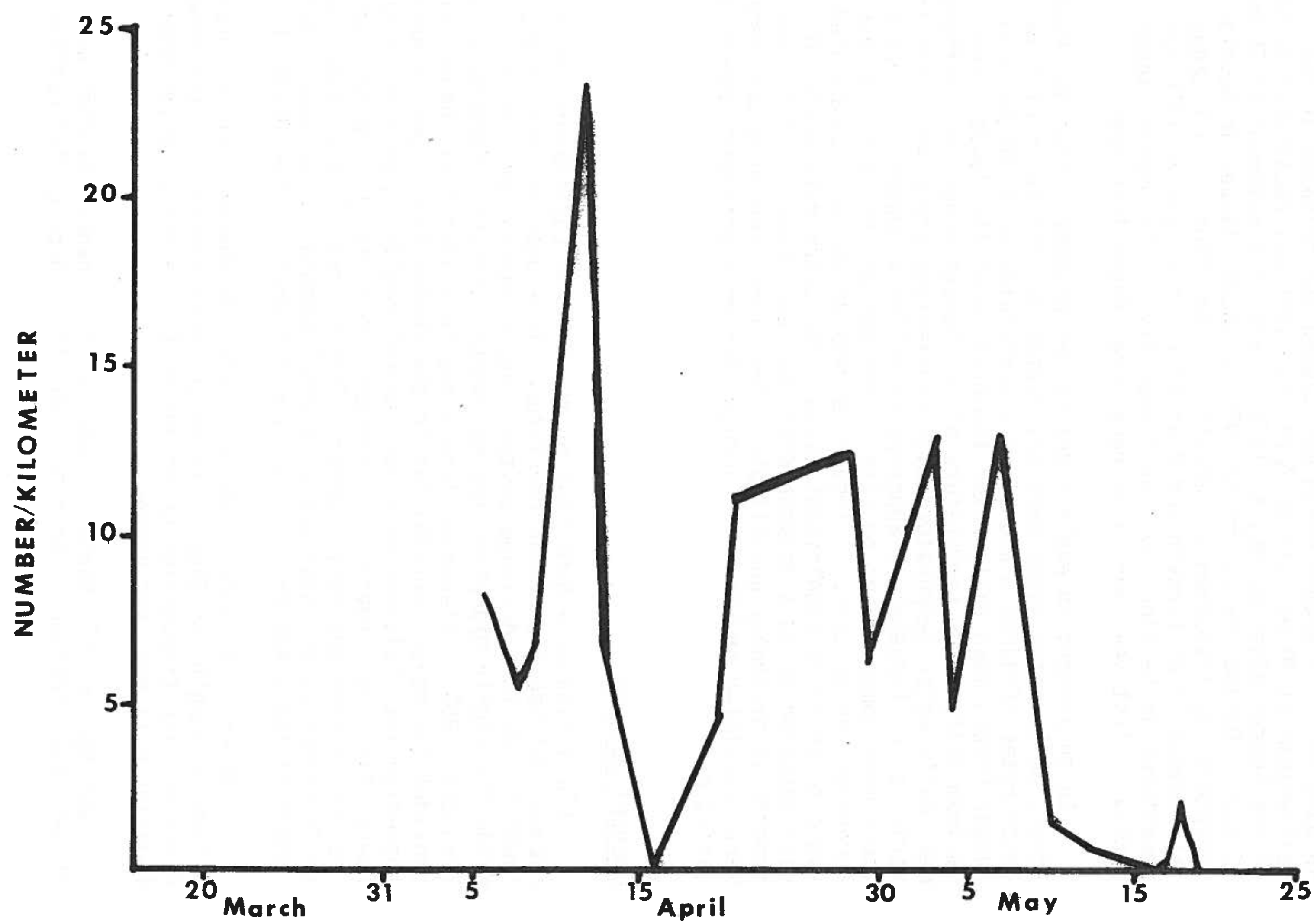

Figure 8. Daily catch rate of sauger at the mouth section, Spring 1976

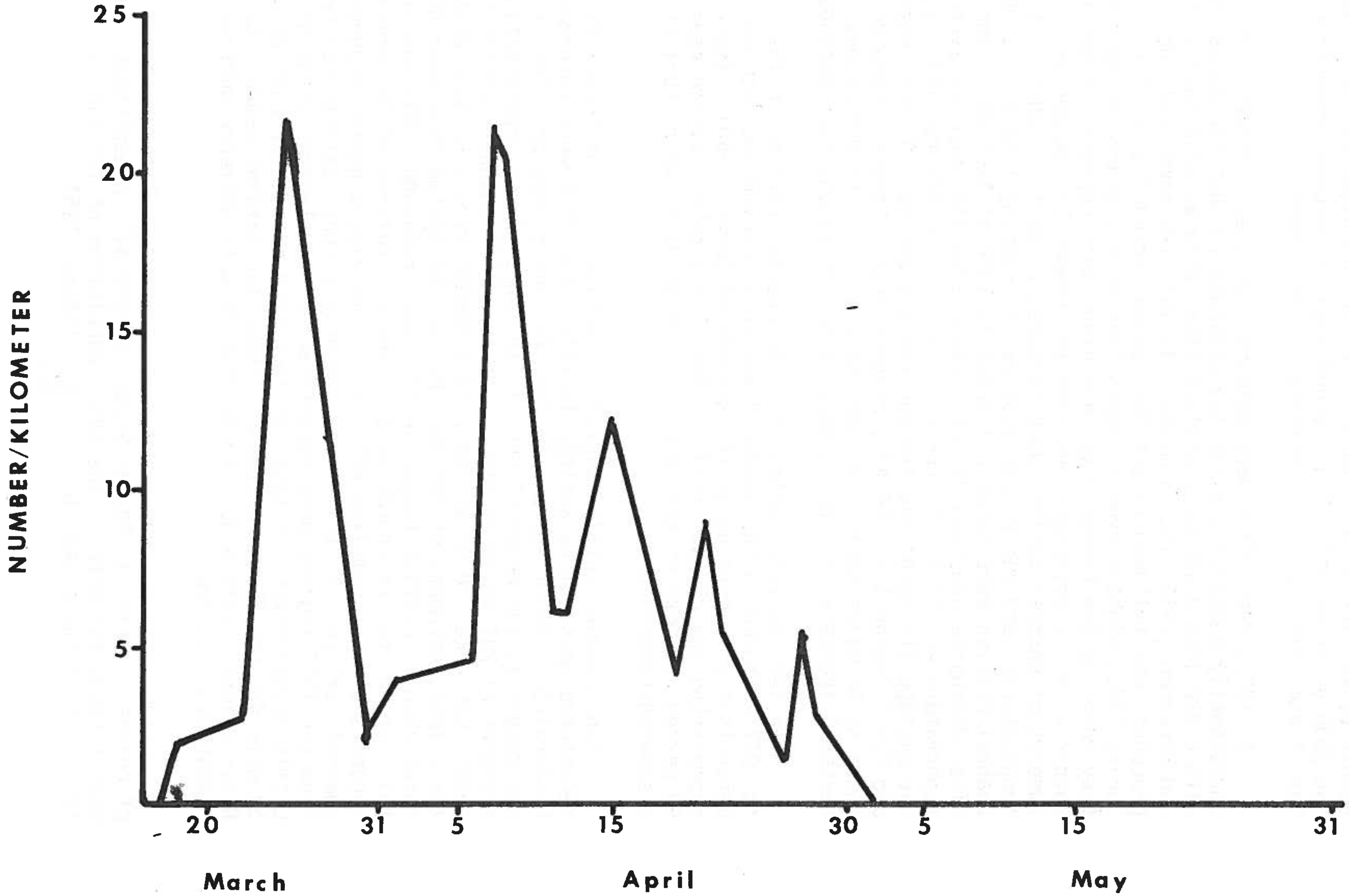

Figure 9. Daily catch rate of sauger at the mouth section, Spring 1977.

between March 25 and May 4. These fish averaged 620 mm in length and 2660 gr in weight. The Little Powder River (Section 5T) was the second collection point. These fish (56) averaged 631 mm in length and 2630 gr in weight. This second location became productive on May 18 and still is at the writting of this report.

In 1976, these fish were measured, weighed, affixed with an individually numbered plastic tag attached through the dorsal musculature with 0.032 inch diameter stainless steel wire as described by Pelgen and McCammon (1955) and released. In 1977 the same handling procedure was followed except the tag was changed to a Floy "cinch-up". During 1976, eighty-seven of these fish were captured in Section 1 as they moved up the Powder River and eight were captured in the Little Powder River, a tributary entering the Powder 249 km upriver. Greatest numbers of channel catfish were captured on April 9, when river temperatures were rising and flow was increasing (Figure 4). While channel catfish were being collected in 1976 at Section 1, the Powder River discharge averaged 747 cfs (range 332-1440) and the average daily temperature was 11.6 C (range 6.1 - 17.5). During the 1977 catfish run, the average discharge and average temperature was 731 cfs (range 490-1100) and 9.6 C (range 1.4 - 16.4^{o}), respectively. Stream discharge had been found to be major factor influencing adult catfish migrations, with seasonal increases in spring expediting migrations (Van Eeckhout 1974).

The left pectoral spines from 30 channel catfish in 1976 and 51 in 1977 captured in the Powder River were removed and sectioned for age determination according to the methods of Sneed (1950). These catfish represented age classes II-XVI. Age IX and older catfish made up 90 percent or more of the sample from both years which further indicates a spawning migration.

Four channel catfish tagged in Section 1 of the Powder River were recaptured upstream by anglers in 1976. Two fish were returned from Powderville (145 km) 32 and 38 days following tagging. The third fish was caught at the mouth of the Little Powder River, representing a movement of 249 km in 33 days. The last 1976 channel catfish tag return was taken 30 km up the Little Powder River, 57 days after tagging for a total movement of 279 km. During the spring fish tagging of 1977, three channel catfish tagged in 1976 were returned. Considering that this rate of return approximates fisherman returns of the previous year suggests similar sampling efficiency, implying a homing tendency of channel catfish. To this date, the only channel catfish tag returns from the 1977 tagging were recaptured during electrofishing on the Little Powder River. A total of four have been taken with an average of 58 days for the 258 km movement. These tag returns suggest the Yellowstone River channel catfish do migrate considerable distance upstream in the Powder River system.

Using these returns as well as assuming that the resident population of channel catfish in Powder River is virtually nonexistant, one can make a rough estimate of the total population of the migrant catfish for 1977. The formula used is: $T = \frac{m}{x/n}$ (Adams, 1951) m = number initially marked (118)

n = total number of recaptures (56)

x = number of marked recaptures (4)

$$T = 1653 \ (694\text{-}3933)$$

$$P\ (694 < N < 3933) = .95$$

Presently a voluntary creel census is being used on the Montana portion of the Powder River. When these are returned (mid-July) a second estimate may be possible to substantiate this first one.

As was done with the sauger, the channel catfish catch rates (Figures 10 and 11) for Section 1 were calculated for each day. These values were correlated with Powder River discharge, Powder River daily maximum water temperatures, Powder River mean daily water temperatures, and degrees difference in mean daily water temperature between the Yellowstone River and the Powder River. A linear regression and a quadratic regression were used. Only the 1976 discharge was found to account for a significant amount of the variation in catch rate (54%). This regression verifies that the magnitude of the channel catfish movement is partially dependent upon spring discharge patterns.

Current field work is being directed toward locating channel catfish "nests" on the Little Powder River. Once these sites are located, physical parameters will be measured to identify spawning flow criteria.

Reproduction

No ripe (sex products easily extrudable) channel catfish have been collected in the Powder River. Of six fish taken by fishermen in Section 1 in late April, four were females with ovaries in the later stages of development. In the 1975 fall sampling, young-of-the-year channel catfish were captured in Sections 1, 2, 4, 5, and 6.

Seining conducted during August 1976 showed a much higher catch rate of young channel catfish in the Little Powder River. On the basis of that observation the spring 1977 work was initiated. During May and June this year, three ripe channel catfish have been captured in the Little Powder River. No sites of reproduction have been located yet.

Burbot

Classified as a game fish by the Montana Legislature in 1975, the burbot (*Lota lota*) represents a very important fishery in early spring in the lower Yellowstone drainage system. Contact with a Powder River fisherman in the Powderville area indicated that a burbot fishery did exist in this river. The 1976 spring sampling revealed three burbot

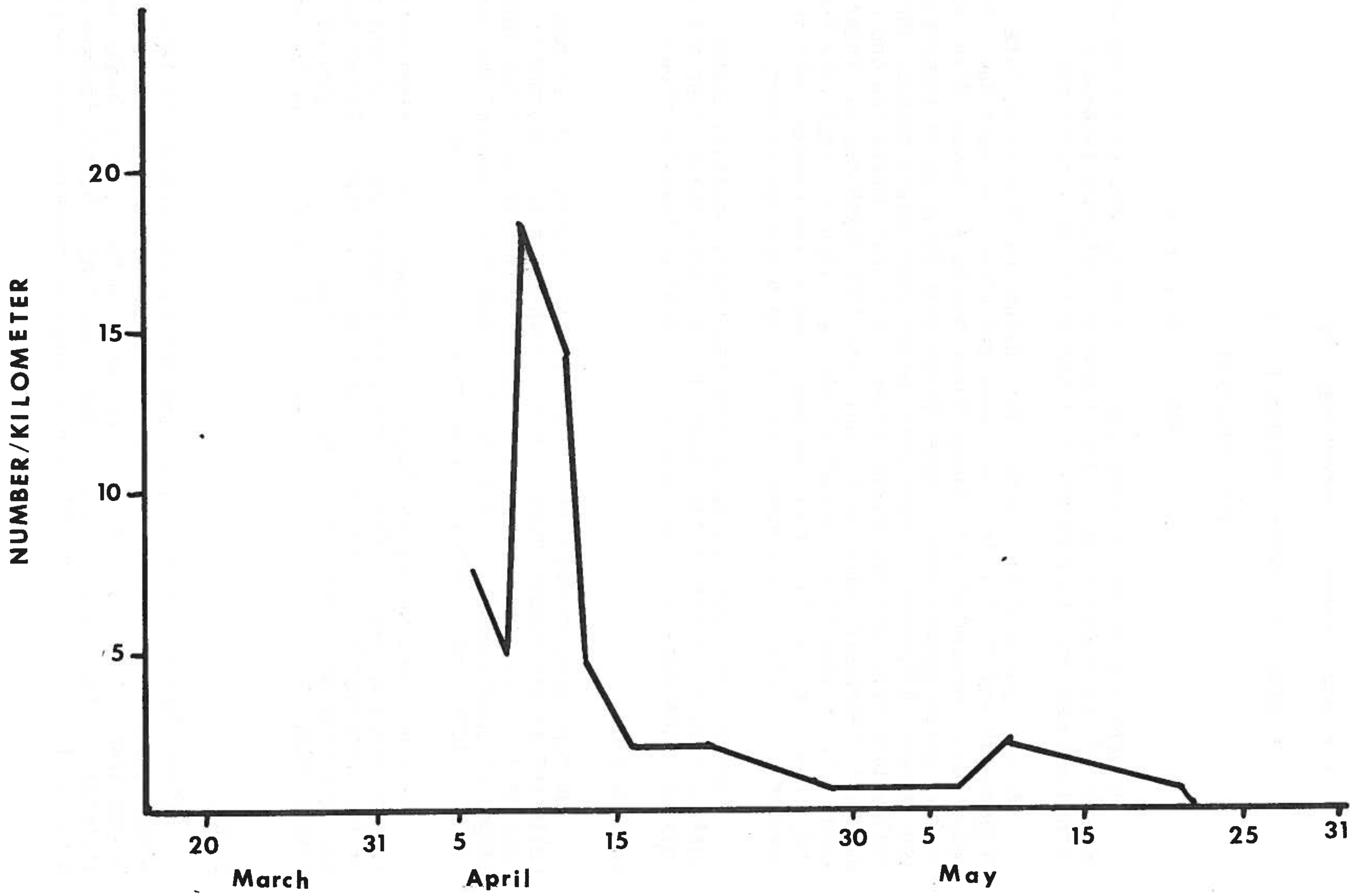

Figure 10. Daily catch rate of channel catfish at the mouth section of the Powder River, Spring 1976.

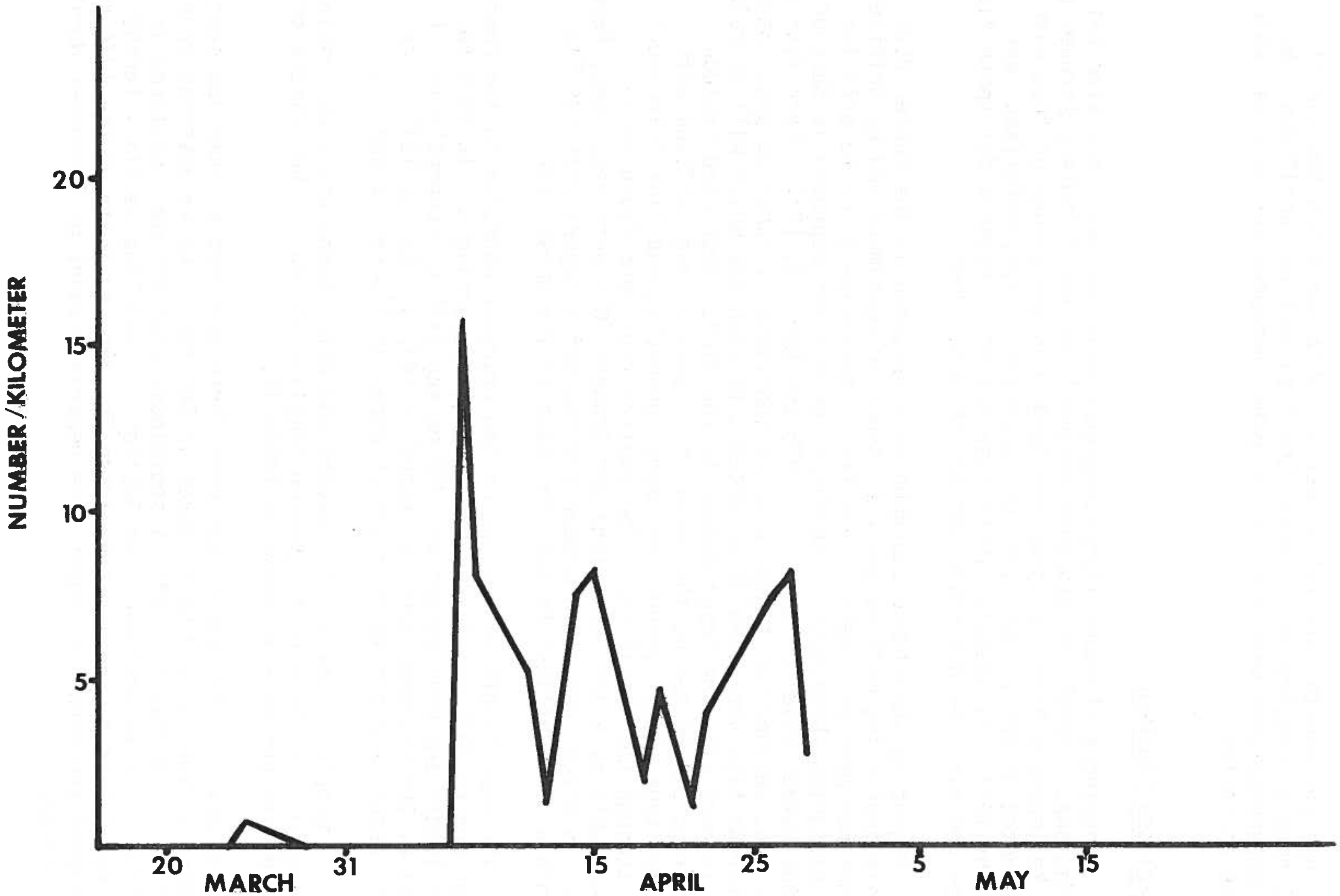

Figure 11. Daily catch rate of channel catfish at the mouth section of the Powder River, Spring 1977.

averaging 341 mm in length and 250 gr in weight. During 1977, 10 burbot were taken averaging 380 mm in length and 380 gr in weight. The mean daily temperature during the period of burbot collection averaged 10.0 C in 1976 and 8.2 C in 1976 and 1977, respectively.

Age and growth information was not obtained since the use of otilithes is required which means the fish must be sacrificed. No sex determinations were made and no other reproduction data was able to be collected.

Shovelnose Sturgeon

Shovelnose sturgeon (*Scaphirhynchus platorynchus*) are also native to Montana. Shovelnose sturgeon evidently ascend tributary streams of the Yellowstone River to spawn and large concentrations of them have been noted in the Tongue River by McFarland (Elser, McFarland, and Schwehr 1977 - in press). These fish provide a fishery for those fishermen who have learned where and how to catch them.

Migrating shovelnose sturgeon were captured in the Powder River by electrofishing with pulsed D.C. shocking equipment and by drifting 3-inch bar mesh gill nets. This latter technique is quite efficient for capturing shovelnose. Shovelnose were first captured in Section 1 of the Powder River on April 13, 1976 and April 8, 1977. Each fish was measured, weighed and tagged with an individually numbered tag. Several different tags were used in an attempt to find one which will be retained the longest with the least damage to the fish. Tags used include Floy tags placed behind the dorsal fin, plastic tags affixed with poultry tags placed around the caudal peduncle, and Floy "cinch-up" tag through the dorsal fin. The poultry tags were found to be undesirable by Elser, McFarland and Schwehr (Old West Reg. Comm. Report 1977, in press) and all sturgeon are now being tagged with the Floy "cinch-up" tag affixed through the base of the dorsal fin.

The mean length and weight of the sturgeon captured in the Powder River during 1976 was 761 mm and 2420 g, respectively. In 1977 the mean length and mean weight was 756 mm and 2450 g, respectively. A total of 203 sturgeon were collected in 1976 and 231 in 1977. The daily catch rate per km of river is shown in Figures 12 and 13.

In general, flow was increasing and water temperature was rising throughout the shovelnose sturgeon sampling period. Other discharge and temperature data is shown on table 11.

On May 11, 1976 shovelnose were first captured at sampling sections further upriver with 8 being taken in Section 2, 48 km upstream from Section 1. On May 13, 1976, 4 shovelnose sturgeon were captured in Section 3, 74 km upstream from Section 1. Sampling sections further upriver failed to produce shovelnose for the remainder of the 1976 season. No tagged shovelnose sturgeon were reported caught by fishermen during this period.

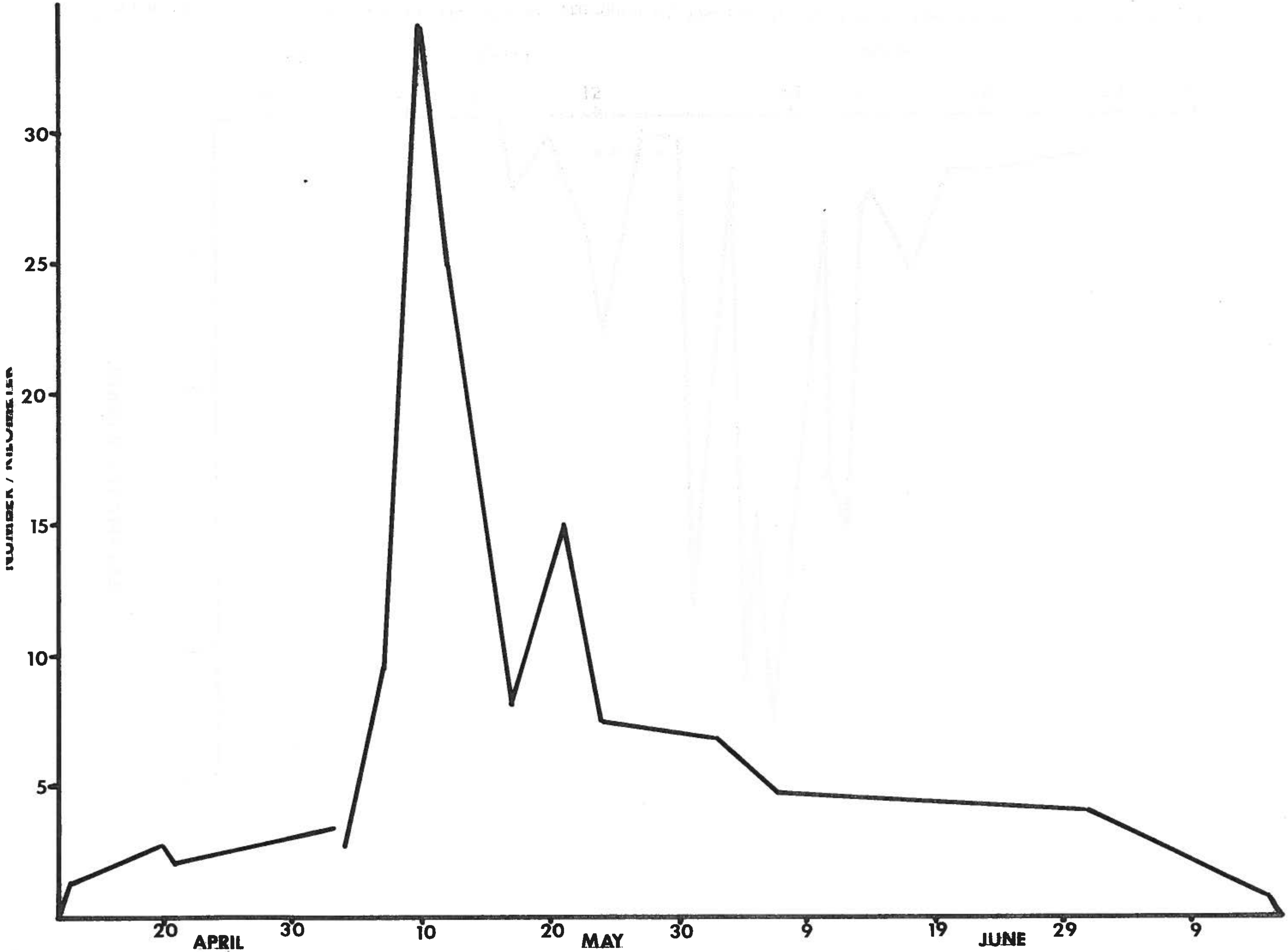

Figure 12. Daily catch rate shovelnose sturgeon at the mouth section of the Powder River, Spring 1976.

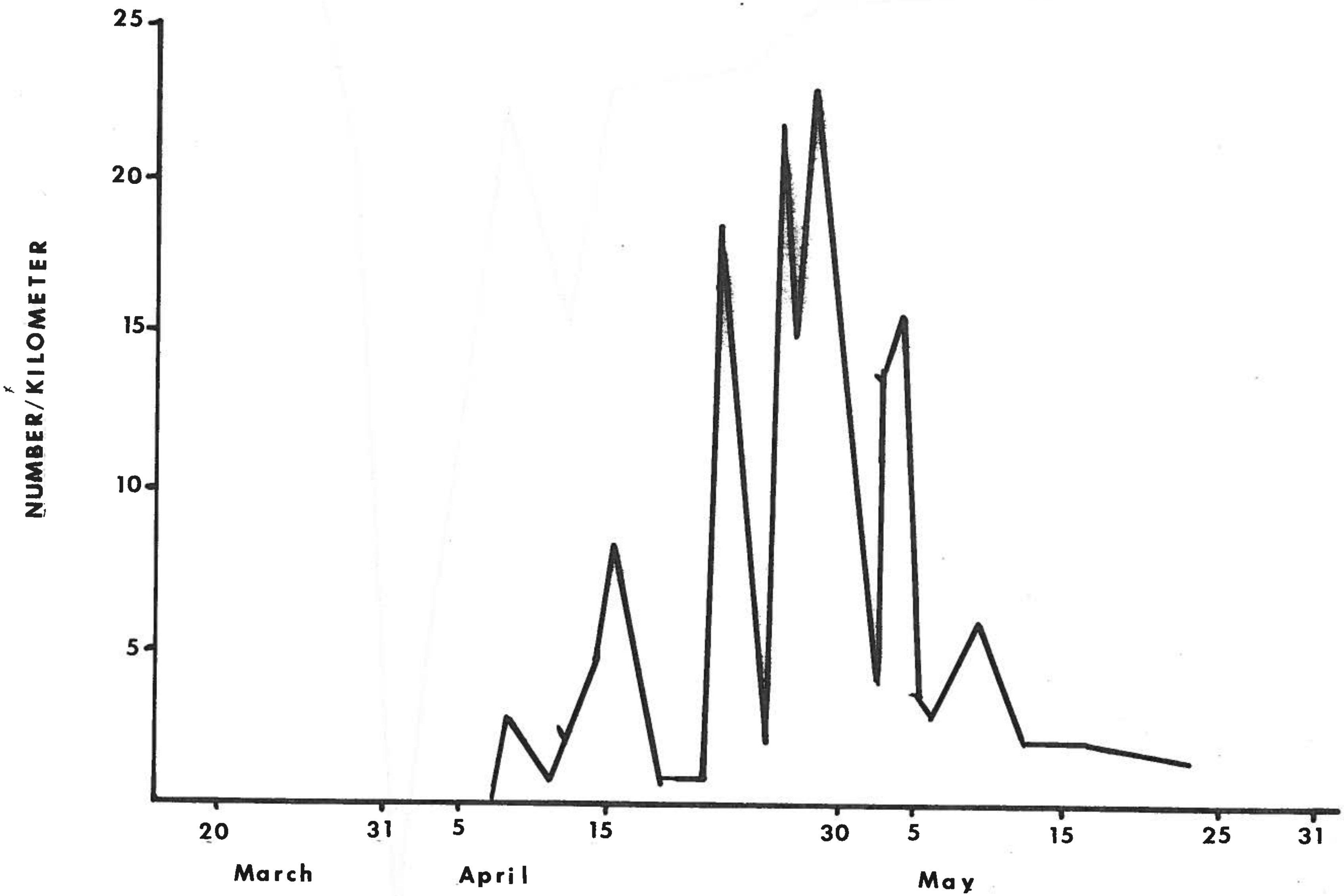

Figure 13. Daily catch rate of shovelnose sturgeon at the mouth section of the Powder River, Spring 1977.

Table 11. Shovelnose sturgeon movements in to Powder River and associated temperatures and discharges.

Year	Period of Run	Mean Discharge For Period	Average Temp. °C	Temperature °C at Which Run Began	Discharge at Which Run Began	Temperature At Peak Catch Rate	Discharge At Peak Catch Rate
1976	4/13 to 7/15	1211 (418-2990)	12.2 (6.1-17.8)	15.6	370	16.1	697
1977	4/8 to 6/9	1157 (285-3230)	12.4 (8.3-24.2)	12.2	950	15.8	490

One shovelnose captured in Section 1 on June 2, 1976 was tagged May 10, 1974 in the Tongue River at Miles City. Another shovelnose tagged on May 3, 1977 in Section 1 was recaptured at Fairview, MT., a downstream distance of 217 km in 21 days.

Age and growth information was not obtained since previous work suggests that pectoral fin ray sections are of dubious value and other techniques require sacrificing the fish. None of the sturgeon were in a "ripe" condition and hence none were sexed.

Catch rates were correlated with water temperatures and discharges and no significant amount of the catch rate variation was accounted for by these parameters.

Paddlefish

The paddlefish (*Polyodon spathula*) is an annual migrant in the lower Yellowstone River. A large population exists on Garrison Reservoir and each spring moves up the Yellowstone River (Robinson 1965). One paddlefish was taken at the mouth of Clear Creek, Wyoming in the early 1970's (Fred Dabny, personal communication). This year during the spring sampling another paddlefish was taken in the Powder River in Section 1. This male fish was collected on May 31, 1977. It's "eye to fork of tail" length was 837 mm and weighed 21 pounds.

Non-Sport Fish

Incidental to the spring sport fish monitoring, cursory observations were made on "rough" fish used of the Powder River at Section 1. Four species were included in this category.

Goldeye (*Hiodon alosoides*) began using the Powder before the first sampling day of March 14, 1977. Their movement into the river closely parallels that of the sauger. The peak number observed was April 7, 1977. However, the goldeye continued to be present in Section 1 until late May. The magnitude of this movement would exceed any other fish migrating into the Powder River.

Carp (*Cyprinus carpio*) were only rarely observed until late April and were not commonly observed after June 1. The size of the carp movement into the Powder River appears to be quite minimal.

River carpsuckers (*Carpoides carpio*) migrated into the Powder River mainly during the last week in April. Lesser numbers were still present in mid-May. The number of carpsuckers making this move appears to be approximately the same as the carp.

Shorthead redhorse (*Moxostoma macrolapidotum*) were noted to move into Section 1 for a very short period (April 10-20, 1977). These fish were never observed to be extremely abundant.

Tributary Fish Sampling

All fish were captured using pulsed D.C. electrofishing equipment or seining. Chemical and physical data collected are presented in Table 12.

Table 12. Chemical and physical data for two tributaries of the Powder River.

Tributary	Date	Salinity	Temp.	Specific Conductance	Dissolved Oxygen	pH
Mizpah Cr.	6/11	1.0/1000	22.8°C	1340 umhos/cm	9.4 ppm	8.90
Little Powder River	6/11	0.8/1000	21.2°C	1180 umhos/cm	6.5 ppm	8.22

Mizpah Creek

During the summer of 1976, tributary fish sampling work was initiated to define those areas of probable game fish use. One of the two large Montana tributaries to the Powder is Mizpah Creek.. Sampling was accomplished with D.C. electrofishing equipment (Table 13) as well as 1/4 inch bar mesh 50-foot bag-seine (Table 14) over a section of 1.50 km. These two collections indicate a total of fifteen species in the lower portion of the creek. This represents the greatest diversity of any sites thus far sampled.

Little Powder River

The Little Powder River is a permanent tributary that enters the Powder River 249 km upstream from the confluence with the Yellowstone. Two sampling runs were made on a 762 meter section approximately 8 km upstream. A mark and recapture population estimate was attempted to determine if it was feasible and applicable to the Powder River.

Flathead chubs (*Hybopsis gracilis*) were not handled due to time limitations. However, they appeared to be the most abundant fish in the stream. The river carpsucker (*Carpoides carpio*) followed by the shorthead redhorse (*Moxostoma macrolepidotum*) were the next most abundant fish species (Table 15). The redhorse appeared to be associated with gravel bottoms in areas of riffles while the carpsuckers were found mainly in areas of silted bottoms and still water.

Of the species present, an estimate using Chapmans modification of the Petersen estimator (Ricker 1958) was made for the shorthead redhorse and river carpsucker (table 16).

Table 13. Electrofishing sample from Mizpah Creek, July 1976.

Species	Number	Mean Length (mm)	Mean Weight (g)
River carpsucker (*Carpoides carpio*)	14	269	286
Goldeye (*Hiodon alosoides*)	6	296	178
Green Sunfish	1	90	20
Channel Catfish (*Ictalurus punctatus*)	1	355	320
Carp (*Cyprinus carpio*)	1	468	120

Table 14. Fish sampled in Mizpah Creek (seining) August 1976.

Species	Number	Percent
Flathead chub	34	27.0
Sand shiner	19	14.3
Channel catfish	16	12.7
River carpsucker	14	11.1
Fathead minnow	13	10.3
Silver minnow	8	6.3
Carp	8	6.3
Plains minnow	5	4.0
Black bullhead	4	3.2
Longnose dace	3	2.4
Shorthead redhorse	1	0.8
White sucker	1	0.8
Creek chub	1	0.8
Total	126	100.0

Table 15. Species and numbers of fish captured in the Little Powder River. May 1976.

Species	Sample 1	Sample 2
Flathead chub (*Hybopsis gracilis*)	*	*
River carpsucker (*Carpoides carpio*)	85	66
Shorthead redhorse (*Moxostoma macrolepidotum*)	57	49
Carp (*Cyprinus carpio*)	54	18
Goldeye (*Hiodon alosoides*)	25	13
White sucker (*Catostomus commersoni*)	9	18
Green sunfish (*Lepomis cyanellus*)	7	3
Stonecat (*Noturus flavus*)	5	5
Channel catfish (*Ictalurus punctatus*)	3	5

Table 16. Estimated numbers of shorthead redhorse and river carpsucker in the study section of the Little Powder River

Species	Population Estimate (95% confidence intervals)
Shorthead redhorse	138 (± 45)
River carpsucker	360 (± 152)

The Little Powder River was again sampled in August 1976 (Table 17). This was accomplished by the use of a 1/4-inch bar mesh seine. On the basis of this work, the spring 1977 work was initiated. The channel catfish fell into 3 general lengths (45, 75 and 195 mm), which appear to be very early age classes. Age determinations of pectoral fin spines have not been completed.

Table 17. August 1976 fish sample from Little Powder River.

Species	Number	Percent
Plains minnow	141	69.5
Silvery minnow	24	11.8
Channel catfish	24	11.9
Goldeye	8	3.9
River carpsucker	3	1.5
Flathead chub	1	0.5
Carp	1	0.5
Stonecat	1	0.5

Clear Creek, Wyoming

In an attempt to recover tagged migrating game fish, one sampling run was made on this tributary of the Powder River which enters near Arvada, Wyoming. Sampling problems limited the section to approximately 0.45 km. The results of the June sampling are given in Table 18. Another sampling run was made in July 1976. The results of this work is shown in Table 19. The presence of both sauger and channel catfish in this sample combined with their non-existance in an earlier one, suggest that these could be migrating fish.

Two other smaller tributaries of the Powder River (Ten Mile Creek and Coal Creek) were also sampled in August 1976. These two tributaries were selected because they still were discharging small amounts of water into the Powder. The data collected is presented in Tables 20 and 21.

The tributary work has shown additional species in the drainage and a definite difference the two major types of tributaries. Summer and fall sampling in the two major Montana tributaries (Mizpah Creek and the Little Powder River) yield small channel catfish while none of the small tributaries yielded any. The explanation appears to be in the timing of the discharge and its duration. Tributary work continued during 1977, but final results have not been tabulated.

Table 18. Species, numbers, mean lengths and mean weights of fish captured in Clear Creek.

Species	Number	Mean Length (mm)	Mean Weight (g)
White sucker (*Catostomus commersoni*)	27	215	116
Flathead chub (*Hybopsis gracilis*)	14	124	---
Shorthead redhorse (*Moxostoma macrolepidotum*)	12	287	221
Longnose sucker (*Catostomus catosumus*)	3	288	270
Goldeye (*Hiodon alosoides*)	3	306	180
Rockbass (*Amblplites rupestris*)	2	125	35
River carpsucker (*Carpoides carpio*)	1	286	250
Carp (*Cyprinus carpio*)	1	455	1000
Brown trout (*Salmo trutta*)	1	290	200

Table 19. Fish sample and percent composition taken on July 13, 1976 in Clear Creek, Wyoming.

Species	Number	Percent
Shorthead redhorse	56	38.3
Goldeye	31	21.2
Flathead chub	24	16.4
White sucker	15	10.3
Longnose sucker	9	6.2
Carp	5	3.4
River carpsucker	3	2.1
Sauger	1	0.7
Rockbass	1	0.7
Channel catfish	1	0.7
Total	146	100.0

Table 20. Fish sampled from Ten Mile Creek (Prairie County) August 1976.

Species	Number	Percent
Plains minnow	57	50.8
Fathead minnow	32	28.6
Green sunfish	10	8.9
Black bullhead	6	5.4
Silver minnow	6	5.4
Creek chub	1	0.9
Total	112	100.0

Table 21. Fish sampled from Coal Creek (Prairie County) August 1976.

Species	Number	Percent
River carpsucker	21	45.7
Creek chub	10	21.7
Hybognathus	9	19.6
Flathead chub	6	13.0
Total	46	100.0

The tributary work has shown additional species in the drainage and a definite difference the two major types of tributaries. Summer and fall sampling in the two major Montana tributaries (Mizpah Creek and the Little Powder River) yield small channel catfish while none of the small tributaries yielded any. The explanation appears to be in the timing of the discharge and its duration. Tributary work continued during 1977, but final results have not been tabulated.

Preliminary Conclusions on the Spring Fish Migration

From the stand-point of fisheries, the important game species utilizing the Powder River extensively are the sauger, channel catfish, and shovelnose sturgeon. Experience on the Tongue River has shown that all three of these species can thrive even though the river is controlled. However, the volume of water, the timing of the discharge and possibly water quality are very important.

Instream discharge needs were made and supported based on two field seasons on the Powder River. The spring reservation represents a minimum discharge for sustaining this migratory fishery. It is based on the movement of fish into the Powder River and how extensive their movement is. A graphic presentation of this information is shown in Figure 14.

The stimulus for movement into the Powder River is not wholly understood. Sauger movement begins at cold water temperatures and moderate spring discharge. However, the cessation of this movement for 2 years was preceded by several days where the mean daily water temperature exceeded 16.0 C. Attempts to explain channel catfish ingression were in part successful. During 1976, 54 percent of the variation in channel catfish movement was explained by discharge. The magnitude and length of the shovelnose sturgeon run appears to depend on the early increasing stages of spring runoff and the presence of a high (823 cfs - May 7, 1976) and stable "plateau" discharge. This pattern was not maintained in 1977 and the shovelnose sturgeon run ended over 1 month earlier than in 1976.

To conclude that discharge alone is responsible for these migrations is of course erroneous. However, the discharge pattern and the temperature regimen of a given drainage are very closely linked. These two factors are concluded to be the most important ones in maintaining this fishery.

The third and relatively unknown variable is that of salinity and the tolerances these species have for dissolved solids. According to the Yellowstone River Basin EIS for water reservation applications (Mt. Dept. of Natural Resources, 1977), the Powder River will be plagued with marked increases in T.D.S. as development increases. The evaporative loss from the originally proposed Moorhead Dam combined with more development, could have a drastic affect on the biota of the Powder River and its irrigation potential.

> TDS concentrations, already extremely high in the water of the Powder River, would increase significantly under any of the levels of development.
>
> A 1,150,000 acre-foot reservoir (the initial storage capacity of Moorhead) was assumed to simulate the possible dilution of salts. It was also conservatively assumed that the application of irrigation water would not increase salts delivered to the river by return flows. Even so, and even for the low level of development (as shown in Table IV-15), in one year out of two, on the average total dissolved solids in the Powder River, which now average over 1,100 mg/l, would increase to over 3,000 mg/l in several low-flow months, including the irrigation season. Occasional (i.e., at the 90th percentile level) values would be even higher.
>
> The TDS concentrations would increase even more for the intermediate and high levels of irrigation development, especially (1) if the irrigation return flows pick up additional salts from the land, and (2) as the dilution volume of the reservoir decreases due to sediment deposition.
>
> The projected total dissolved solids in the Powder River of 3,000 mg/l would greatly exceed the recommended values for irrigation water.

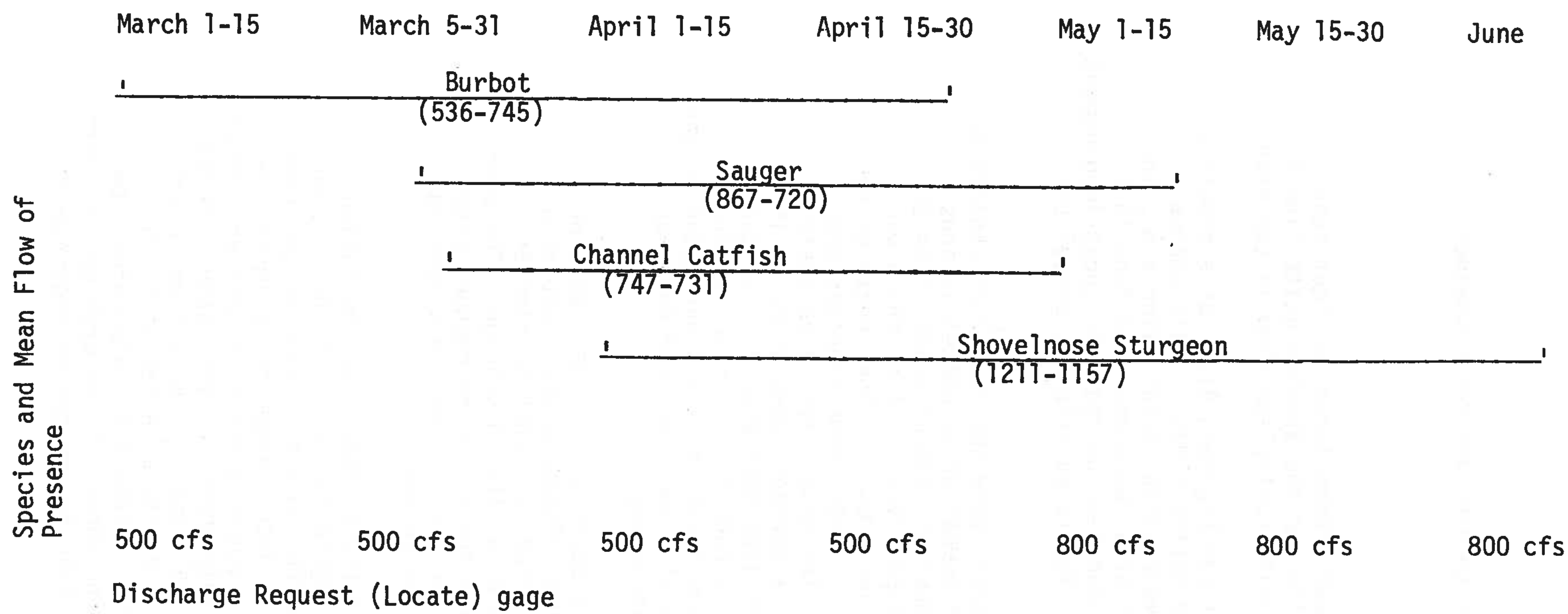

Figure 14. Instream flow needs of several species of fish in the Powder River.

Morphological Changes of Powder River Channel and Basin Changes

Aerial Photographs

The aerial photograph analysis was accomplished for that reach of the Powder River between Powderville and the Wyoming state line to evaluate possible changes associated with controlled flow in the river.

Changes in channel morphology of the Big Horn River as a result of impounding the river was evaluated by Martin (1976). Main channel length, total area of bank riparian vegetation, total river area, and total vegetated island and gravel bar areas were measured from 1939 aerial photographs (pre-impoundment) and 1974 photographs (post-impoundment) at approximately the same discharge. Vegetated islands, gravel bars, and lateral bars were also counted.

Changes in the Bighorn River channel were the result of controlled discharge and channel degradion. The number of vegetated islands, number of island gravel bars, and number of lateral gravel bars all decreased (30.6%, 51.4%, and 9.1%, respectively). Also there was a trend toward area reduction of those land masses. The length of the main channel increased 1.2 percent. The total bank riparian area increased 37.5 percent (3330 acres). The total river area (water, islands and gravel bars) decreased 25.4 percent (3395 acres). The total vegetated islands and gravel bar area decreased 35.1 percent (3001 acres). It can be noted that the reduction in river channel area came from the vegetated island and gravel bars and was added to the total bank riparian area. This certainly shows the need for peak spring flows in maintaining channel morphology.

The Powder River measurements are based on a flight taken on September 22, 1976 when the Powder River discharge was measured at 69 cfs (USGS Provisional data). Vegetated "islands" totaled 54, however, they were not isolated by water at that discharge. The other measurements are given in table 22 with the projected changes after impoundment. These changes are based entirely on Martin's work and does not include man-caused river-bottom changes.

Such channel changes would have definite impacts on the biology of the Powder River. Increasing the vegetative cover of the silt bars would reduce stream sedimentation, thereby possible changing the invertebrate population and fish population. Such changes could impact the Canada goose (*Branta canadensis*) use patterns since silt bars are commonly used resting areas. The largest possible impact of the channel changes caused by a dam would be the agricultural impact. The current river bottom with its large wildlife resource exists as a result of the respect held for Powder River ice jams. A deep water discharge from a main stream impoundment could reduce the threat of ice problems for part of the river. This would undoubtedly lead to man caused reduction of the cottonwood bottom.

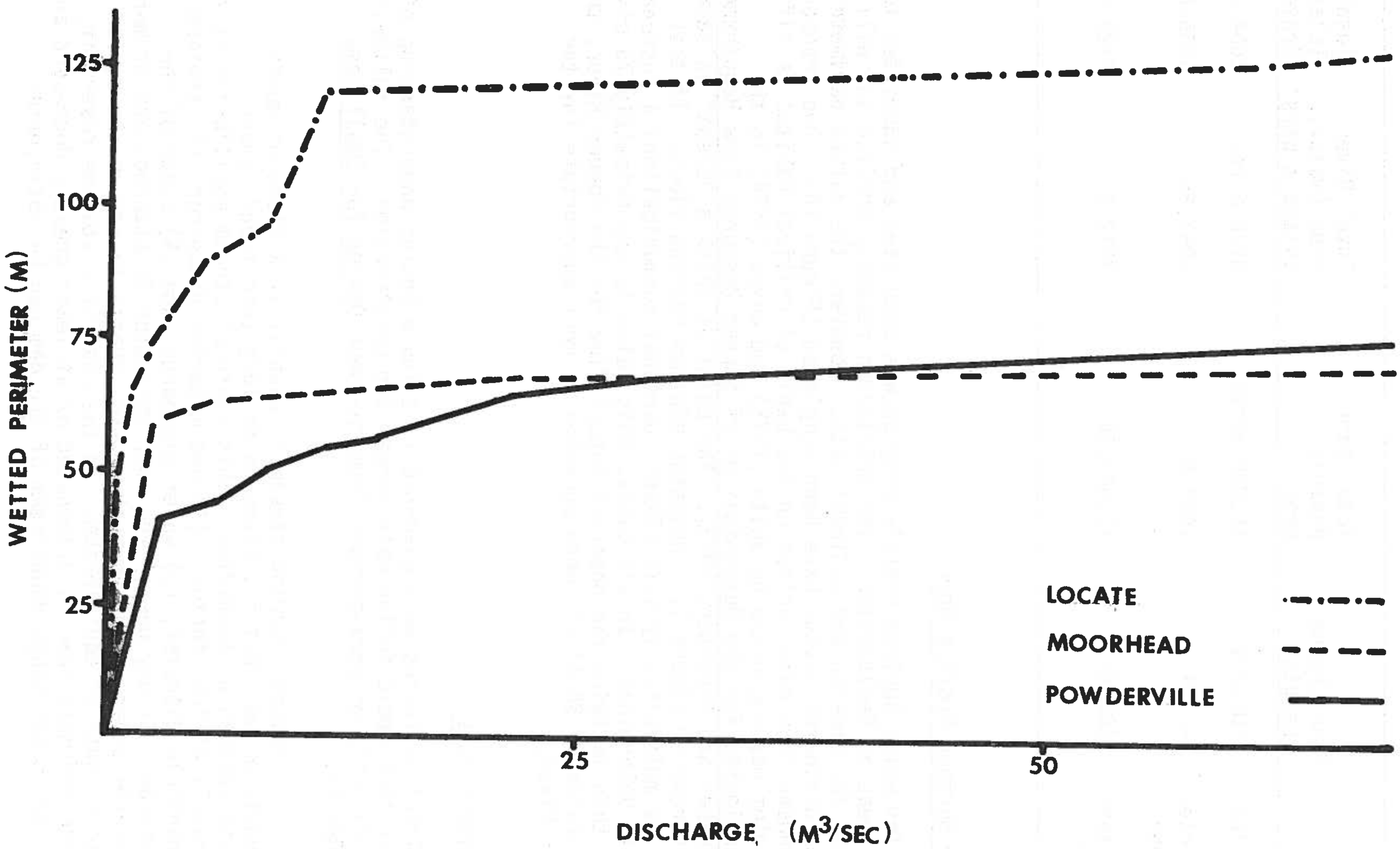

Figure 15. Discharge - wetted perimeter plot with arrows depicting recommended rearing flows.

Table 22. Powder River measurements and projected changes for the Powderville to Wyoming section.

	Main Channel Length	Total Bank Riparian Area	Total River Area (water, island & bars)	Total Veg. Islands & Gravel Bars
Existing	101.2 mi.	15,026 acres	3770 acres	2664 acres
Projected change	+1.21 mi.	+957.58	-957.58	-935.06
Resultant areas	102.41	15,983.58	2812.42	1728.94

Water Surface Profile Work

The Water Surface Profile program was completed and submitted to the Bureau of Reclamation. The print-outs recently arrived and will be gleaned for erosion and sediment data. However, the wetted perimeter versus discharge graphs have been completed (Figure 15). One transect was chosen from each section on the basis of critical habitat (a riffle). This plot was suggested by White (1975) and Bovee (1974) in the Methodologies for the Determination of Stream Resource Flow Requirement, (Stalnaker and Arnetter, 1976). The point at which a "break" is seen (the arrows in figure 1), indicates minimum rearing flows. If this value is multiplied by 0.75 (Elser, personal communication) a sustenance flow is determined. In all cases, this value is approximately 75 cfs. Since this is twice the observed August flow for the Powder River, the Jones value of 30-47 cfs were accepted as most appropriate for the Powder River.

Tractive Forces

Tractive forces were examined to allow a better understanding of the erosion that would follow main stream dam construction. The following is taken directly or para-phrased from the book Design for Small Dams pp. 789-795.

> A natural flowing stream is usually in a state of quasi-equilibrium; that is, there is no long term trend toward aggradation or degradion. This state of stream equilibrium is the result of four factors: (1) bed material discharge, (2) sediment particle diameter, (3) water discharge, and (4) slope of the stream. If any one of the four variables is altered, one or more of the other variables must undergo change to return the stream to a state of equilibrium. In the case of a storage reservoir, the sediment load is eliminated or at least greatly decreased and a decreased slope downstream of the dam can be anticipated

and the sediment particles remaining in the streambed will be the coarser fractions of the original material. This process of removing sediment particles from the streambed and banks is referred to a degradation.

Several laboratory investigations have shown that the size of a particle plucked from a streambed is proportional to the velocity of flow near the bed. The velocity at which the particle starts to move is referred to as the competent bottom velocity. The competent bottom velocity has been found to be approximately equal to 0.7 times the mean channel velocity.

Tractive force is the drag or shear acting on the wetted area of the channel bed and can be expressed as:

T.F. = y d S where T.F. = tractive force in lb/ft^2
y = unit weight of water (62.4 lb/ft^3)
d = mean water depth in feet
S = stream gradient in fl/ft

$$\text{Tractive force} = 62.4 \times \text{hydraulic radius} \times \left(\frac{\text{discharge}}{\text{conveyance factor}^2}\right)$$

$$\text{Hydraulic radius: } \frac{\text{cross sectional area}}{\text{wetted parimeter}}$$

$$\text{Conveyance factor} = 1.486 \times \text{area} \times \left(\frac{\text{hydraulic radius}}{\text{roughness coefficient}}\right) 2/3$$

Figure 16 shows tractive force versus transportable sediment size. While these curves are for concrete lined canals and stabilized channels, they show the concept of tractive force. The following calculations are based on the curve for clean water (discharge from impoundment-denoted by star) and a mean particle diameter of 0.5 mm. It can be concluded that sediment transport will begin when a tractive force of 0.03 is equalled. According to the WSP printout, this tractive force is achieved at a discharge of slightly less than 100 cfs. Other work being done on the Powder River verifies that at this discharge the sediment transport increases rapidly (Clark Judy, personal communication). However, field observations made during the Powder River's only clear water period (mid to late September) show virtually no sediment transport occurring at flows less than 30 cfs.

It must be cautioned that the tractive forces shown on the WSP printout are not of extremely high quality. The technique used to accomplish the projected water surface elevations is one of making these "runs" with a known elevation and discharge and then manipulating the roughness coefficients until agreement is made. This procedure

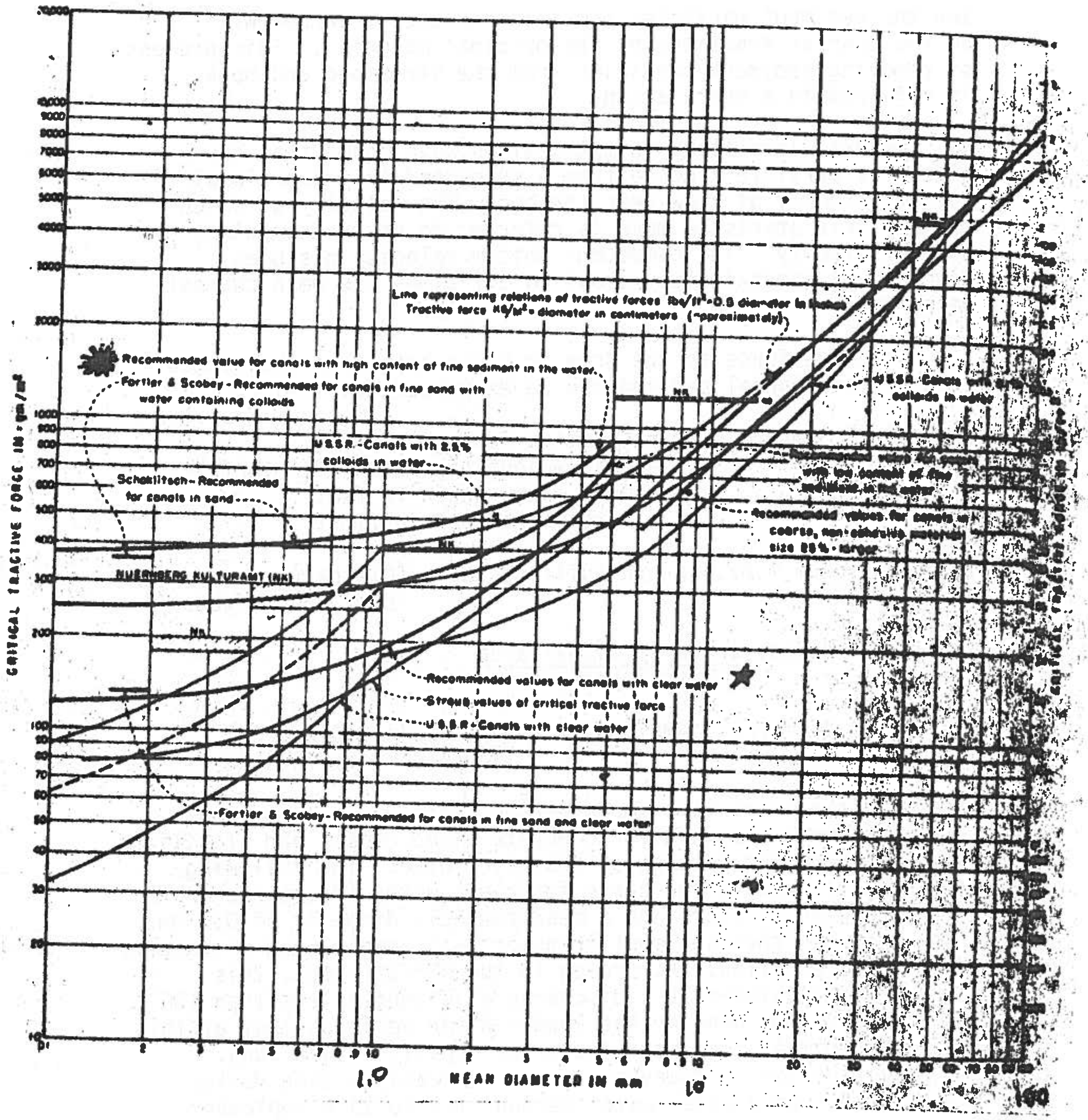

Figure 16. Tractive force versus transportable sediment size (Strand 1973)

could yield slightly different "N" values which have a significant influence on the calculated tractive force.

Example: Tractive force = 0.1836 at N = 0.035
Tractive force = 0.0939 at N = 0.025

These calculations can yield interpretations of biological value if the armoring effect is considered. This armoring effect states that the finer particles will be removed from the streambed until particles of a large enough size remain that can't be moved by the highest discharge. This would definitely mean that the Powder River channel would be degraded until the substrate would be comprised of gravel or rock (the size of which could be predicted once a flow regime was known). Such substrate would be a more desirable invertebrate habitat resulting in increased populations and increased production. However, the invertebrate population structure would change with the probable consequence of an altered fish population.

Information was located that presents current levels of irrigation development in the Powder River subbasin and projected future levels of increase. To estimate the amount of water currently used for irrigation, a general rule of 3 af/acre/year is a commonly used approximation. The information is presented in tables 23 and 24 (Montana Department of Natural Resources and Conservation 1976).

Table 23. Present and future development of irrigated land in the Powder River subbasin (data from DNRC, October 1976).

County	Present Number of Irrigated Acres	Feasibly Irrigable Acreage at High Level of Development
Powder River	33,339	46,853
Custer	12,995	26,438
Prairie	-0-	1,914
	46,334	75,205

Similarly, an estimate of instream water required to maintain the Powder River aquatic system in its present state was achieved. These monthly values (table 25) are the product of historic flow data and biological information.

Table 24. The increase in water depletion for consumptive use in 2000 for Powder River Subbasin (af/y).

	Irrigation	Energy	Municipal	Total
Low level of development	50,140	860	360	51,360
Intermediate level of development	100,280	18,880	600	119,760
High level of development	150,400	28,150	1,140	179,690

Table 25. Monthly estimates of instream water need (cfs) in the Powder River.

Reach of Powder River	J	F	M	A	M	J	J	A	S	O	N	D
Clear Creek to Little Powder River	100	100	400	400	600	750	120	30	30	100	100	100
Little Powder River to Yellowstone River	80	75	500	500	800	800	200	47	40	85	80	86

The estimates for the months of July through February are adopted from Jones (1974) and are presented in the Northern Great Plains Resources Program (1974). For the months of March through June, a slightly higher figure was arrived at on the basis of the spring game fish movements into the Powder River.

Invertebrate Studies

October of 1976 marked the end of one full field season of invertebrate sampling. All invertebrates collected were identified with the aid of Wand and Whipple (1959), Jenson (1966), and Usinger (1956).

The distribution of all organisms identified is presented in figure 17. Four genera of insects other than deperans, were identifed which have not been found in the Yellowstone or Tongue Rivers (Newell 1976). The mayfly (*Anepeorus*) is an eastern and mid-western genus, apparently unknown in Montana; 47 individuals of this genus were collected during the year. *Cinygma*, another mayfly, is a mountain river organism. The only two specimens were collected in the same sample and were in poor shape for identification. *Hetaerina americana*, a damselfly, has been collected in the Yellowstone drainage (Roemhild 1975) although not in the river. The alderfly (*Sialis*) is not uncommon but is often missed in random sampling (Oswald, personal communication). Among the dipterans, a very difficult order with which to work, three families and seven genera of the family Chironomidae were not in Newell's (1976) report. These are, Ceratopogonidae, Stratiomyidae, Tipulidae, *Calopsectra*, *Conchapelopia*, *Dicrotendipes*, *Endochironomus*, *Paratendipes*, *Polypedilum*, and *Pseudochironomus*. Little work has been done on the Diptera of Montana. In the future, the recognized distribution of many dipterans will probably be expanded.

A total of 4,789 organisms were collected in the invertebrate sampling. In all, 256 samples were analyzed: 63 kick samples, 185 Water's samples and 8 Ekman dredge samples. The raw data from each sample is available in the Appendix Tables. Ephemeroptera and Trichoptera together accounted for over 60 percent of all organisms collected at each station (Table 26). When Plecoptera and Diptera are added to those figures, the four orders accounted for from 81.7 to 99.6 percent of the organisms at each station (Figure 18). This community structure is similar to those found in the Yellowstone River (Newell 1976) and in the Musselshell River of central Montana (Gorges 1976).

No stoneflies were found at the two tributary collecting sites. This may be due to water chemistry characteristics related to the high conductivity in the two streams. The Little Powder River samples were, by far, the richest samples in our collection. The most obvious external characteristic possibly accounting for this is the narrow stream channel with relatively stable flows in relation to the main river. It should be noted in the Appendix Tables that some of the samples yielded no organisms. The lack of organisms at Station 2 in May was probably due to sampling substrates recently inundated by flood waters.

Table 27 shows the invertebrates by family as they were collected in the quantitative samplers. Stratiomyidae, Corixidae and Sialidae, although never found in Water's samples, were collected in kick samples.

Figure 17. Geographic distribution of aquatic macroinvertebrates collected in the Powder River Drainage.

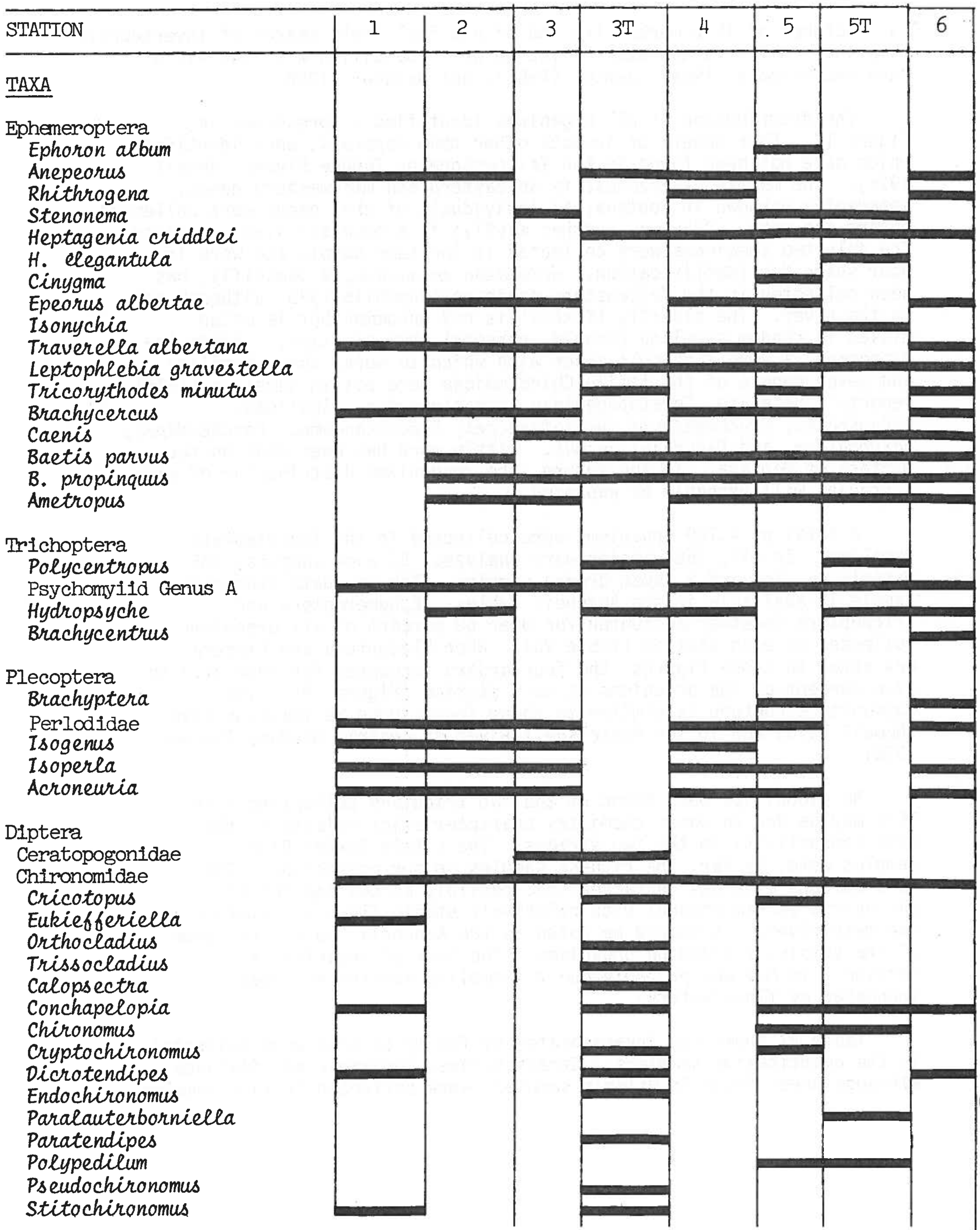

Figure 17 Continued

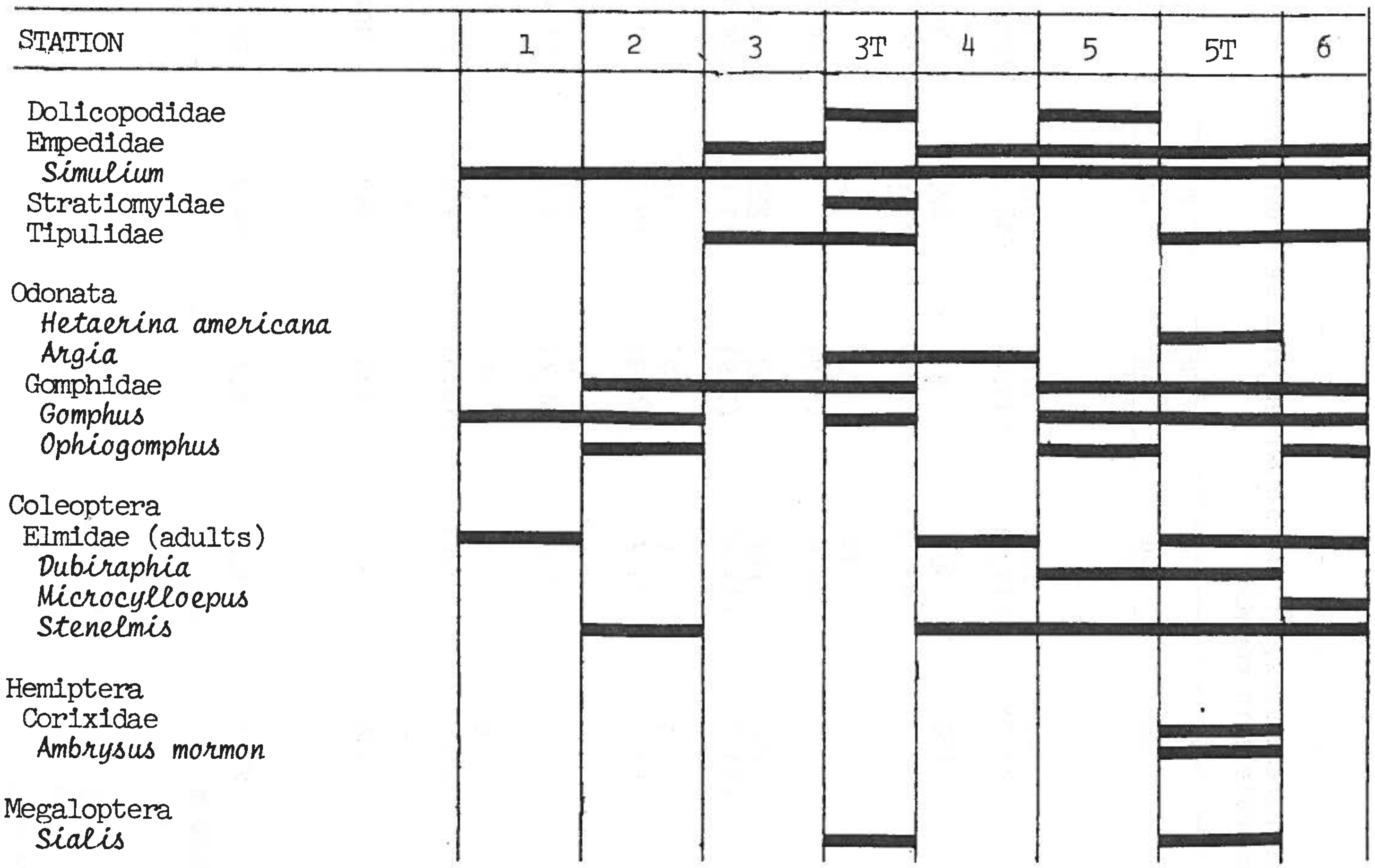

Table 26. Total numbers and percent composition (in parentheses) of macroinvertebrates by order from all collections at each station. Hyphens indicate zero counts.

Station No. of Samples	1 32	2 36	3 36	3T 20	4 36	5 32	5T 28	6 36	Line Totals
ORDER									
Ephemeroptera	14 (3.6)	22 (9.1)	53 (20.6)	179 (41.2)	108 (19.0)	120 (43.2)	676 (40.7)	266 (27.7)	1438 (30)
Trichoptera	264 (69.9)	159 (65.7)	132 (51.4)	136 (31.3)	307 (54.1)	63 (22.7)	525 (31.6)	346 (36.0)	1932 (40)
Plecoptera	49 (12.6)	45 (18.6)	60 (23.3)	-	34 (6.0)	22 (7.9)	-	61 (6.3)	271 (6)
Diptera	58 (14.9)	5 (2.1)	11 (4.3)	107 (24.7)	112 (19.8)	22 (7.9)	223 (13.4)	240 (24.9)	778 (16)
Odonata	3 (0.8)	3 (1.2)	1 (0.4)	4 (0.9)	1 (0.2)	12 (4.3)	12 (0.7)	5 (0.5)	41 (1)
Coleoptera	1 (0.3)	2 (0.8)	-	-	2 (0.4)	4 (1.4)	151 (9.1)	43 (4.5)	203 (4)
Others	-	6 (2.5)	-	8 (1.8)	3 (0.2)	35 (12.6)	73 (4.4)	1 (0.1)	126 (3)
Totals	389	242	257	434	567	278	1660	962	4789
No. of organisms per sample	12.2	6.7	7.1	21.7	15.8	8.7	59.3	26.7	

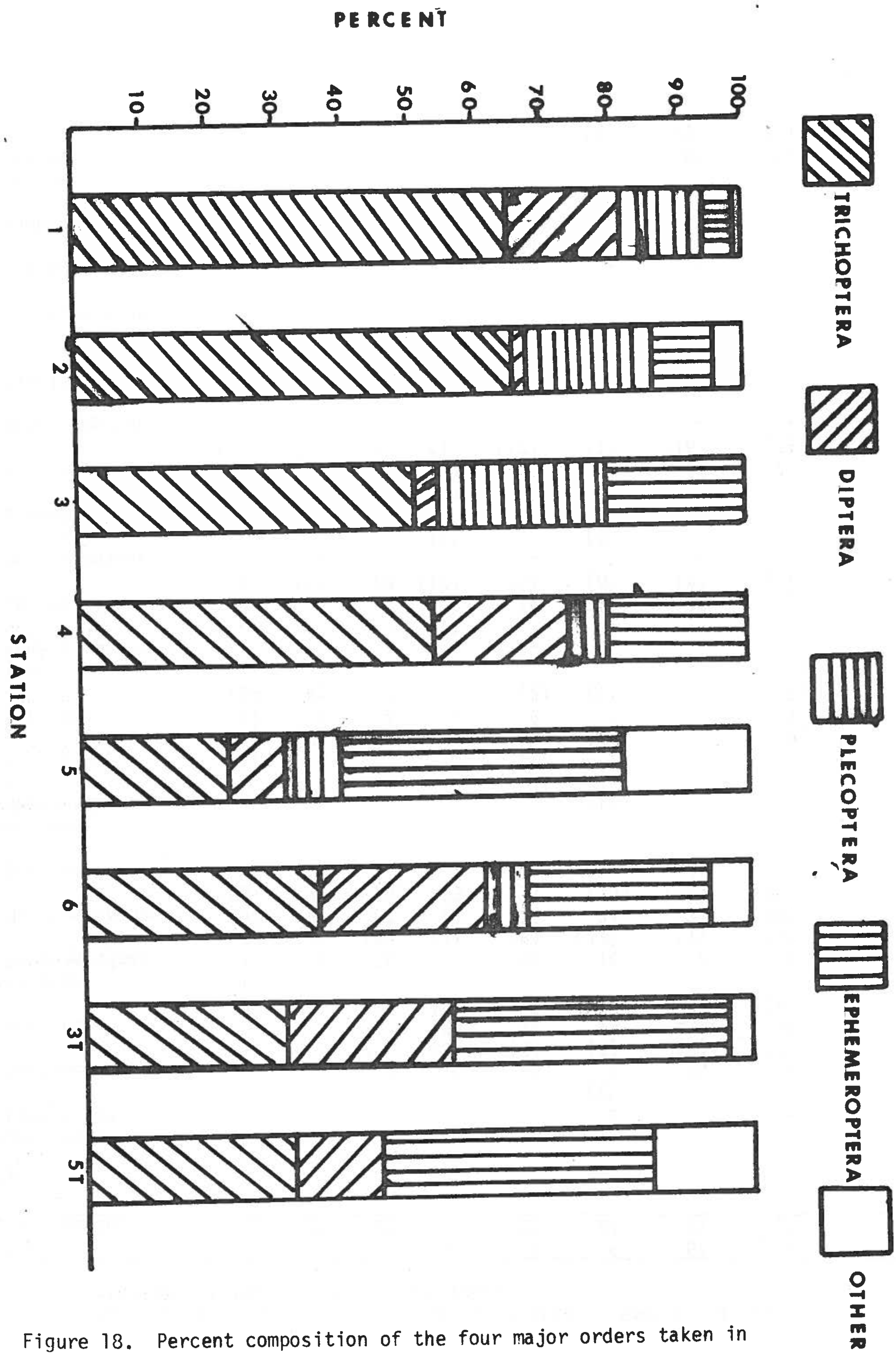

Figure 18. Percent composition of the four major orders taken in all samples.

Table 27. Families of invertebrates collected in Water's Samples* at each station. Hyphens indicate zero counts.

Station	1	2	3	3T	4	5	5T	6
No. of Samples	24	27	27	17	27	24	21	27
FAMILIES								
Ephemeroptera								
Ephemeridae	-	-	-	-	-	2 (2)	-	-
Heptageniidae	-	-	2 (1)	6 (3)	8 (2)	5 (4)	78 (8)	6 (2)
Baetidae	5 (2)	8 (6)	37 (21)	129 (61)	24 (6)	13 (11)	432 (45)	58 (18)
Trichoptera								
Psychomyiidae	12 (5)	4 (3)	14 (8)	1 (1)	32 (8)	16 (13)	2 (1)	3 (1)
Hydropsychidae	202 (79)	99 (79)	86 (50)	28 (13)	235 (57)	24 (20)	121 (13)	205 (62)
Brachycentridae	-	-	-	-	-	-	-	1 (1)
Plecoptera								
Nemouridae	-	-	-	-	-	1 (1)	-	-
Perlodidae	11 (4)	9 (7)	23 (13)	-	12 (3)	7 (6)	-	6 (2)
Perlidae	12 (5)	6 (4)	4 (2)	-	8 (2)	1 (1)	-	1 (1)
Diptera								
Ceratopogonidae	-	-	-	1 (1)	-	-	-	-
Chironomidae	8 (3)	4 (3)	6 (3)	36 (17)	19 (5)	10 (8)	25 (3)	7 (2)
Dolicopodidae	-	-	-	1 (1)	-	2 (2)	-	-
Empedidae	-	-	-	- (1)	1 (1)	1	-	5 (2)
Simuliidae	6 (2)	1 (1)	1 (1)	2 (1)	68 (17)	1 (1)	154 (16)	23 (7)
Stratiomyidae	-	-	-	-	-	-	-	-
Tipulidae	-	-	-	2 (1)	-	-	-	-
Odonata								
Calopterygidae	-	-	-	-	-	-	1 (1)	-
Coenagrionidae	-	-	-	2 (1)	1 (1)	-	-	-
Gomphidae	1 (T)	3 (2)	-	1 (1)	-	2 (2)	3 (1)	-
Coleoptera								
Elmidae	-	-	-	-	2 (1)	3 (2)	89 (9)	15 (5)

Table 27 continued

Hemiptera								
Corixidae	-	-	-	-	-	-	-	-
Naucoridae	-	-	-	-	-	-	18 (2)	-
Megaloptera								
Slalidae	-	-	-	-	-	-	-	-
Others	-	3 (2)	-	3 (1)	-	35 (28)	27 (3)	1 (1)

* Eight Ekman dredge samples included in Station 3T.

Among the quantitative samples, Station 5T accounted for almost three times as many organisms per sample as any other station (Table 28). The two tributary collecting sites, 3T and 5T, have greater estimated standing crops of invertebrates than any of the main river sites. The estimate for Station 3T is questionable due to the difference in sampling techniques and the smaller number of samples. Although fewer samples were taken at Station 5T than at any of the main stream sites, the standing crop estimate is a reasonable figure when the number of organisms in each sample is considered. Newell (1976) had estimates from his Water's samples on the Yellowstone River ranging from 21 to almost 12,000 organisms per square meter.

The diversity indexes were calculated in the same manner previously mentioned. Families were used because all the insects were identified, at least, to that taxanomic level. Diversities were not run on individual samples or on individual collecting dates because the numbers of organisms collected were so small that many of the indexes would have been meaningless due to lack of diversity.

Station 5 had the most families identified in its samples; it also accounted for the least number of organisms collected. Correspondingly, Station 5 had the greatest diversity among our sampling sites. Diversities were generally higher and redundancies lower at upstream sites than at downstream stations. This could result from increased siltation and more dissolved solids in the downstream sections of the river. Station 6 does not fit into that pattern.

Aquatic macroinvertebrates are not abundant in the Powder River in Montana. Sedimentation and turbidity are probably the main factors involved, however, the chemical characteristics of the river should not be overlooked. The community structure and diversity indices for our sampling sites have been presented. This baseline information will be varified or modified by future sampling. Nevertheless, the data is available to monitor changes in the aquatic community. Future sampling at each site on a quarterly basis will keep a check on possible changes in the community structure; when such changes are noted, indepth quantitative sampling should be reinstated. The extra time available due to reduced sampling should be spent attempting to correlate the habitat characteristics at each site with the invertebrates collected.

Modifying the flows of the Powder River would change its sedimentation pattern, bottom features, temperature regime, and water chemistry. These factors determine the macroinvertebrate community. Monitoring changes in the community structure will be facilitated by this study and by future investigations.

Table 28. Diversities and related figures for the families of organisms collected in Water's Samples* at each station.

Station	1	2	3	3T	4	5	5T	6
Number of samples	24	27	27	17	27	24	21	27
Total number of organisms	257	137	173	212	410	123	950	331
Average number of organisms per sample	10.7	5.1	6.4	12.5	15.2	5.1	45.2	12.3
Estimated number of organisms per sq. meter	115	55	69	361	163	55	486	132
Number of families	8	9	8	12	11	15	11	12
Diversity	1.3045	1.6246	2.0689	1.8249	2.0728	3.0652	2.3851	1.8941
Maximum diversity	2.9999	3.1699	2.9999	3.5849	3.4594	3.9068	3.4594	3.5849
Minimum diversity	0.2568	0.4962	0.3580	0.4738	0.2464	0.9446	0.1192	0.3253
Redundancy	0.6180	0.5779	0.3524	0.5657	0.4315	0.2841	0.3216	0.5187
Evenness	0.4348	0.5125	0.6896	0.5090	0.5882	0.7845	0.6894	0.5283
Equitability	0.1629	0.2288	0.2782	0.2361	0.2388	0.4415	0.2411	0.2262
Species richness	1.1416	1.3957	1.7906	1.5887	1.8340	2.6237	2.1440	1.6678

* Eight Ekman dredge samples included in Station 3T.

APPENDIX

Appendix Table 1. Discharge (cfs) of Powder River at Locate (Provisional), Spring 1976.

Date	March	April	May	June
1	Ice	484	760	1550
2	Ice	478	718	1730
3	Ice	478	781	2150
4	Ice	448	816	1930
5	Ice	418	830	1720
6	Ice	394	823	1890
7	Ice	394	725	2020
8	Ice	370	599	2030
9	Ice	348	662	1990
10	Ice	332	697	1810
11	Ice	332	-	1750
12	Ice	370	-	1670
13	Ice	418	-	1570
14	Ice	472	-	2030
15	Ice	490	-	2990
16	Ice	490	-	
17	Ice	718	-	
18	Ice	697	1380	
19	1480	662	1440	
20	1360	704	1370	
21	1160	704	1340	
22	966	802	1390	
23	830	718	1590	
24	802	648	1780	
25	753	585	1870	
26	704	526	1830	
27	641	484	1930	
28	578	520	1960	
29	578	578	1850	
30	538	655	1780	
31	532		1600	

Appendix Table 2 . Discharge (cfs) of Powder River at Locate (Provisional), Spring 1977.

Date	March	April	May	June
1	320	634	958	564
2	330	578	1160	472
3	400	538	1350	424
4	500	578	1480	364
5	550	599	1610	315
6	600	739	1670	305
7	620	774	1700	285
8	641	950	1440	
9	667	1100	1370	
10	711	1080	1230	
11	760	1100	1200	
12	635	1020	1730	
13	592	958	2000	
14	634	918	2120	
15	620	910	1990	
16	767	838	1570	
17	704	830	2250	
18	718	781	2780	
19	802	746	3230	
20	746	697	2310	
21	662	704	1940	
22	592	690	1720	
23	592	669	1680	
24	550	648	1450	
25	550	613	1710	
26	592	550	1060	
27	634	496	934	
28	613	490	846	
29	613	578	774	
30	704	725	746	
31	641		606	

Appendix Tables 3

APRIL - WATER TEMPERATURES
POWDER RIVER
1976

Date	Interstate	Powderville	Moorhead
1	-	-	-
2	-	-	-
3	-	11.7	-
4	-	12.2	-
5	-	11.1	12.8
6	-	12.5	11.7
7	12.2	13.9	11.9
8	11.9	14.4	12.2
9	12.2	14.4	13.1
10	-	13.6	11.1
11	-	10.6	12.8
12	-	10.3	14.2
13	15.6	10.0	15.6
14	13.6	10.0	13.6
15	12.8	10.6	13.6
16	11.9	10.8	9.7
17	7.8	-	8.3
18	6.7	-	10.3
19	7.5	-	10.3
20	8.1	-	10.0
21	9.4	-	11.1
22	8.9	11.1	10.6
23	9.4	11.1	11.1
24	8.6	10.3	12.2
25	9.2	10.6	12.2
26	9.7	10.0	10.0
27	7.5	10.6	5.8
28	6.4	6.4	5.6
29	6.1	7.2	6.9
30	6.9	9.7	10.0
Mean =	9.638	11.0043	11.0269
N =	21	23	26
	202.4	253.1	286.7
S.E.	2.6509	1.9592	2.4295

Appendix Table 4.

MAY - WATER TEMPERATURES
POWDER RIVER
1976

Date	Interstate	Powderville	Moorhead
1	8.3	13.1	12.5
2	9.7	12.8	12.8
3	10.0	13.3	13.6
4	11.1	15.0	15.0
5	11.9	15.3	14.7
6	11.7	15.8	13.9
7	12.2	15.8	14.2
8	13.6	16.9	16.4
9	14.2	18.1	16.9
10	16.1	18.3	17.8
11	16.1	18.9	16.7
12	13.1	14.7	13.1
13	10.8	14.4	13.3
14	14.2	-	16.7
15	14.4	-	14.4
16	13.9	-	13.9
17	15.6	-	15.6
18	16.4	-	18.1
19	16.1	-	19.2
20	17.5	-	19.2
21	17.5	-	18.1
22	16.4	-	16.9
23	17.2	-	14.7
24	15.0	-	13.6
25	14.7	-	16.9
26	13.3	-	15.6
27	15.3	-	16.9
28	17.8	-	19.4
29	-	-	18.3
30	-	-	18.3
31	-	-	19.2
Mean =	14.0750	15.5692	15.9967
N =	28	13	31
	394.1	202.4	495.9
S.E.	2.5805	2.0055	2.1473

Appendix Table 5

JUNE - WATER TEMPERATURES
POWDER RIVER
1976

Date	Interstate	Powderville	Moorhead
1	-	-	20.3
2	-	-	20.0
3	-	-	20.0
4	-	-	20.8
5	20.6	-	17.5
6	21.1	-	17.8
7	19.7	-	21.7
8	20.3	-	21.9
9	20.3	-	22.5
10	20.8	-	22.2
11	21.4	-	-
12	21.4	-	-
13	18.6	-	-
14	15.8	-	-
15	15.0	-	-
16	-	-	-
17	-	-	-
18	-	-	-
19	-	-	-
20	-	-	20.8
21	-	-	22.5
22	-	-	21.4
23	-	-	19.4
24	-	-	17.2
25	-	-	16.9
26	-	-	16.9
27	-	-	18.3
28	-	17.2	20.0
29	-	18.9	21.1
30	-	20.3	22.2
Mean =	19.5454	18.8	20.0666
N =	11	3	21
	215.0	56.4	421.4
S.E.	2.2074	1.5524	1.9303

Appendix Table 6

JULY - WATER TEMPERATURES
POWDER RIVER
1976

Date	Interstate	Powderville	Moorhead
1	-	21.1	24.4
2	-	22.5	22.5
3	-	23.9	22.5
4	-	22.5	24.4
5	-	23.9	24.7
6	-	25.0	25.6
7	-	26.1	24.7
8	-	26.1	25.3
9	-	26.1	26.1
10	-	26.9	26.1
11	-	26.4	26.7
12	-	26.1	26.1
13	-	26.7	25.0
14	-	25.0	23.9
15	-	24.7	23.6
16	-	23.6	24.2
17	-	23.1	25.2
18	-	24.2	25.0
19	-	25.6	25.8
20	-	24.2	24.4
21	-	24.4	25.6
22	-	24.7	25.3
23	-	25.0	25.6
24	-	26.1	25.8
25	-	23.1	23.9
26	-	23.9	23.6
27	-	23.6	23.6
28	-	21.4	22.8
29	-	22.2	21.7
30	-	21.9	22.8
31	-	22.2	23.9
Mean =	-	24.2645	24.5419
N =	-	31	31
	-	752.2	760.8
S.E.	-	1.6396	1.2526

Appendix Table 7

AUGUST - WATER TEMPERATURES
POWDER RIVER
1976

Date	Interstate	Powderville	Moorhead
1	-	21.1	21.7
2	-	21.1	21.9
3	-	22.8	23.6
4	-	23.3	22.8
5	-	20.8	22.2
6	-	20.6	22.5
7	-	21.1	23.9
8	-	22.8	23.1
9	-	-	22.8
10	-	-	23.1
11	-	-	22.5
12	-	-	21.9
13	-	-	21.1
14	-	-	22.5
15	-	-	21.9
16	-	-	21.9
17	-	-	21.7
18	-	-	23.3
19	-	-	24.4
20	-	-	24.2
21	-	-	23.9
22	-	-	23.3
23	-	-	23.3
24	-	-	22.2
25	-	24.7	23.1
26	-	19.7	20.6
27	-	16.7	17.2
28	-	18.1	18.6
29	-	21.4	21.1
30	-	19.4	19.4
31	21.9	21.4	21.4
Mean =	-	21.0000	22.1645
N =	-	15	31
Ex	-	315.0000	687.1
S.E.	-	2.0206	1.5902

Appendix Table 8

SEPTEMBER - WATER TEMPERATURES
POWDER RIVER
1976

Date	Interstate	Powderville	Moorhead
1	21.7	21.7	21.4
2	18.3	20.0	20.3
3	19.2	19.4	20.3
4	20.6	21.1	21.4
5	21.7	21.9	21.7
6	19.7	20.6	19.7
7	14.2	16.7	17.8
8	13.3	14.2	15.3
9	14.4	14.4	15.3
10	16.1	16.4	16.7
11	17.2	17.2	17.2
12	16.4	17.2	17.2
13	18.1	18.3	18.6
14	18.9	17.2	17.2
15	21.7	19.7	18.9
16	21.1	20.6	19.4
17	21.7	20.8	20.6
18	18.1	20.0	20.3
19	16.1	16.4	14.4
20	14.4	14.2	14.7
21	15.8	15.6	16.4
22	15.3	15.8	16.1
23	15.3	16.4	16.7
24	12.2	16.4	16.1
25	15.0	17.5	15.6
26	11.4	14.4	13.6
27	10.6	12.2	12.8
28	12.2	12.2	12.2
29	13.6	13.6	13.3
30	14.7	14.4	13.9
Mean =	16.6333	17.2166	17.1700
N =	30	30	30
Ex	499.00	516.50	515.10
S.E	3.3087	2.8375	2.7732

Appendix Table 9

OCTOBER - WATER TEMPERATURES
POWDER RIVER
1976

Date	Interstate	Powderville	Moorhead
1	15.3	14.7	14.2
2	14.4	15.3	16.7
3	12.2	13.1	12.8
4	7.5	8.9	9.7
5	6.7	7.2	7.8
6	9.2	8.9	8.6
7	8.3	8.6	8.3
8	10.0	9.4	9.4
9	10.6	10.6	10.6
10	10.8	10.3	11.1
11	12.2	11.9	12.2
12	11.7	11.4	11.7
13	10.6	10.3	10.8
14	8.1	10.0	8.9
15	4.2	4.2	6.7
16	3.6	3.9	4.4
17	2.5	2.5	4.4
18	1.9	1.4	3.1
19	1.4	0.8	-
20	2.8	2.5	-
21	2.2	3.1	4.4
22	3.3	3.1	4.4
23	2.5	3.3	4.4
24	3.1	3.1	4.2
25	1.7	1.9	2.8
26	2.2	1.4	3.3
27	3.3	1.7	3.6
28	2.2	2.5	3.6
29	5.0	3.9	4.4
30	5.8	4.4	4.4
31	5.0	5.0	5.6
Mean =	6.4612	6.4290	7.4655
N	31	31	29
Ex	200.3	199.3	216.50
S.E.	4.2127		3.8500

Appendix Table 10

NOVEMBER - WATER TEMPERATURES
POWDER RIVER
1976

Date	Interstate	Powderville	Moorhead
1	5.8	4.2	4.7
2	4.2	5.0	4.7
3	3.3	3.9	5.0
4	2.2	2.2	3.9
5	3.6	2.5	3.6
6	3.6	3.6	3.9
7	1.9	3.1	4.4
8	3.3	1.4	3.6
9	2.5	2.8	3.6
10	0.3	3.3	4.7
11	0.0	1.1	2.8
12	0.0	0.0	0.8
13	0.3	0.0	0.3
14	0.0	0.0	0.3
Mean =	2.2142	2.3642	3.2357
N =	14	14	14
Ex	31.0000	33.10	45.30
S.E.	1.8650	1.6443	1.6457

Appendix Table 11

MARCH - WATER TEMPERATURES
POWDER RIVER
1977

Date	Interstate	Powderville	Moorhead
17	2.5	3.3	0.0
18	2.8	2.9	0.0
19	2.2	1.9	0.0
20	1.7	1.9	0.3
21	2.2	2.2	0.3
22	5.8	5.3	1.7
23	6.1	6.4	5.0
24	6.7	7.5	5.6
25	5.3	5.0	3.3
26	5.3	5.0	4.4
27	6.1	7.0	5.0
28	5.3	3.0	3.1
29	2.5	0.0	0.0
30	1.4	0.8	0.3
31	2.5	1.9	3.1
Mean =	3.8933	3.6066	2.1400
N =	15	15	32.1
S.E.	1.9080	2.2957	2.1596

Appendix Table 12

APRIL - WATER TEMPERATURES
POWDER RIVER
1977

Date	Interstate	Powderville	Moorhead
1	3.6	4.2	3.1
2	3.3	4.4	4.7
3	2.5	4.4	4.7
4	2.8	5.3	6.1
5	6.7	7.2	8.1
6	9.2	9.5	9.7
7	10.6	11.1	11.1
8	12.2	10.6	12.5
9	13.3	12.5	12.8
10	13.1	12.5	12.5
11	11.1	10.6	10.0
12	11.7	11.1	11.1
13	11.4	-	-
14	13.6	12.8	11.7
15	13.1	12.8	12.5
16	15.0	14.2	13.6
17	13.1	12.5	13.6
18	9.7	10.0	9.2
19	9.7	10.6	9.7
20	8.3	9.2	9.7
21	9.2	10.0	10.8
22	13.3	13.1	13.6
23	14.5	14.2	13.3
24	14.2	14.2	15.3
25	14.7	14.5	15.0
26	16.4	15.8	16.1
27	15.6	16.4	17.2
28	15.8	15.6	16.1
29	17.8	17.2	17.5
30	18.9	18.1	18.3
Mean =	11.4800	11.5379	11.7103
N =	30	29	29
Ex =	344.4	334.6	339.6
S.E.	4.3521	3.7924	3.8981

Appendix Table 13

MAY - WATER TEMPERATURES
POWDER RIVER
1977

Date	Interstate	Powderville	Moorhead
1	15.8	16.1	15.3
2	16.1	15.0	14.7
3	17.2	16.4	13.9
4	16.7	14.7	13.6
5	12.2	13.1	12.3
6	12.5	13.1	13.1
7	14.5	12.8	15.0
8	18.3	14.7	18.9
9	21.4	16.1	19.7
10	20.3	17.0	20.6
11	20.9		
12	20.0		
13	20.6		
14	20.0		
15	17.0		
16	15.3		
17	17.2		
18	15.3		
19	12.3		
20	13.3		
21	15.6		
22	16.7		
23	18.1		
24	20.9		
25	20.9		
26	20.0		
27	20.0		
28	17.5		
29	18.3		
30	19.5		
31	20.0		
Mean =	17.5612		
N =	31		
Ex =	544.4		
S.E.	2.7732		

Appendix Table 14.

JUNE - WATER TEMPERATURES
POWDER RIVER
1977

Date	Interstate
1	22.5
2	21.1
3	18.6
4	22.5
5	23.1
6	23.1
7	24.2

Appendix Table 15. Organisms collected in October 1975.

Station	1				2				3				4				5			
Sample	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																				
Ephemeroptera														2		1				
Rhithrogena													-	2	3	-	3			
Heptagenia													-	1	-	-	1	1	2	-
Leptophlebia													-	2	1		3	3	2	-
Tricorythodes																				
Trichoptera																				
Hydropsyche													-	2	-	-	7	2	-	-
Cheumatopsyche	5	-	1	-	3	11	7	2	-	-	-	1	-	35	106	8	8	7	-	-
Brachycentrus																	9	-	1	-
Plecoptera																				
Perlodidae	1	-	-	-	11	1	-	-									15	1	-	-
Isogenus					-	-	1	-	-	-	-	1	-	-	-	1				
Acroneuria									-	-	-	1	-	1	2	-	1	-	-	-
Diptera																				
Chironomidae					-	1	-	-	-	1	-	1	-	1	1	16	2	-	1	1
Empedidae																	10	-	-	-
Simulium													-	4	39	8	11	1	-	-
Odonata																				
Argia													-	1	-	-				
Coleoptera																				
Elmidae (adults)																	-	8	4	-
Microcylloepus																	13	-	-	-
Stenelmis																	12	1	1	-

*K - Kick Sample

1 - First Water's Sample

2 - Second Water's Sample

3 - Third Water's Sample

Appendix Table 16. Organisms collected in March 1976.

Station	1				2				3				3T				4				5				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	E*	E	E	E	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																												
Ephemeroptera																												
Rhithrogena																									2	-	-	-
Leptophlebia gravestella													-	3	-	-												
Caenis													1	-	-	-												
Baetis parvis													-	1	-	-									1	1	-	-
Ametropus					1	-	-	-	2	-	-	-									1	-	-	-				
Trichoptera																												
Hydropsyche																									4	10	-	-
Cheumatopsyche	8	11	52	40	-	2	2	-	-	-	2	-	2	-	4	-	18	32	-	4					8	2	-	4
Brachycentrus																												
Plecoptera																												
Brachyptera																					-	1	-	-				
Perlodidae	10	-	6	1					6	2	-	5					-	-	1	-	1	-	-	-	15	-	-	1
Isogenus	1	-	-	-													-	-	3	-								
Acroneuria	3	-	1	1																								
Diptera																												
Ceratopogonidae													-	1	-	-												
Chironomidae*	6	-	1	-									10	8	-	1					2	3	-	-	8	-	2	2
Cricotopus													x	x							x							
Eukiefferiella			x																									
Trissocladius													x															
Conchapelopia	x												x								x							
Dicrotendipes	x												x															
Endochironomus														x														
Pseudochironomus													x			x												
Stitochironomus	x													x														
Dolicopodidae													1	1	-	-												
Empedidae																	2	1	-	-					1	5	-	-
Simulium													29	-	2	-	1	-	-	-					38	-	1	1
Stratiomyidae													1	-	-	-												
Tipulidae													2	-	1	-												
Odonata																												
Gomphus	2	1	-	-																								
Coleoptera																												
Elmidae (adults)																	-	-	1	-					1	-	-	-
Others					3	-	-	2					4	2	-	-												

* E - Ekman Dredge Samples
* X - Denotes the presence of that genus

Appendix Table 17. Organisms collected in April 1976.

Station	2				3				3T				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	E	E	E	E	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																												
Ephemeroptera																												
Stenonema																					-	8	1	1				
Leptophlebia																					-	4	3	5				
Gravestella																												
Caenis									3	-	74	-									-	2	-	-				
Baetis parvis																					-	1	-	-				
Ametropus	2	-	-	-																								
Trichoptera																												
Polycentropus																					-	-	1	-				
Hydropsyche																					-	-	1	-				
Cheumatopsyche	-	3	-	1	-	-	2	-	-	-	3	-	-	-	9	4					-	7	3	3	-	1	-	-
Plecoptera																												
Perlodidae	-	2	-	3	-	3	3	1					-	-	3	2	-	1	-	3					-	1	-	-
Acroneuria	-	1	-	-									-	-	-	1												
Diptera																												
Ceratopogonidae					1	-	-	-	2	-	-	-																
Chironomidae	-	-	1	1	-	1	2	1	11	-	23	-					-	-	4	-	-	-	1	-				
Cricotopus											x																	
Conchapelopia											x																	
Paratendipes											x																	
Stitochironomus							x	x																				
Empedidae																	-	-	1	-								
Simulium													1	7	1	-					-	-	97	57				
Tipulidae									-	-	1	-																
Odonata																												
Argia									-	-	1	-																
Omphidae																	-	2	-	-								
Coleoptera																												
Dubiraphia																					-	7	-	-				
Stenelmis													-	1	-	-					-	6	-	5				
Others									-	-	-	1					-	-	1	-	-	-	2	2				

ppendix Table 18. Organisms collected in May 1976.

Station	1	2	3	3T	4	5	5T	6
Sample No.	K 1 2 3	K123	K 1 2 3	K 1 2 3	K 1 2 3	K 1 2 3	K 1 2 3	K 1 2 3
TAXA								
Ephemeroptera								
Anepeorus								
Stenonema								6 2 - -
Epeorus							3 1 - 2	
albertae						2 - - -		8 1 - -
Leptophlebia								
gravistella							30 3 1 6	
Caenis				- 13 18 16			1 - 1 2	- 4 - -
Baetis parvis							2 - - 1	
Ametropus			- - - 1			1 - - -		
Trichoptera								
Polycentropus				- - - 1				
Hydropsyche							- 1 - -	
Cheumatopsyche	1 1 3 -			- 3 - -	- 1 3 -	1 - - 1	4 3 - 7	
Plecoptera								
Perlodidae	2 - 2 1		12 1 5 -		- 1 - -	3 - - 2		14 2 - 1
Acroneuria	1 - - -				2 1 - -			
Diptera								
Chironomidae					- - 1 -		20 2 7 -	1 - 3 -
Conchapelopia								x
Dolicopodidae						- 2 - -		
Empedidae			1 - - -				2 - - -	1 - - -
Simulium						- 1 - -	4 - - -	
Tipulidae			1 - - -				4 - - -	1 - - -
Odonata								
Argia				- 1 - -				
Gomphidae				- 1 - -			1 - - -	1 - - -
Coleoptera								
Dubiraphia						- - - 3	3 2 3 4	
Stenelmis							19 1 - -	
Hemiptera								
Ambrysus mormon							1 - - -	
Others						- - - 34	2 - 1 -	- - - 1

Appendix Table 19. Organisms collected in June 1976.

Station	1				2				3				3T				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																																
Ephemeroptera																																
Anepeorus	-	-	1	-	1	-	-	-					8	-	-	-	2	-	-	-	2	-	-	2					4	-	2	-
Stenonema																					-	1	-	-								
Heptagenia criddlei													5	1	-	3					1	-	-	-	12	5	1	6				
Epeorus albertae					2	-	-	-	-	1	-	1					2	-	1	-									7	-	1	-
Leptophlebia gravestella													-	-	-	1									19	6	2	-				
Caenis									-	-	1	-	12	-	1	-																
Baetis parvis																									2	-	-	-	1	-	-	-
B. propinquus					-	-	1	-					4	-	-	-					-	-	1	4								
Ametropus																					-	-	-	1					2	-	-	-
Trichoptera																																
Psychomyiid Genus A	-	-	2	9	-	3	1	-	3	12	1	-					-	-	31	1	-	2	12	-	-	-	1	-	-	2	-	1
Hydropsyche																									3	3	-	-	-	1	-	-
Cheumatopsyche	4	-	5	2	1	-	1	-	1	2	3	-	70	13	1	3	2	-	1	-					4	7	1	-				
Plecoptera																																
Isoperla	2	-	1	-	10	1	-	-	11	2	-	-					2	-	1	-	3	-	1	-					3	-	-	-
Acroneuria					-	-	-	1									2	-	-	-												
Diptera																																
Chironomidae													1	-	-	-																
Odonata																																
Gomphus																									-	2	-	-				
Ophiogomphus																	-	1	-	-	1	-	-	-								
Coleoptera																																
Elmidae (adults)																									1	-	-	-				
Stenelmis																					1	-	-	-	13	1	-	-	-	1	-	-
Hemiptera																																
Ambrysus mormon																									9	1	-	-				
Others																									-	-	-	3				

	1	2	3	3T	4	5	5T	6
	1.4366	2.000	1.7533	0.4854	0.7254	1.5196	2.4180	1.8112
	1.9999	2.3219	2.3219	1.0000	2.3219	1.9999	2.9999	1.9999
	.8475	2.000	1.0144	.2974	.7254	.7416	1.1828	1.5487
	.4888	1.000	.4348	.7324	.9999	.3817	.3202	.4182
	.7183	.8613	.7551	.4854	.3124	.7598	.8060	.9056
	.3324	.6666	.3875	.1142	.1403	.3314	.4574	.6037
	1.1042	1.3333	1.3657	.3711	.5851	1.1882	1.9605	1.2075
K	.9182	1.0949	1.0529	1.2323	1.9219	1.8112	2.2194	1.2896
T	1.5903	1.8333	1.8896	1.2101	1.5427	2.1149	2.5101	1.9411

Appendix Table 20. Organisms collected in July 1976.

Station	1				2				3				3T				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																																
Ephemeroptera																																
Ephoron album																									2	-	-	-				
Anepeorus					1	-	-	-									4	-	-	-	5	-	-	-					7	-	-	-
Heptagenia criddlei													3	-	2	-	1	-	-	-					2	2	-	-				
Epeorus albertae																													1	-	-	-
Traverella albertana	3	1	-	3	6	1	2	1	-	1	-	-					30	1	1	-	61	-	-	-					11	-	2	-
Leptophlebia gravestella													2	-	-	-									2	4	1	2				
Tricorythodes minutus																					1	-	-	-					2	-	-	-
Brachycercus																					6	-	-	-					3	-	-	-
Caenis									-	1	-	-	5	1	-	-																
Baetis parvis																	1	-	-	-									-	-	2	-
B. propinquus									-	-	-	1	-	1	-	-	-	1	-	-	8	-	-	-	2	-	-	-	2	-	-	-
Ametropus																									5	2	-	-				
Trichoptera																																
Psychomyiid Genus A	2	-	-	1					-	-	1	-									3	1	-	1					2	-	-	-
Hydropsyche													2	-	-	-									-	1	-	-	1	-	-	-
Cheumatopsyche	1	-	-	-	-	1	-	-	-	1	2	-	33	-	1	-	4	-	1	-	3	-	-	-	1	11	1	-	10	-	1	2
Plecoptera																																
Perlodidae					-	1	-	-																								
Acroneuria	3	-	-	3	-	2	-	-	1	1	-	-					3	-	-	-	5	-	-	-								
Diptera																																
Chironomidae													8	1	-	4																
Cricotopus													x																			
Orthocladius														x		x																
Calopsectra																x																
Conchapelopia													x			x																
Cryptochironomus													x																			
Dicrotendipes													x																			
Simulium	-	-	2	-													1	-	-	-												
Odonata																																
Gomphidae					-	-	1	-													5	-	-	-								
Gomphus													1	-	-	-									1	-	-	-				
Ophiogomphus					-	1	-	-									3	-	-	-									1	-	-	-
Coleoptera																																
Stenelmis																									2	7	2	1				
Hemiptera																																
Ambrysus mormon																									-	-	1	-				

Appendix Table 20 continued.

Megaloptera								
Sialis				1 - - -				
Others		- 1 - -			3 - - -		2 1 - -	1 - - -
	1.8464	2.3219	1.8112	1.7609	0.8112	0	2.0628	0.9852
	1.9999	2.5849	1.9999	1.9999	1.0000		2.5849	1
	1.3567	2.1609	1.5487	1.3567	.8112		.9038	.5916
	.2387	.6203	.4182	.3716	1.0000		.3105	.0361
	.9232	.8982	.9056	.8804	.8112		.7980	.9852
	.5558	.6989	.6037	.5301	.4056		.3990	.3509
	1.2906	1.6229	1.2070	1.2308	.4056		1.6638	.6342
	1.8910	.5916	0	1.6371	1.6673	1.2475	2.1148	1.8441
	2.0418	2.0157	1.8910	1.8014	1.6390	1.3158	2.2968	1.7798

Appendix Table 21. Organisms collected in August 1976.

Station	1				2				3				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																												
Ephemeroptera																												
Ephoron albertae																					-	-	-	2				
Heptagenia criddlei																					10	6	8	10				
Cinygma																	2	-	-	-								
Isonychia																					1	-	-	-				
Traverella albertana	1	-	-	-	-	-	1	-	2	2	2	-	32	7	2	6									86	12	1	20
Leptophlebia gravestella																					10	2	-	8				
Tricorythodes minutus													2	-	-	-	1	-	-	-					1	1	-	-
Baachycercus	4	-	1	-	-	1	-	-	1	20	7	0	1	-	-	-	2	-	1	-								
Caenis									-	-	1	-																
Baetis parvis																					2	-	1	-	6	-	1	-
Trichoptera																												
Psychomyiid Genus A	1	-	-	-									1	-	-	-	1	-	-	-								
Hydropsyche													1	1	-	-					5	-	-	-	1	-	-	1
Cheumatopsyche	5	1	21	7	1	-	-	-	7	6	6	3	14	10	5	3					125	-	1	6	-	2	-	-
Plecoptera																												
Acroneuria	1	3	-	-					-	1	-	-	2	2	1	-	-	-	-	1					-	1	-	-
Diptera																												
Chironomidae																	-	1	1	-	1	1	1	-	1	-	-	-
Conchapelopia																					x							
Cryptochironomus																		x										
Dicrotendipes																									x			
Polypedilum																			x			x	x					
Simulium	-	-	2	-					-	-	-	1	19	-	4	5					1	-	-	-	33	4	2	1
Odonata																												
Gomphidae																	1	-	-	1								
Gomphus																	2	-	-	-								
Coleoptera																												
Stenelmis					1	-	-	-													14	-	1	1				
Hemiptera																												
Ambrysus mormon																					6	-	-	1				
Others																					1	-	1	2				

Appendix Table 22. Organisms collected in September 1976.

Station	1				2				3				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																												
Ephemeroptera																												
Rhithrogena																									3	-	-	-
Stenonema									1	-	-	-									3	-	-	-				
Heptagenia criddlei																	-	2	-	-	3	-	-	-	2	-	-	-
Traverella																									9	-	1	-
Leptophlebia gravestella													-	-	1	-	-	1	1	1	9	-	-	-	6	-	1	-
Tricorythodes minutus																	1	-	-	-								
Brachycercus					1	-	-	-	1	-	-	-	-	1	-	-	3	1	-	-					-	-	1	1
Caenis																					1	-	-	-				
Baetis parvis					1	-	-	-									-	1	-	-					25	-	2	-
Ametropus									5	-	-	-	-	1	-	-	1	-	-	-	1	-	-	-				
Trichoptera																												
Hydropsyche																									2	-	-	-
Cheumatopsyche	-	1	-	19	37	2	4	2	2	3	-	-	-	3	-	-	1-	12	6	5	2	-	-	-	20	26	37	12
Plecoptera																												
Perlodidae	1	-	-	-	6	-	-	-																				
Acroneuria	-	-	1	3	-	-	-	1	1	1	-	-					1	-	-	-					2	-	-	-
Diptera																												
Chironomidae																	5	1	-	-								
Chironomus																	x	x										
Simulium	33	1	-	1	-	1	-	-	1	-	-	-					1	-	-	-	2	-	-	-	100	-	7	6
Odonata																												
Gomphidae									1	-	-	-					1	-	-	-								
Gomphus																					6	-	-	-				
Ophigomphus																									1	-	-	-
Coleoptera																												
Elmidae (adults)	1	-	-	-																								
Stenelmis					1	-	-	-													1	-	-	-	2	-	-	-
Hemiptera																												
Corixidae																					5	-	-	-				

Appendix Table 23. Organisms collected in October 1976.

Station	1				2				3				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																												
Stenonema																					5	2	4	15				
Heptagenia elegantula																					–	–	–	1				
Leptophlebia gravestella													1	–	–	–	–	1	–	–	41	18	85	270				
Caenis																					–	–	2	–				
Ametropus									2	–	–	–																
Trichoptera																												
Hydropsyche					–	–	1	–													40	–	–	–	4	6	1	–
Cheumatopsyche	23	6	31	1	14	30	27	3	19	–	55	–	–	7	–	–	5	–	–	–	218	8	18	45	60	64	19	7
Plecoptera																												
Perlodidae	1	–	–	–	1	–	–	–					2	–	–	–									1	–	–	–
Acroneuria					2	1	–	–	2	–	–	–	1	–	–	–												
Diptera																												
Chironomidae	–	–	6	–	–	–	1	–													4	1	9	3				
Cricotopus																					x							
Conchapelopia																					x		x					
Chironomus																						x	x					
Cryptochironomus																							x	x				
Dicrotendipes			x				x																					
Simulium																					6	–	–	–				
Odonata																												
Hetaerina americana																					–	–	–	1				
Gomphus					–	–	–	1													–	–	–	1				
Ophigomphus					–	1	–	–																	2	–	–	–
Coleoptera																												
Dubiraphia																					–	–	3	–				
Stenelmis																					9	–	10	35				
Hemiptera																												
Ambrysus mormon																					1	–	–	15				
Megaloptera																												
Sialis																					1	–	–	–				
Others																					–	3	8	4				

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List of waters:

Powder River 21-0750
Little Powder River 21-0550
Mizpah Creek 21-0675
Ten Mile Creek - Mouth in Prairie County 21-1050
Coal Creek - Prairie County 21-0119